Clearwater County

Part of the North Saskatchewan and South Saskatchewan River Basins
Tp 031 to 047, R 04 to 11, W5M
Regional Groundwater Assessment

Prepared for:

In conjunction with:

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

Prepared by
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Our File No.: **02-221**

February 2004

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HYDROGEOLOGICAL CONSULTANTS LTD.

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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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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. Terry Dash – AAFC-PFRA
Mr. Glen Brandt – AAFC-PFRA
Mr. Kim Nielsen – Clearwater County

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

- 1-800-GEO-WELL
- The Groundwater Centre/Regional Groundwater Assessment
- Prairie Farm Rehabilitation Administration branch of Agriculture and Agri-Food Canada (AAFC-PFRA)

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

http://www.agr.gc.ca/pfra/water/groundw.htm

1 PROJECT OVERVIEW

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

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

1.1 Purpose

This project is a regional groundwater assessment of Clearwater County prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration branch of Agriculture and Agri-Food Canada (AAFC-PFRA) and Clearwater County. The project study area (herein referred to as the County) includes the eastern half of the County, and the Sunchild and O'Chiese First Nation lands. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for 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 County.**

The regional groundwater assessment will:

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

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

[1] See glossary
[2] See glossary

1.2 The Project

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

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

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

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

1.3 About This Report

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

Additional technical details are available from files on the CD-ROM 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 for the portion of the County within townships 031 to 047, ranges 04 to 11, W5M plus a buffer area of 5,000 metres. For convenience, poster-size maps and cross-sections have been prepared as a visual summary of the results presented in this report. Copies of these poster-size drawings have been forwarded with this report, and are included as page-size drawings in Appendix D.

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

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

Appendix C includes the following:

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

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

Appendix D includes page-size copies of the poster-size figures provided with this report.

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

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[3] See glossary

2 INTRODUCTION

2.1 Setting

Clearwater County is situated in southwestern Alberta. The County is within the North Saskatchewan River and the South Saskatchewan River basins (see CD-ROM). The extreme northern boundary is the North Saskatchewan River; a part of the southeastern boundary is the Red Deer River and the James River. The other County boundaries follow township or section lines, which include parts of the area bounded by townships 031 to 047, ranges 04 to 11, W5.

Regionally, the topographic surface varies between 800 and 2,800 metres above mean sea level (AMSL). The lowest elevations occur in association with the North Saskatchewan River in the extreme northern part of the County and in the northeastern portion of the County; the highest elevations are in the southwestern parts of the County as shown on Figure 1 and page A-4.

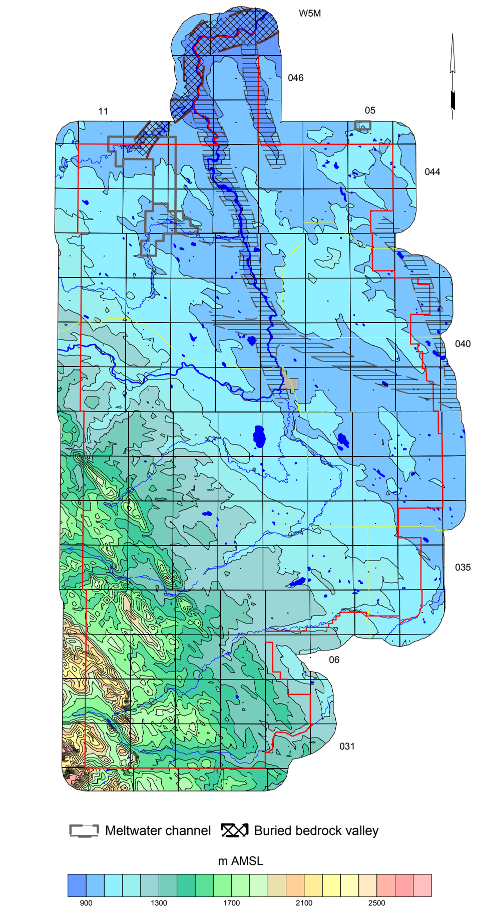

Figure 1. Surface Topography

2.2 Climate

Clearwater County lies within the Dfb climate boundary. This classification is based on potential evapotranspiration[4] values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Leggat, 1981) shows that the County is located mainly in the Low Boreal Mixedwood Region, and the Upper and Lower Boreal-Cordilleran regions; a small portion in the eastern part of the County is in the Aspen Parks Region and a small portion of the southwestern part of the County is in the Sub-Alpine Region. Increased precipitation and cooler temperatures, resulting in additional moisture availability, influence these vegetation changes.

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

The mean annual precipitation averaged from six meteorological stations within the County measured 503 millimetres (mm), based on data from 1958 to 1993. The mean annual temperature averaged 2.1° C, with the mean monthly temperature reaching a high of 13.7° C in July, and dropping to a low of -11.5° C in January. The calculated annual potential evapotranspiration is 429 millimetres.

[4] See glossary

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently 11,708 records in the groundwater database for the County, of which 8,283 are water wells. Of the 8,283 water wells, there are records for domestic (4,388), domestic/stock (1,096) or stock (623) purposes. The remaining 2,176 water wells were completed for a variety of uses, the main ones being industrial (1,578) municipal (102) and observation (101); 216 of the 2,176 water wells have an "unknown" purpose. Based on a rural population of 11,505[5] (Phinney, 2003), there are two domestic/stock water wells per family of four. In the groundwater database for the County, there are 5,695 domestic or stock water wells with a completed depth, of which 5,012 (88%) are completed at depths of less than 50 metres below ground surface. Details for lithology[6] are available for 6,643 water wells.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 5,434 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 5,434 water wells for which aquifers could be defined, 177 are completed in surficial aquifers, with 139 (78%) having a completion depth of less than 30 metres below ground surface. The adjacent map shows that the water wells completed in the surficial deposits occur mainly in the southeastern part of the County, and frequently adjacent to creeks and rivers.

The data for 5,257 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. From Figure 2 (also see page A-6), it can be seen that water wells completed in bedrock aquifers occur throughout the County.

Within Clearwater County, there are currently records for 159 springs in the groundwater database, including 23 springs that were documented by Borneuf (1983). There are 135 springs having at least one total dissolved solids (TDS) value, with 85% having a TDS of less than 500 milligrams per litre (mg/L). There are 21 springs in the groundwater database with flow rates that range from less than two to more than 10,000 litres per minute (lpm). The flow rates were measured mainly in November and December 1969.

A large spring, an outcrop of the Dalehurst Member, flows in the order of 10,000 lpm near the Raven River in 03-05-036-05 W5M. The spring is fed by overlying gravels of 11 metres thickness, and is used to supply water to the Raven trout fish hatchery.

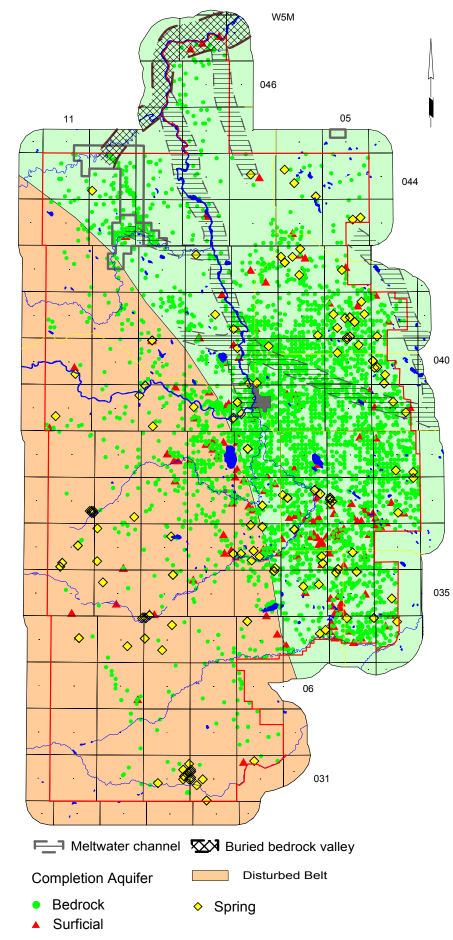

Figure 2. Location of Water Wells and Springs

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5 Mr. Kim Nielsen estimates that the rural population of the study area would be closer to 11,380
6 See glossary

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 6,431 water wells, with 6,386 (99%) indicated as having a diameter of less than 275 mm and 45 (1%) having a diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored or dug water wells and those with a surface-casing diameter of less than 275 mm are mainly drilled water wells. The groundwater database suggests that the 45 above-mentioned water wells in the County were bored, hand dug, or dug by backhoe. The complete water well database for the County suggests that 126 of the water wells in the County were bored or hand dug.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. Within the County, casing-diameter information is available for 168 of the 177 water wells completed in the surficial deposits, of which 162 surficial water wells have a casing diameter of less than 275 millimetres and are assumed to be drilled water wells. Within the County, casing-diameter information is available for 5,197 of the 5,257 water wells completed below the top of bedrock, of which 5,183 have a surface casing diameter of less than 275 mm and have been mainly completed with either a perforated liner or as open hole; there are seven bedrock water wells completed with a water well screen.

Where the casing material is known, steel surface casing materials have been used in 95% of the drilled water wells over the last 50 years. For the remaining drilled water wells with known surface casing material, 3% were completed with galvanized steel casing, 2% with plastic casing and 0.2% with wood, concrete or other surface casing materials (used mostly in the 1960s and 1970s). The main years where the type of surface casing was undocumented were between 1955 and 1965. Steel casing was in use in the 1950s and is still used in 95% of the water wells being drilled in the County. Galvanized steel surface casings were mainly used prior to 1955 and from the mid-1960s to the early 1980s, at which time plastic casing started to replace the use of galvanized steel casing.

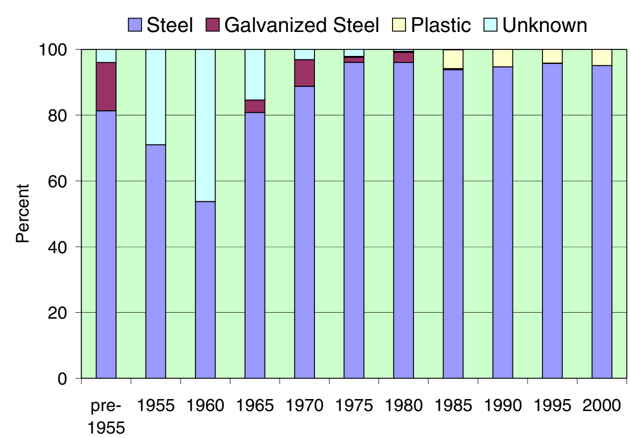

Figure 3. Surface Casing Types Used in Drilled Water Wells

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

2.3.4 Dry Water Test Holes

In the County, there are 11,708 records in the groundwater database. Of these 11,708 records, 105 (less than 1%) are indicated as being dry or abandoned with “insufficient water”[7]. Of the 105 “dry” water test holes, 95 are completed in bedrock aquifers; the remaining ten “dry” water test holes are completed in surficial deposits. Only about 11% of all water wells with apparent yield estimates were judged to yield less than 6.5 m³/day (1 igpm).

[7] “dry” can be due to a variety of reasons: skill of driller, type of drilling rig/method used, the geology

2.3.5 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 cubic metres per year [m³/year] or 750 imperial gallons per day[8]), (2) the diversion from 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 which 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 August 2003 update from the Alberta Environment (AENV) groundwater database, 1,461 groundwater licences and registrations were shown to be within the County, with the most recent groundwater user being registered in April 2003. Of the 1,461 licensed and registered groundwater users, 1,270 (87%) are registrations of Traditional Agriculture Use under the *Water Act*. These 1,270 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 1,270 registrations, only 372 (29%) could be linked to the AENV groundwater database. Of the remaining 191 from the 1,461 groundwater users, 88 are for agricultural purposes (mainly stock watering), 60 are for industrial purposes (mainly enhanced recovery or injection), 26 are for commercial purposes (mainly oil/gas companies), eight are for municipal purposes (mainly urban), six are recreation purposes, and the remaining three are for fishery purposes. Of these 191 licensed groundwater diversion in the County, 124 (65%) 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 registrations is 16,235 m³/day, although actual use could be less. Of the 16,235 m³/day, 2,978 m³/day (18.3%) is registered for Traditional Agriculture Use, 811 m³/day (5%) is licensed for agricultural purposes, 11,804 m³/day (72.7%) is licensed for industrial purposes, 275 m³/day (1.7%) is licensed for commercial purposes, 301 m³/day (1.9%) is licensed for municipal purposes, 54 m³/day (0.3%) is licensed for recreation purposes, and the remaining 12 m³/day is licensed for fishery purposes (0.1%), as shown below in Table 1. A figure showing the locations of the groundwater users with a licence and/or registration is in Appendix A (page A-7) and on the CD-ROM. Table 1 also shows a breakdown of the 1,461 groundwater licenses and/or registrations by the aquifer in which the water well is completed. Approximately 70% of the total quantity of licensed and registered groundwater use is in the Dalehurst Aquifer. The water wells associated with the 112 licensed and registered use where a specific aquifer cannot be determined is because insufficient completion information is available.

Aquifer **	No. of Licences and Registrations	Registrations (m³/day)	Licensed Groundwater Users* (m³/day) Agricultural	Industrial	Commercial	Municipal	Recreation	Fishery	Total Quantity of Licensed and Registered Groundwater Diversion (m³/day)	Percentage
Multiple Surficial Completions	68	150	21	0	18	0	10	0	199	1.2
Upper Sand and Gravel	39	49	76	3	1	0	7	0	136	0.8
Lower Sand and Gravel	34	78	64	0	10	0	7	0	159	1.0
Disturbed Belt	93	115	10	3,496	145	95	0	0	3,861	23.8
Dalehurst	1,114	2,361	637	8,268	101	206	30	12	11,615	71.5
Upper Lacombe	1	0	0	37	0	0	0	0	37	0.2
Unknown	112	225	3	0	0	0	0	0	228	1.4
Total	1,461	2,978	811	11,804	275	301	54	12	16,235	100
Percentage		18.3	5.0	72.7	1.7	1.9	0.3	0.1	100	

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

Table 1. Licences and Registrations of Groundwater by Aquifer

8 see conversion table on page 60

Based on the 2001 Agriculture Census (Statistics Canada), the calculated water requirement for 350,611 livestock for the County is in the order of 12,137 m³/day. This value includes intensive livestock use but not domestic animals and is based on an estimate of water use per livestock type. Of the 12,137 m³/day average calculated livestock use, AENV has authorized a groundwater diversion of 3,788 m³/day (agricultural and registration) (32%) and licensed a surface-water diversion based on a consumptive use of 115 m³/day (<1%); the remaining 67% of the calculated livestock use would have to be mainly from unlicensed sources.

2.3.6 Groundwater Chemistry and Base of Groundwater Protection

Groundwaters from an aquifer in the surficial deposits can be expected to be chemically hard, having a total hardness of at least a few hundred mg/L, and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. There were two groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) for the surficial aquifers and twelve groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ for the upper bedrock aquifer(s); a plot of Nitrate + Nitrite (as N) in surficial aquifers is on the accompanying CD-ROM. The TDS concentrations in the groundwaters from the upper bedrock in the County range from less than 500 to more than 1,000 mg/L (page A-32). Groundwaters from the bedrock aquifers frequently are chemically soft, with generally low concentrations of dissolved iron. The chemically soft groundwater is high in concentrations of sodium. Eight percent of the chemical analyses for upper bedrock water wells indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring in the eastern-central part of the County (page A-33).

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	1,485	202	4,129	440	500
Sodium	1,090	0	1,035	82	200
Sulfate	1,188	0	1,308	18	500
Chloride	1,286	0	355	2	250
Fluoride	1,117	0	8.11	0.2	1.5

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

SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial-Territorial Committee on Drinking Water, April 2002

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

The minimum, maximum and median[9] concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the upper bedrock in the County have been compared to the SGCDWQ in Table 2. Of the five constituents compared to the SGCDWQ, none of the median concentrations exceed the guidelines.

[9] see glossary

In general, Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater will have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, formation elevations, and Alberta Energy and Utilities Board (EUB) information indicating the formations containing the deepest useable water for agricultural needs, a value for the depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[10] method to prepare a depth to the Base of Groundwater Protection surface. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well has total dissolved solids exceeding 4,000 mg/L, the groundwater use does not require licensing by AENV. In the County, the depth to the Base of Groundwater Protection ranges from less than 400 metres in the northern and eastern parts of the County to more than 2,300 metres in the southwestern parts of the County, as shown on Figure 4, on some cross-sections presented in Appendix A, and on the CD-ROM.

There are 7,700 water wells with completed depth data, of which two are completed below the Base of Groundwater Protection. Both water wells completed below the Base of Groundwater Protection are/were used for industrial purposes. Chemistry data are not available for the two water wells. There is a water well that was drilled for domestic purposes in NW 33-039-05 W5M with a TDS concentration of 4,129 mg/L. The completion depth of the water well is above the Base of Groundwater Protection.

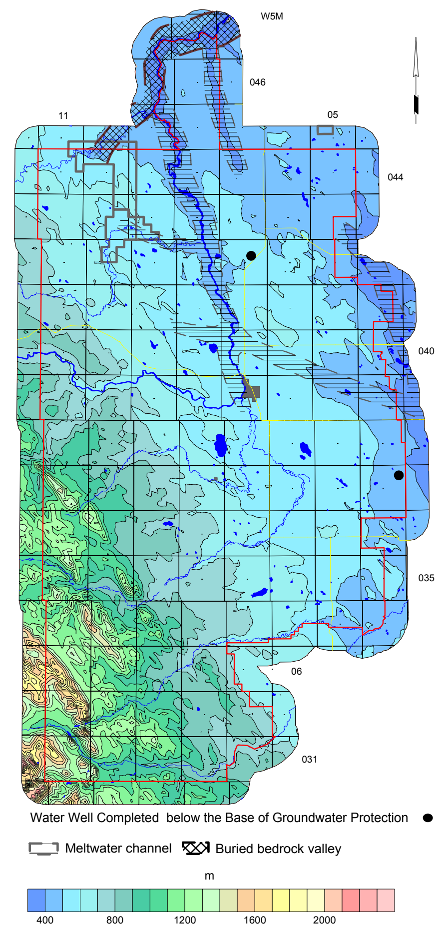

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are two AENV-operated observation water wells within the County (see page A-42 for observation water well locations). Additional data can be obtained from 38 water source wells and observation water wells of the licensed groundwater diversions. In the past, the data for authorized diversions have been difficult to obtain from AENV, in part because of the failure of the applicant to provide the data.

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

10 See glossary

3 TERMS

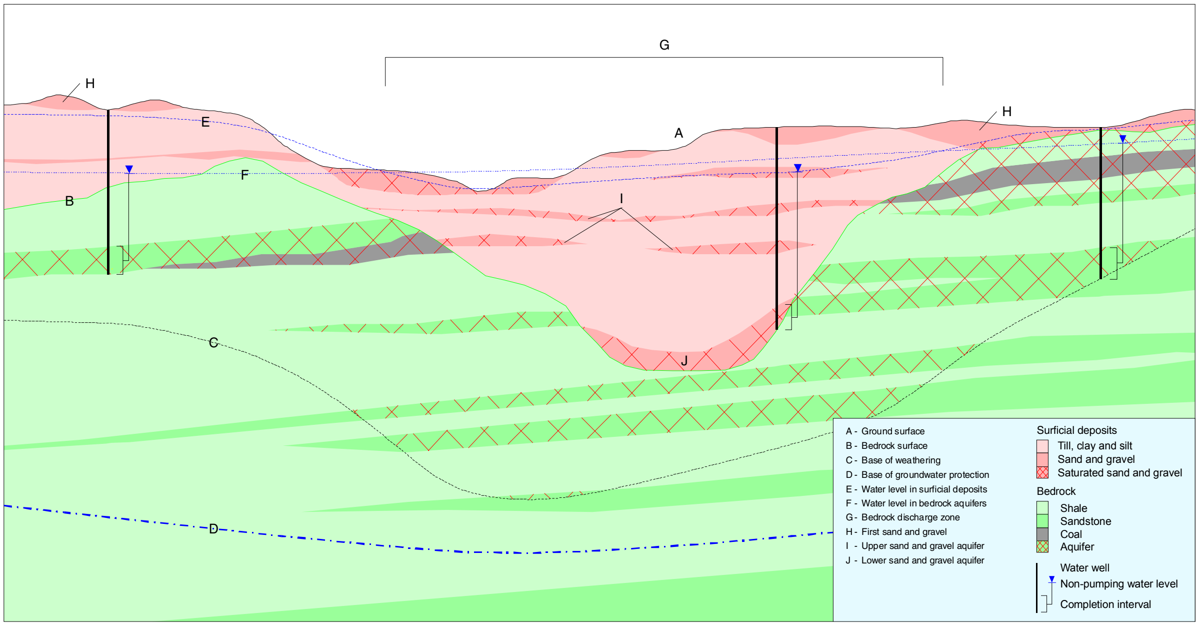

Figure 5. Generalized Cross-Section (for terminology only)

(for larger version, see page A-9)

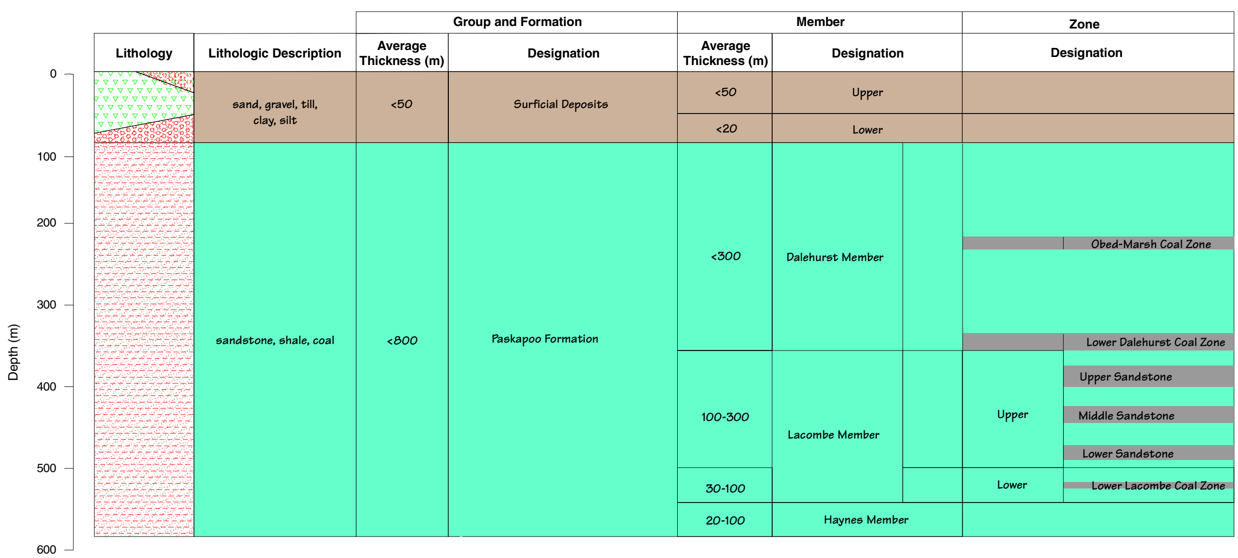

Figure 6. Geologic Column

(for larger version, see page A-10)

4 METHODOLOGY

4.1 Data Collection and Synthesis

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

1) water well drilling reports
2) aquifer test results from some water wells
3) location of some springs
4) locations for some water wells determined during water well surveys
5) chemical analyses for some groundwaters[11]
6) location of some flowing shot holes
7) location of some structure test holes
8) a variety of data related to the groundwater resource.

The main disadvantage to the database is the reliability of the information entered into the database. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information. Any duplicate water wells that have been identified within the County have been removed from the database used in this regional groundwater assessment.

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

The present project uses the 10TM coordinate system based on the NAD27 datum. This means that a record for the NE ¼ of section 14, township 034, range 05, W5M would have a horizontal coordinate with an Easting of 28,052 metres and a Northing of 5,750,308 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 County, more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a digital surface was prepared representing the minimum depth for water wells and a second digital surface was prepared for the maximum depth. Both of these surfaces are used in the groundwater query on the CD-ROM. When the maximum and minimum water well depths are similar, there is only one aquifer that is being used at a given location.

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

[11] 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.

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[12].

Also, where sufficient information is available, values for apparent transmissivity [13] and apparent yield [14] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological map covering the northern two-thirds of the County was published in 1971 (Tokarsky, 1971), more than 2,400 values for apparent transmissivity and apparent yield have been added to the groundwater database. Since the last regional hydrogeological map covering the area of the County that includes townships 031 to 034, ranges 04 to 12, W5M was published in 1977 (Ozoray and Barnes, 1977), 150 values for apparent transmissivity and apparent yield have been added to the groundwater database. The median apparent yield of the water wells with apparent yield values in the County is 185 m³/day. Approximately 17% of the apparent yield values for these water wells are less than ten m³/day. With the addition of the apparent yield values, including a 0.1-m³/day value assigned to "dry" water wells and water test holes, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the County (Figure 7 and page A-11). The map is based on groundwater being obtained from all aquifers and has been prepared to allow direct comparison with the results provided on the Alberta Research Council (ARC) hydrogeological maps. In general, the ARC map shows higher estimated long-term yields. The differences between the two maps may be a result of substantially fewer apparent yield values and the gridding method employed by ARC.

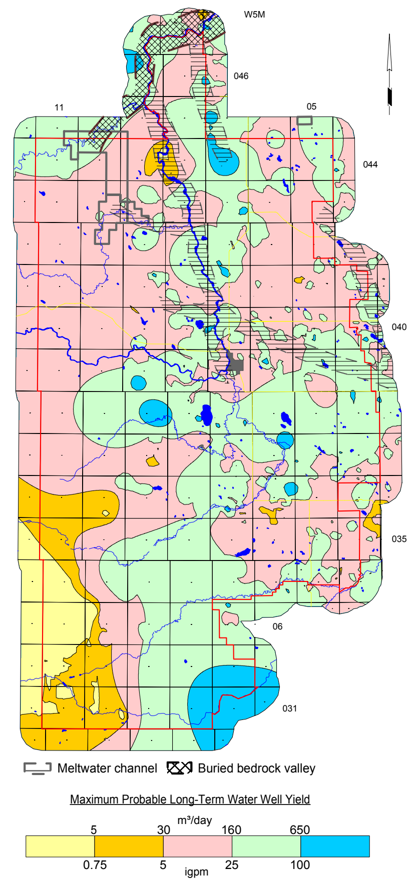

Figure 7. Hydrogeological Map

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.

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12 See glossary
13 For definitions of Transmissivity, see glossary
14 For definitions of Yield, see glossary

4.2 Spatial Distribution of Aquifers

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

1) lithologs provided by the water well drillers
2) geophysical logs from structure test holes
3) geophysical logs for wells drilled by the oil and gas industry
4) data from existing cross-sections.

The aquifers are defined by mapping the tops and bottoms of individual geologic units. The values for the elevation of the top and bottom of individual geologic units at specific locations help to determine the spatial distribution of the individual surfaces. Establishment of a surface distribution digitally requires preparation of a grid. The inconsistent quality of the data necessitates creating a representative sample set obtained from the entire data set. If the data set is large enough, it can be treated as a normal population and the removal of extreme values can be done statistically. When data sets are small, the process of data reduction involves a more direct assessment of the quality of individual points. Because of the uneven distribution of the data, all data sets are gridded using the Kriging method.

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

4.3 Hydrogeological Parameters

Water well records that indicate the depths to the top and bottom of their completion interval are compared digitally to the spatial distribution of the various geological surfaces. This procedure allows for the determination of the aquifer in which individual water wells are completed. When the completion depth of a water well cannot be established, the data from that water well are not used in determining the distribution of hydraulic parameters.

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity, and apparent water well yield. The NPWL given on the water well record is usually the water level recorded when the water well was drilled, measured prior to the initial aquifer test. In areas where groundwater levels have since fallen, the NPWL may now be lower and accordingly, the potential apparent yield would be reduced. The total dissolved solids, sulfate and chloride concentrations from the chemical analyses of the groundwaters are also assigned to applicable aquifers. In addition, chemical parameters of Nitrate + Nitrite (as N) are assigned to surficial aquifers and fluoride is assigned to upper bedrock aquifer(s). Nitrate + Nitrite (as N) concentrations are often related to well-specific data and may not indicate general aquifer conditions.

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid. The representative data set included using the available data from townships 031 to 047, ranges 04 to 11, W5M, 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.

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual geologic units. For example, the relationship between an upper bedrock unit and the bedrock surface must be determined. This process provides both the outline and the thickness of the geologic unit.

Once the appropriate grids are available, the maps are prepared by contouring the grids. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

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

Once the technical details of a cross-section are correct, the drawing file is moved to the software package CorelDraw! for simplification and presentation in a hard-copy form. Eight cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only one (G-G') is included in the text of this report. The cross-sections are also included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

4.5 Software

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

- Acrobat 5.0
- ArcView 3.2
- AutoCAD 2002
- CorelDraw! 11.0
- Microsoft Office XP
- Surfer 8

5 AQUIFERS

5.1 Background

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

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. These include pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly as a result of glaciation. The *lower surficial deposits* include pre-glacial fluvial[15] and lacustrine[16] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the traditional glacial sediments of till[17] and ice-contact deposits. Pre-glacial materials are expected to be mainly present in association with linear bedrock lows. Meltwater channels are associated with glaciation.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeologic unit, they consist of three hydraulic units. The first unit is the sand and gravel deposits of the lower surficial deposits, when present. These deposits are mainly saturated. The second and third hydraulic units are associated with the sand and gravel deposits in the upper surficial deposits. The sand and gravel deposits in the upper surficial deposits occur mainly as pockets. The second hydraulic unit is the saturated part of these sand and gravel deposits; the third hydraulic unit is the unsaturated part of these deposits. For a graphical depiction of the above description, please refer to Figure 5, page 9 and to page A-9. While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for soluble contaminants to move downward into the groundwater.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on Figure 8 in the following page. Regionally, the bedrock surface varies between 750 and 1,850 metres AMSL. The lowest elevations occur mainly in the north-central part of the County, as shown on Figure 8 and page A-20.

Over the majority of the County, the surficial deposits are less than 30 metres thick (see CD-ROM). The exceptions are mainly in the north-central part of the County where the buried bedrock valley and meltwater channels are present and in the southwestern half of the County, where the deposits can have a thickness of more than 50 metres.

The Buried Drayton Valley (Carlson, 1971a) is a southwest-northeast-trending linear bedrock low that it is occupied by the present-day North Saskatchewan River, which forms the extreme northern border of the County. In the County, the Buried Drayton Valley ranges approximately from four to eight kilometres wide, with local bedrock relief being less than 100 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 five metres.

[15] See glossary
[16] See glossary
[17] See glossary

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. In the County, lower surficial deposits occur mainly in linear bedrock lows having an elevation of less than 1,000 metres AMSL. The total thickness of the lower surficial deposits is mainly less than 30 metres, but can be more than 30 metres in the linear bedrock lows (see CD-ROM). The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. The lowest sand and gravel deposits are of fluvial origin, are usually less than two metres thick and may be discontinuous (see CD-ROM). The lowest sand and gravel deposits can be more than five metres thick in areas of linear bedrock lows, and in the southeastern part of the County.

In the County, the main linear bedrock lows trend mainly northwest to southeast and are indicated as being of meltwater origin. Because sediments associated with the lower surficial deposits are indicated as being present in most of the meltwater channels, it is possible that the meltwater channels were originally tributaries to the Buried Drayton Valley and to the Buried Red Deer Valley in Red Deer County.

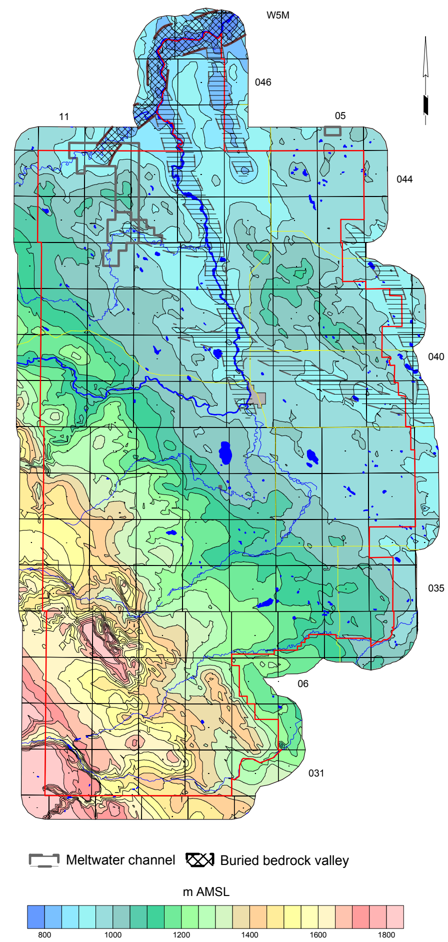


Figure 8. Bedrock Topography

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. The thickness of the upper surficial deposits is mainly less than 30 metres. The exceptions are mainly in the north-central part of the County, where the buried bedrock valley is present at an elevation of greater than 800 metres AMSL, and in the southwestern half of the County, where the deposits can have a thickness of more than 50 metres. The upper sand and gravel deposits are usually less than two metres thick (see CD-ROM). The upper sand and gravel deposits occur mainly where linear bedrock lows are not present in the County (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 two metres but can be more than five metres in association with linear bedrock lows, along the North Saskatchewan River north of Rocky Mountain House and within the broad valleys of parts of the Clearwater River, Prairie Creek and the James River.

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 35% of the County where sand and gravel deposits are present, the sand and gravel deposits are more than 30% of the total thickness of the surficial deposits (page A-23). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly associated with river valleys and linear bedrock lows.

5.2.2 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 more than 50% of the County, the sand and gravel deposits are not present, or if present, are not saturated; these areas are designated as grey on the adjacent map. In the County, the thickness of the Sand and Gravel Aquifer(s) is generally less than five metres, but can be more than five metres mainly in the southeastern part of the County, and in areas of, or near, river and creek valleys and linear bedrock lows, as shown in Figure 9, in Appendix A and on the CD-ROM.

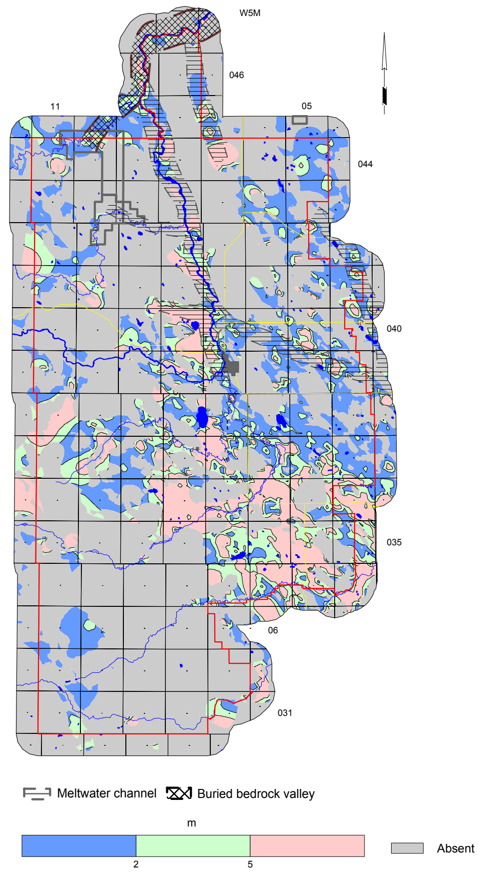


Figure 9. Thickness of Sand and Gravel Aquifer(s)

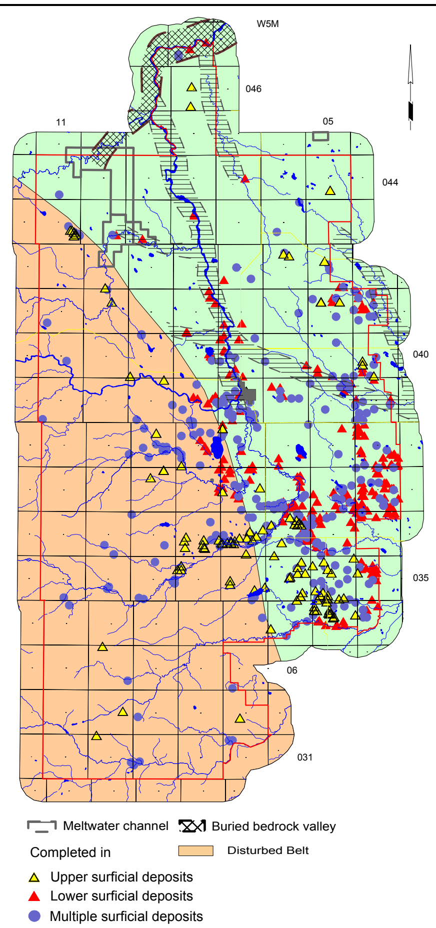


Figure 10. Water Wells Completed Surficial Deposits

Of the 8,283 water wells in the database, 177 were defined as being completed in surficial aquifers, based on lithologic information and water well completion details. From the present hydrogeological analysis, 679 water wells are completed in aquifers in the surficial deposits. Of the 679 water wells, 121 are completed in aquifers in the upper surficial deposits, 247 are completed in aquifers in the lower surficial deposits, and 311 water wells are completed in multiple surficial aquifers. This number of water wells (679) is nearly four times the number (177) determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the elevation of the bedrock surface determined from the gridded bedrock topographic surface at the same location, then the water well is considered to be completed in an aquifer in the surficial deposits.

Water wells completed in the upper surficial deposits are mainly in areas where the sand and gravel deposits exceed five metres in the southeastern part of the County. Water wells completed in the lower surficial deposits are located mainly along the linear bedrock lows and in the southeastern part of the County.

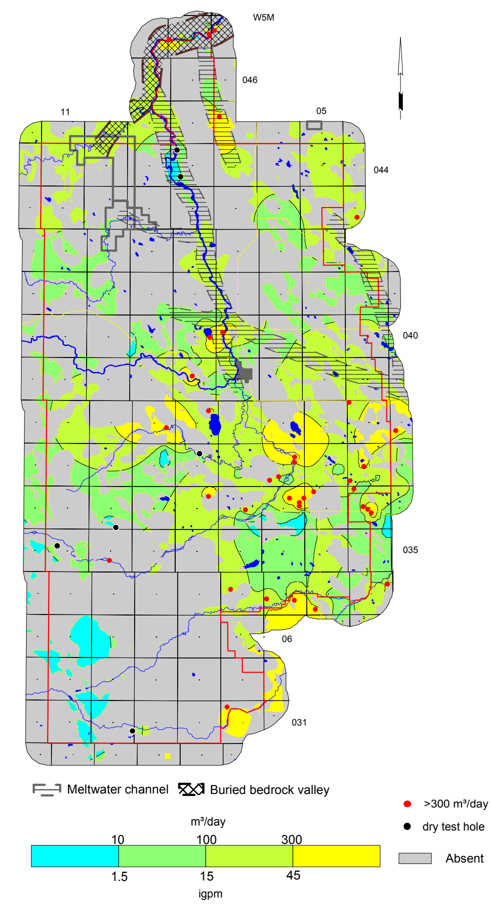


Figure 11. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

In the County, there are 113 records for surficial water wells with apparent yield data, which is 17% of the 679 surficial water wells. Of the 113 water well records with apparent yield values, 80 have been assigned to aquifers associated with specific geologic units. Nine percent (10) of the 113 water wells completed in the Sand and Gravel Aquifer(s) have apparent yields that are less than ten m³/day, 38% (43) have apparent yield values that range from 10 to 100 m³/day, and 53% (60) have apparent yields that are greater than 100 m³/day, as shown in Table 3. In addition to the 113 records for surficial water wells, there are ten records that indicate that the water well 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 ten dry test holes prior to gridding. Nine of the ten dry test holes are in multiple surficial completions.

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 100 m³/day from the Sand and Gravel Aquifer(s) can be expected in 60% of the County where the Sand and Gravel Aquifer(s) are present. The most notable areas where yields of more than 300 m³/day are expected are along the creek and river valleys in the southeastern part of the County, where the saturated thickness of sand and gravel deposits is more than five metres.

A six-hour aquifer test was conducted in August 1967 by the Water Resources Division with a water well completed from 21.0 to 22.3 metres below ground level in sand and gravel deposits in 09-09-035-10 W5M adjacent to the Clearwater River. The results of the aquifer test indicated a transmissivity of 540 m²/day (Tokarsky 1971). Tokarsky estimated that long-term yields of at least 3,200 m³/day may be possible in the sand and gravel deposits adjacent to the Clearwater River based on transmissivity values between 450 and 600 m²/day, and assuming a saturated sand and gravel thickness of at least 12 metres. The water well in 09-09-035-10 W5M shown on Figure 11 is indicated as being in an area where saturated sands and gravels are absent. This area is a reflection of gridding a limited amount of data.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Upper Surficial	11	3	4	4
Lower Surficial	69	3	29	37
Multiple Completions	33	4	10	19
Totals	113	10	43	60

* - does not include dry test holes

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

In the County, there are 141 licensed and/or registered water wells that are completed in the Sand and Gravel Aquifer(s), for a total groundwater use of 494 m³/day (Table 1, page 6).

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analyses results of groundwaters from the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In Clearwater County, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 200 and less than 500 mg/L (see CD-ROM).

The Piper tri-linear diagram[18] for the surficial deposits (page A-30) shows that the groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate waters. Seventy-eight percent of the groundwaters from the surficial deposits have a TDS concentration of less than 500 mg/L. Forty-three percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than or equal to the aesthetic objective (AO) of 0.3 mg/L. However, many iron analyses results are questionable due to varying sampling and analytical methodologies.

In some areas, the groundwater chemistry of the surficial aquifers is such that sulfate is the major anion[19]. 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 80% of the samples analyzed for surficial deposits in the County, the chloride ion concentration is less than ten mg/L (see CD-ROM).

In the County, the Nitrate + Nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of ten mg/L in three of the 128 groundwater samples analyzed (up to about 1986).

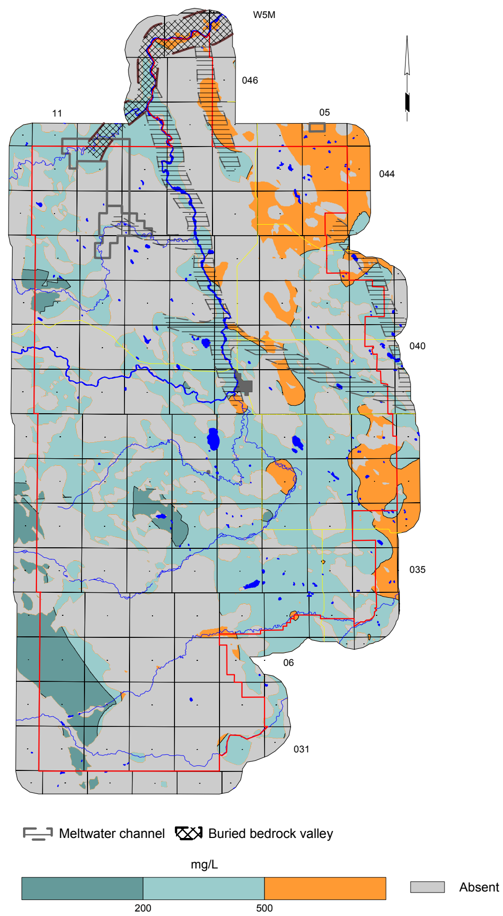


Figure 12. Total Dissolved Solids in Groundwater from Surficial Deposits

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and Nitrate + Nitrite (as N) in the groundwaters from water wells completed in the surficial deposits in the County have been compared to the SGCDWQ in the adjacent table. The range of concentrations shown in Table 4 is derived 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 County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	199	163	1,879	354	500
Sodium	158	0	294	14	200
Sulfate	202	0	265	13	500
Chloride	197	0	964	2	250
Nitrate + Nitrite (as N)	128	0	31	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial-Territorial Committee on Drinking Water, April 2002

Table 4. Concentrations of Constituents in Groundwaters from Surficial Deposits

Of the five constituents that have been compared to the SGCDWQ, none of the median values exceeds the guidelines.

18 See glossary
19 See glossary

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers are present within the surficial deposits at no particular depth. Saturated sand and gravel deposits in the upper surficial deposits are not usually continuous over large areas but are expected over approximately 25% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the surficial deposits; and (2) the depth to the bedrock surface or the depth to the top of the lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel Aquifer is generally less than five metres.

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. Shallow sand and gravel aquifers can be more susceptible to drought, and in some cases, may have a higher vulnerability to contamination. 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.

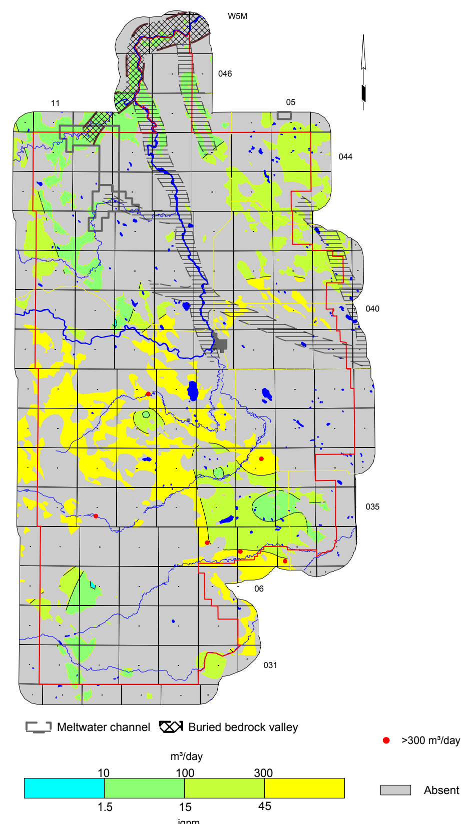


Figure 13. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

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.

Apparent yields for water wells completed through the Upper Sand and Gravel Aquifer range from less than 10 m³/day to more than 300 m³/day. The most notable areas where yields of more than 300 m³/day and as much as 2,000 m³/day may be possible are along the creek and river valleys in the central part of the County, where the saturated thickness of sand and gravel deposits is more than five metres. The areas west of range 08, W5M where yields of more than 300 m³/day are expected are based on the results of aquifer tests conducted by the Water Resources Division in August 1967. In the County, there are no dry water test holes completed in the Upper Sand and Gravel Aquifer.

In the County, there are 39 licensed and/or registered water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 136 m³/day (Table 1, page 6). The maximum amount is 20.3 m³/day for agricultural purposes. Fifteen of the 39 water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper part of the linear bedrock lows. The top of the lower surficial deposits is based on more than 1,000 control points across Alberta.

5.2.4.1 Aquifer Thickness

The thickness of the Lower Sand and Gravel Aquifer is mainly less than two metres, but can be up to ten metres in the linear bedrock lows (see CD-ROM).

5.2.4.2 Apparent Yield

Apparent yields for water wells completed through the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 300 m³/day. The most notable areas where yields of more than 300 m³/day are expected are mainly in areas where the thickness of the Lower Sand and Gravel Aquifer is greater than five metres.

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

In the County, there are 34 licences and/or registrations for water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 159 m^3/day.

Of the 34 water wells, three have been licensed for agricultural purposes, 28 are for registrations and are expected to be used for stock watering and/or crop spraying purposes, two are for commercial purposes and one is for recreation purposes. The highest groundwater authorization of 54 m³/day is for agricultural purposes for a water well in 13-18-040-04 W5M.

One water well used for commercial purposes is the 1984 Water Supply Well in 16-11-037-05 W5M licensed to Newalta Corporation to divert 6.8 cubic metres per day.

Twelve of the 34 licensed and registered water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

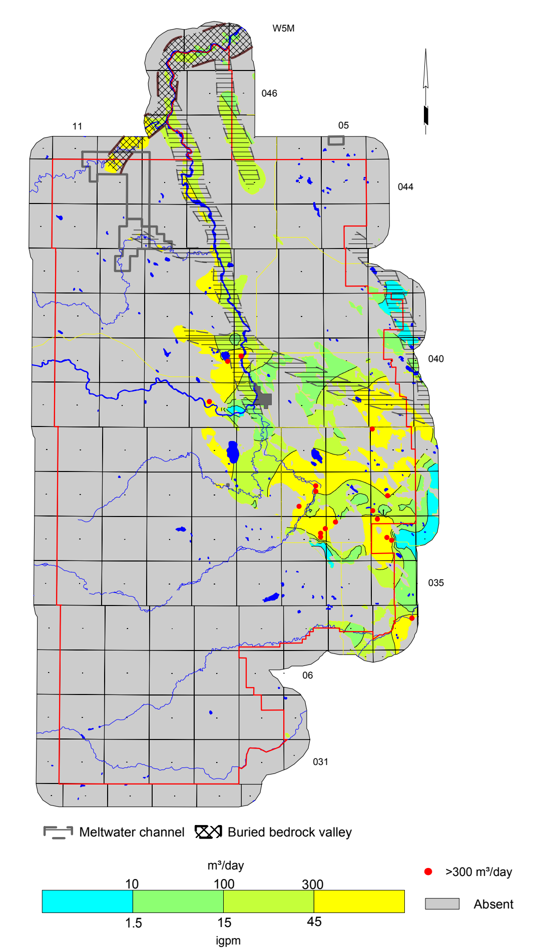
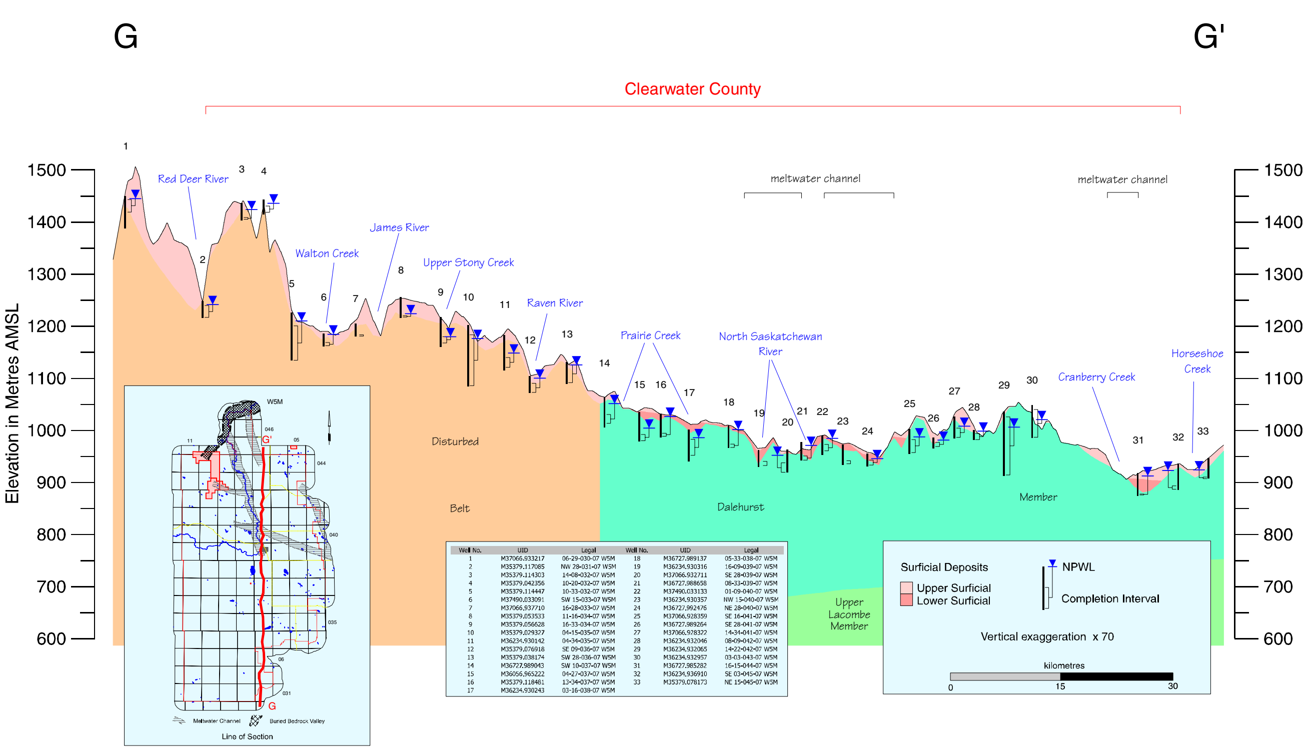


Figure 14. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

5.3 Bedrock

5.3.1 Bedrock Aquifers

The upper bedrock includes formations that are generally less than 200 metres below the bedrock surface. In the County, the upper bedrock includes the Disturbed Belt and the Dalehurst Member of the Paskapoo Formation, as shown below on cross-section GG' (see page A-18). Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones may be friable[20] and water well screens are a necessity.



Well No.	UID	Legal	Well No.	UID	Legal
1	M37066.933217	06-29-030-07 W5M	18	M36727.989137	05-33-038-07 W5M
2	M35379.117085	NW 28-031-07 W5M	19	M36234.930316	16-09-039-07 W5M
3	M35379.114303	14-08-032-07 W5M	20	M37066.932711	SE 28-039-07 W5M
4	M35379.042356	10-20-032-07 W5M	21	M36727.988658	08-33-039-07 W5M
5	M35379.114447	10-33-032-07 W5M	22	M37490.033133	01-09-040-07 W5M
6	M37490.033091	SW 15-033-07 W5M	23	M36234.930357	NW 15-040-07 W5M
7	M37066.937710	16-28-033-07 W5M	24	M36727.992476	NE 28-040-07 W5M
8	M35379.053533	11-16-034-07 W5M	25	M37066.928359	SE 16-041-07 W5M
9	M35379.056628	16-33-034-07 W5M	26	M36727.989264	SE 28-041-07 W5M
10	M35379.029327	04-15-035-07 W5M	27	M37066.928322	14-34-041-07 W5M
11	M36234.930142	04-34-035-07 W5M	28	M36234.932046	08-09-042-07 W5M
12	M35379.076918	SE 09-036-07 W5M	29	M36234.932065	14-22-042-07 W5M
13	M35379.038174	SW 28-036-07 W5M	30	M36234.932957	03-03-043-07 W5M
14	M36727.989043	SW 10-037-07 W5M	31	M36727.985282	16-15-044-07 W5M
15	M36056.965222	04-27-037-07 W5M	32	M36234.936910	SE 03-045-07 W5M
16	M35379.118481	13-34-037-07 W5M	33	M35379.078173	NE 15-045-07 W5M
17	M36234.930243	03-16-038-07 W5M			

Figure 15. Cross-Section G - G'

[20] See glossary

5.3.2 Geological Characteristics

In the County, the upper bedrock comprises the Disturbed Belt, and the Dalehurst Member of the Paskapoo Formation.

The Disturbed Belt is the upper bedrock in the western half of the County. The outline of the Disturbed Belt has been defined based on the Geological Map of Alberta (Hamilton et al, 1998, and Green, 1972). The Rocky Mountains and Foothills together form the Disturbed Belt, which is an area that has been deformed by folding and thrust faulting (Tokarsky, 1971). Water wells that were located within the Disturbed Belt boundary were defined as being completed in surficial deposits or in the Disturbed Belt Aquifer. The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991). A generalized geologic column is illustrated in Figure 6, in Appendix A, and on the CD-ROM.

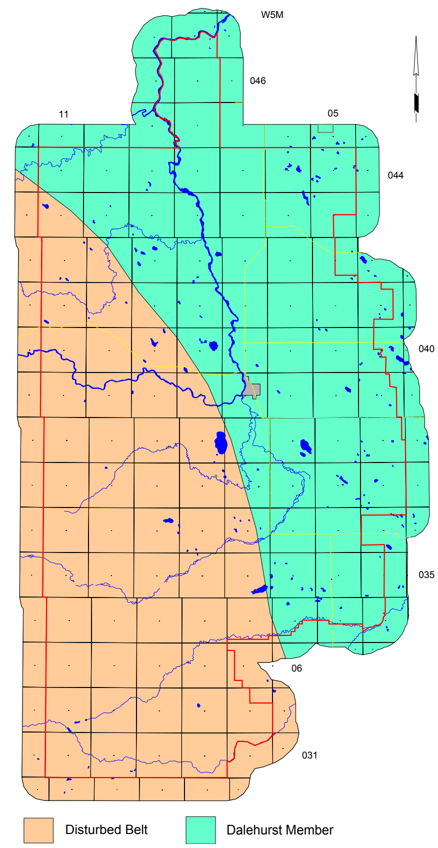


Figure 16. Bedrock Geology

The Dalehurst Member is the upper bedrock and outcrops or subcrops in the eastern half of the County. This Member has a maximum thickness of 220 metres within the County and is mostly composed of shale and siltstone with sandstone, bentonite and coal seams or zones. Two prominent coal zones within the Dalehurst are the Obed-Marsh Coal (up to 30 metres thick) and the Lower Dalehurst Coal (up to 50 metres thick). The bottom of the Lower Dalehurst Coal is the border between the Dalehurst and Lacombe members (Demchuk and Hills, 1991). In the County, the coal seams are not well developed. If the coal seams are not fractured, they are impermeable.

There will be no direct review of the Lacombe and Haynes members of the Paskapoo Formation in the text of this report; there are insufficient or no hydrogeological data within the study area to prepare meaningful maps. The only maps associated with these formations to be included on the CD-ROM will be structure-contour maps.

5.3.3 Upper Bedrock Completion Aquifer(s)

Of the 8,283 water wells in the database, 5,257 were defined as being completed below the top of bedrock, based on lithologic information and water well completion details. However, at least a reported completion depth is available for 6,938 water wells completed below the bedrock surface. Of these 6,938 water wells, five are completed below the upper bedrock in the Lacombe Member and three are in saline formations, giving a total of 6,930 water wells completed in upper bedrock aquifer(s). Assigning a water well to a specific geologic unit is possible only if the completion interval is identified. In order to make use of additional information within the groundwater database, it was assumed that the top of the completion interval was 80% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for an additional 831 bedrock water wells, giving a total of 6,088 water wells. The remaining 842 of the total 6,930 upper bedrock water wells are identified as being completed in more than one bedrock aquifer, as shown in Table 5. The bedrock water wells are mainly completed in the Dalehurst Aquifer.

Geologic Unit	No. of Bedrock Water Wells
Disturbed Belt	1,195
Dalehurst	4,893
Multiple Completions	842
Total	6,930

Table 5. Completion Aquifer for Upper Bedrock Water Wells

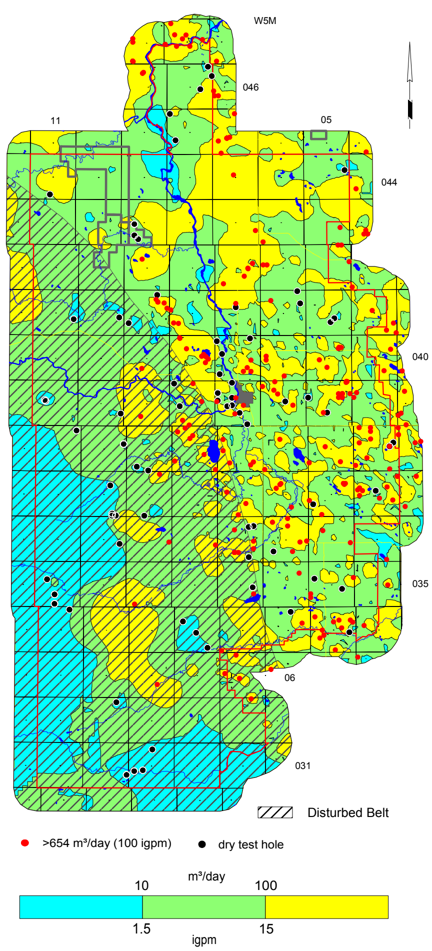


Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 2,287 records for bedrock water wells that have apparent yield values, which is 33% of the 6,930 bedrock water wells in the County. Yields for water wells completed in the upper bedrock aquifer(s) are mainly between 10 and 100 m³/day and have a median apparent yield of more than 45 m³/day. Apparent yield data are largely available for bedrock water wells completed below an elevation of 1,500 metres AMSL. The areas of apparent yields of less than ten m³/day in the southwestern part of the County are a result of the gridding process using limited data control. In addition to the 2,287 records for bedrock water wells with apparent yield values, there are 96 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 96 dry water test holes prior to gridding.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Disturbed Belt	488	99	268	121
Dalehurst	1,960	292	1,082	586
Upper Lacombe	1	1	0	0
Lower Lacombe	2	0	2	0
Multiple Completions	324	80	164	80
Totals	2,287	373	1,248	666

* - does not include dry test holes

Table 6. Apparent Yields of Bedrock Aquifers

Of the 2,287 water well records with apparent yield values, 1,963 have been assigned to aquifers associated with specific geologic units. Sixteen percent (373) of the 2,287 water wells completed in bedrock aquifers have apparent yields that are less than ten m³/day, 55% (1,248) have apparent yield values that range from 10 to 100 m³/day, and 29% (666) have apparent yield values that are greater than 100 m³/day, as shown in Table 6.

5.3.4 Chemical Quality of Groundwater

The Piper tri-linear diagram for bedrock aquifers (page A-30) shows that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are bicarbonate types, with no dominant cation.

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 200 mg/L to more than 1,000 mg/L, with 98% of the values being less than 1,000 mg/L (page A-32). Ninety-five percent of the sulfate concentrations in upper bedrock aquifer(s) are less than 100 mg/L.

In the County, more than 95% of the chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 50 mg/L.

The Nitrate + Nitrite (as N) concentrations are less than 0.1 mg/L in 65% of the chemical analyses for upper bedrock groundwaters. Approximately 65% of the total hardness values in the groundwaters from the upper bedrock aquifer(s) are less than 250 mg/L.

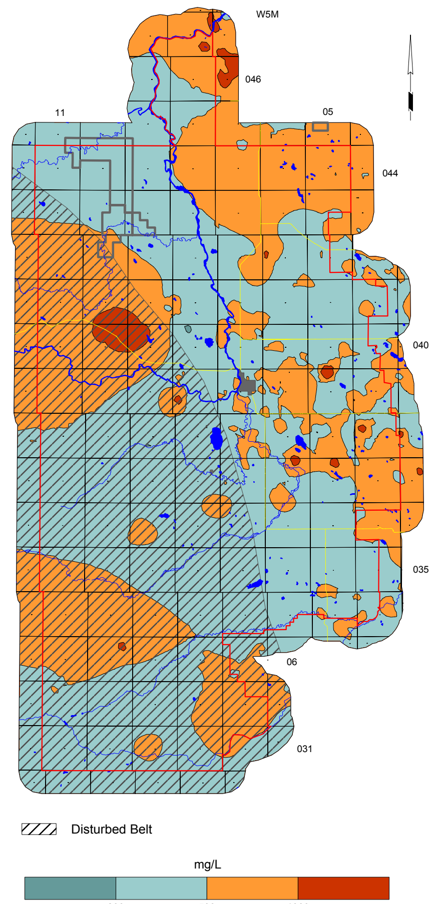


Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

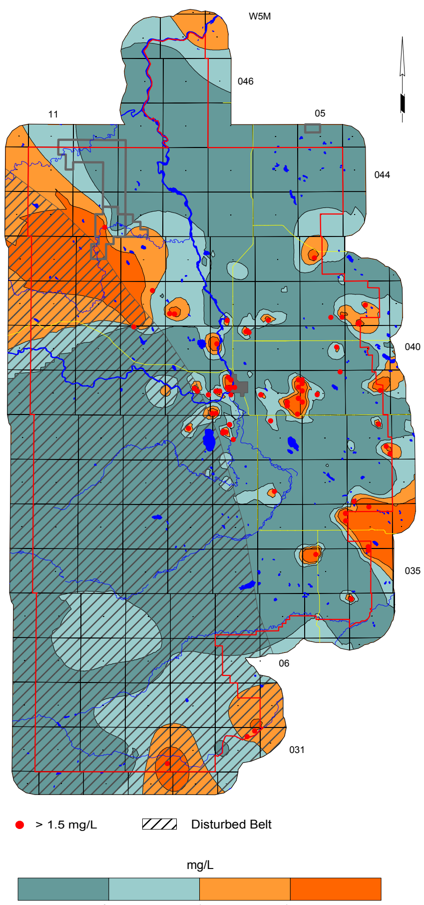


Figure 19. Fluoride in Groundwater from Upper Bedrock Aquifer(s)

In the County, approximately 81% 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 11% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 8% exceed the maximum acceptable concentration (MAC) for fluoride of 1.5 mg/L. Fluoride concentrations of greater than 1.5 mg/L are mainly associated with groundwaters from the Dalehurst Aquifer.

5.3.5 Disturbed Belt Aquifer

The Disturbed Belt Aquifer comprises the permeable parts of the Disturbed Belt, as defined for the present program. The regional groundwater flow direction in the Disturbed Belt Aquifer is toward the Clearwater and North Saskatchewan rivers (see CD-ROM).

5.3.5.1 Depth to Top

The depth to the top of the Disturbed Belt is mainly less than 30 metres and is a reflection of the thickness of the surficial deposits.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Disturbed Belt Aquifer are mainly in the range of 10 to 100 m³/day as shown on Figure 20. The available apparent yield data for water wells completed through the Disturbed Belt Aquifer are mainly limited to the eastern half of the Aquifer.

Shown on the adjacent map are the locations of 47 dry water test holes.

There are 93 licensed and/or groundwater users that have water wells completed through the Disturbed Belt Aquifer, for a total groundwater diversion of 3,861 m³/day.

The highest groundwater use is for four licences that allow Husky Oil Operations Ltd. (Husky) to divert up to 1,723 m³/day for gas and petroleum purposes in sections 24 and 34 to 36, township 036, range 10, W5M. The highest authorization is for a Husky water source well in 11-24-036-10 W5M that is licensed to divert 645 m³/day and is completed from 11.5 to 42.6 metres below ground surface in the Disturbed Belt Aquifer.

Of the 93 licences and/or registrations, 48 could be linked to water wells in the AENV groundwater database.

More than 50% of the water wells completed through the Disturbed Belt Aquifer were drilled for oil and gas companies, with the main water well owners at the time of drilling being Northrock Resources Ltd., Amerada Hess Canada Ltd./Amerada Petroleum Corporation, Gulf Canada Resources Ltd., Shell Canada Resources Ltd., Canadian Hunter Exploration Ltd., Poco Petroleum Ltd., and Petro-Canada Oil & Gas Ltd.

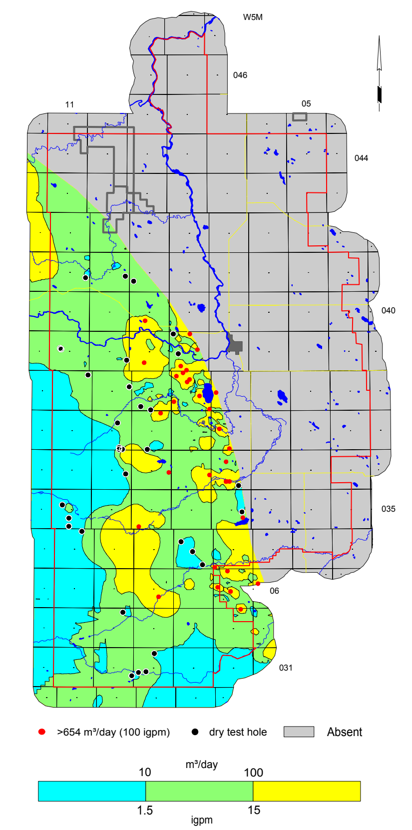


Figure 20. Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer

5.3.5.3 Quality

The groundwaters from the Disturbed Belt Aquifer are mainly a bicarbonate type, with no dominant cation, with 60% of the groundwater samples having TDS concentrations of less than 500 mg/L (page A-36). Eighty percent of the sulfate concentrations in groundwaters from the Disturbed Belt Aquifer are less than 50 mg/L. More than 80% of the chloride concentrations in groundwaters from the Disturbed Belt Aquifer are less than ten mg/L, and 7% of the fluoride concentrations exceed the recommended maximum concentration of 1.5 mg/L.

5.3.6 Dalehurst Aquifer

The Dalehurst Aquifer comprises the permeable parts of the Dalehurst Member, as defined for the present program. The Dalehurst Member subcrops under the surficial deposits in the eastern half of the County. The thickness of the Dalehurst Member varies from less than 150 metres at the eastern edge of the subcrop to more than 450 metres in the western part of the subcrop. The regional groundwater flow direction in the Dalehurst Aquifer is toward the North Saskatchewan River (see CD-ROM).

5.3.6.1 Depth to Top

The depth to the top of the Dalehurst Member ranges from less than ten metres to more than 30 metres in the northern part of the County and is a reflection of the thickness of the surficial deposits (page A-37).

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Dalehurst Aquifer are mainly in the range of 10 to 100 m³/day, as shown on Figure 21. The areas showing water wells with yields of greater than 100 m³/day are expected to be throughout the area extent of the Aquifer.

There are 1,114 licensed and/or registered groundwater users that have water wells completed through the Dalehurst Aquifer, for a total authorized groundwater diversion of 11,615 m³/day.

Of the 1,114 licences and/or registrations, 404 could be linked to water wells in the AENV groundwater database.

The highest authorized groundwater use is for 14 licences that allow Petro-Canada Oil & Gas to divert up to 3,201 m³/day for injection purposes, mainly in sections 24 to 26, township 041, range 09, W5M.

Nearly 20% of the water wells completed through the Dalehurst Aquifer were drilled for oil and gas companies, with the main water well owners at the time of drilling being Amerada Hess Canada Ltd./Amerada Petroleum Corporation, Poco Petroleum Ltd., Dome Petroleum Ltd., and Northrock Resources Ltd.

Between 1978 and 2000, extended aquifer tests with water test holes have been conducted by Mow-Tech Ltd. for numerous energy companies throughout the eastern part of Clearwater County. The results of aquifer tests have indicated long-term yields for water wells completed in the Dalehurst Aquifer in or near the Rose Creek area that can vary from less than 30 m³/day in 01-05-047-08 W5M to more than 800 m³/day in 01-17-045-07 W5M.

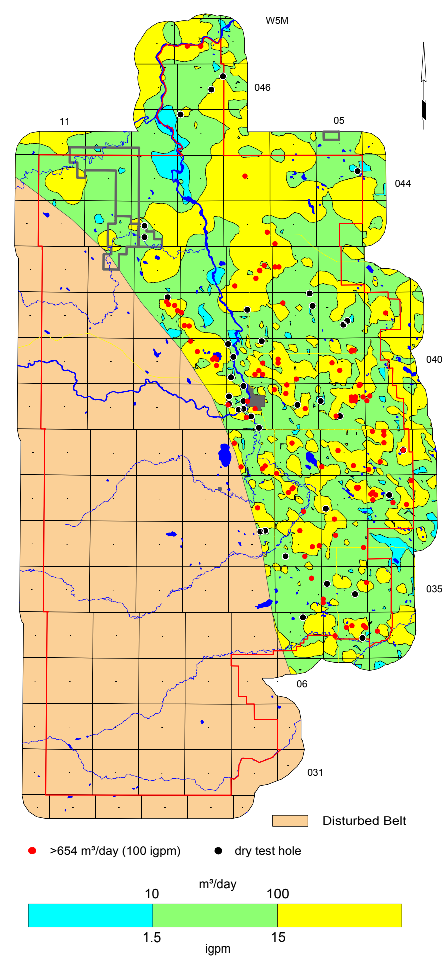


Figure 21. Apparent Yield for Water Wells Completed through Dalehurst Aquifer

5.3.6.3 Quality

The groundwaters from the Dalehurst Aquifer are mainly a bicarbonate type, with no dominant cation, with 75% of the groundwater samples having TDS concentrations of less than 500 mg/L (page A-39). Eighty percent of the sulfate concentrations in groundwaters from the Dalehurst Aquifer are less than 50 mg/L. More than 80% of the chloride concentrations in groundwaters from the Dalehurst Aquifer are less than ten mg/L, and 8% of the fluoride concentrations exceed the recommended maximum concentration of 1.5 mg/L.

6 GROUNDWATER BUDGET

6.1 Hydrographs

In the County, there are two observation water wells that are part of the AENV regional groundwater monitoring network. These are two locations where water levels are being measured and recorded as a function of time: Water Well No. 83-4 in SW 09-036-07 W5M near Ricinus and AENV Obs Water Well No. 95 (Raven Trout Brooding Station) in SW 05-036-05 W5M (see page A-42).

Water Well No. 83-4 was drilled in April 1983 for Alberta Energy & Natural Resources for observation purposes and was monitored by AENV in 1987, from September 1989 to September 1994, and from May 1996 to May 1997. Water Well No. 83-4 was drilled to a total depth of 61.0 metres and completed from 20.1 to 24.7 metres below ground surface in the Disturbed Belt Aquifer.

The adjacent hydrograph shows annual cycles of rise and decline throughout the monitoring period. In an area where there are no expected seasonal uses of groundwater, the highest water level will usually occur in late spring/early summer and the lowest water level will be in late winter/early spring. The rise in water level in late spring/early summer could be associated with recharge when the frost leaves the ground. Overall annual fluctuations in Water Well No. 83-4 mainly range from 0.2 to 0.4 metres. From 1990 to 1997, there was a net decline in the water level of approximately of 0.6 metres.

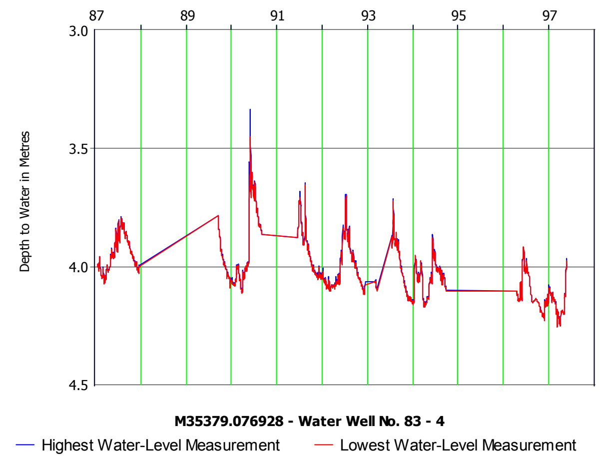


Figure 22. Hydrograph – Water Well No. 83-4

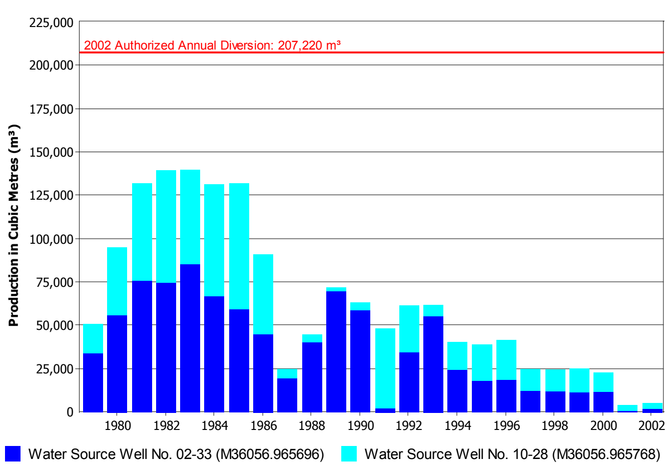


Figure 23. Annual Production from WSW Nos. 02-33 and 10-28

Enerplus Resources Corporation (Enerplus), formerly Suncor Inc., maintains two water source wells and five observation water wells for its Medicine River Unit No. 3 enhanced-oil-recovery project in the eastern part of Clearwater County. Enerplus is authorized to divert 207,220 m³/year from Water Source Well (WSW) Nos. 02-33 and 10-28, which are completed in the Dalehurst Aquifer. Mow-Tech Ltd.[21] has been monitoring the water levels in the two water source wells and five observation water wells since 1978.

Enerplus has diverted from WSW No. 02-33 and WSW No. 10-28 as much as 139,650 m³/year in 1983 (67% of the authorized amount) to as little as 3,855 m³/year in 2001 (2% of the authorized amount).

Observation WW No. 02-28 is one of the five observation water wells that is monitored as part of the Enerplus groundwater monitoring program. Observation WW No. 02-28 in 02-28-038-04 W5M is completed open hole from 7.3 to 18.3 metres below ground surface in the Dalehurst Aquifer and is 800 metres south of WSW No. 10-28 and 1,630 metres south of WSW No. 02-33.

[21] Mow-Tech Ltd. 1-800-GEO-WELL

A mathematical model aquifer [22] was used to calculate water levels in Obs WW No. 02-28 based on the Enerplus weekly groundwater production from 1979 to the end of 2002, with an aquifer transmissivity of 90 m²/day and a corresponding storativity of 0.00001. The calculations are based on an aquifer that is homogeneous and isotropic. No allowance has been made for aquifer recharge. Therefore, if there were a decrease in recharge to the groundwater, a water-level decline could occur and the simulation would not account for the change.

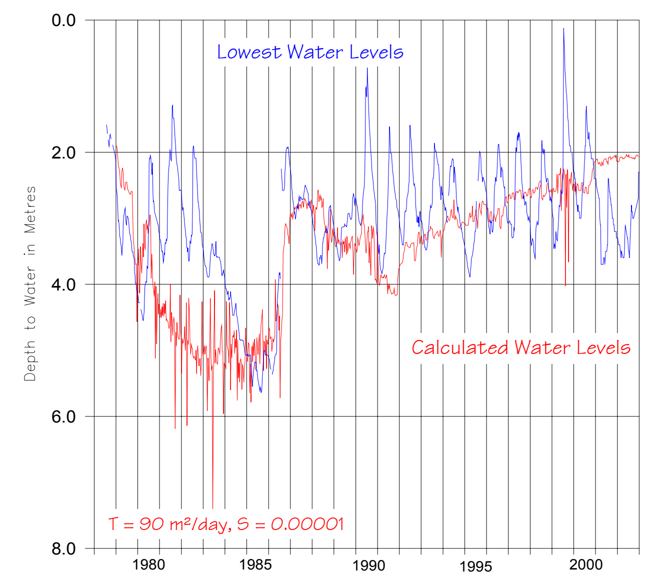


Figure 24. Water-Level Comparison - Obs WW No. 02-28

A comparison of the measured and calculated water levels shows a reasonable match when compared to the general patterns of the lowest weekly water-level fluctuation in Obs WW No. 02-28. The main exception to this is from mid-1980 to the latter part of 1984, when the average calculated water levels are in the order of 0.5 to 1.5 metres lower than the measured water levels. This discrepancy is considered due to the higher than average spring and summer aquifer recharge events in 1980, 1981 and 1982, as indicated by the rise in the measured water levels in Obs WW No. 02-28 shown below in Figure 25.

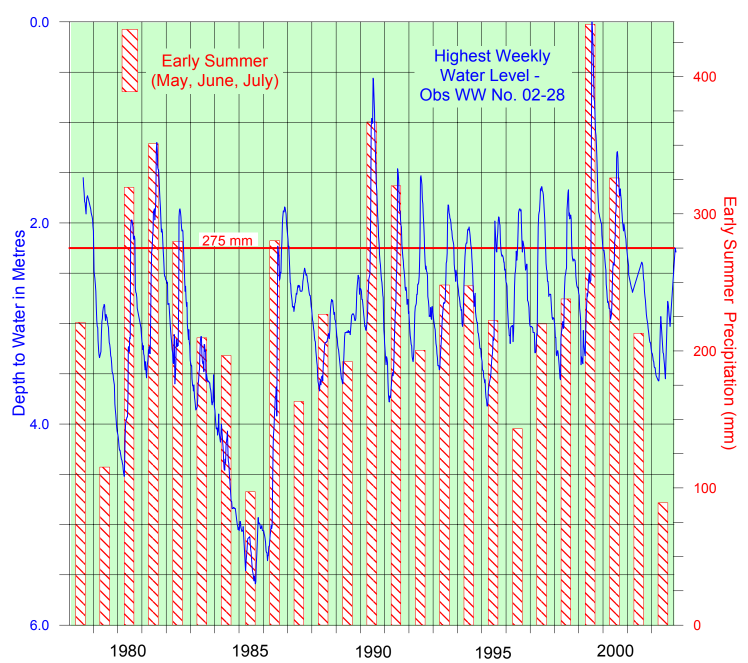


Figure 25. Obs WW No. 02-28 Measured Water Level and Early-Summer Precipitation

The water level in Obs WW No. 02-28 for the majority of years shows a similar fluctuation. There is a rise in water level during the first half of the year followed by a general water-level decline until the first half of the following year. This type of pattern is best illustrated in the years 1980, 1981 and 1982. From 1978 to 2002, the water levels in Obs WW No. 02-28 have ranged mainly between close to 1.5 metres and close to 3.5 metres below the reference point.

The adjacent graph indicates that when the early-summer precipitation exceeds 275 millimetres, measured at the Red Deer meteorological station, the water level in Obs WW No. 02-28 can be expected to reach a high of 2.0 metres below the reference point, regardless of whether the groundwater diversion is 139,600 m³/year (1982) or 22,370 m³/year (2000).

Since monitoring began in 1978, the general pattern of the water levels measured in the water source wells and the five observation water wells is a reflection of groundwater production combined with spring and summer recharge to the sandstone and shale aquifer within the Dalehurst Member in which the water source wells are completed.

[22] IAAM (see glossary)

Magin Energy Inc. (Magin) diverts groundwater from a water source well in 14-36-039-05 W5M for its enhanced-oil-recovery project in the eastern part of Clearwater County. Mow-Tech Ltd. has been monitoring the water levels in the water source well and three observation water wells since October 1998. One of the water wells monitored by Mow-Tech Ltd. is the DeMonnin Domestic (Dom) Obs WW in SE 02-040-05 W5M. The DeMonnin Dom Obs WW is completed at a depth of 24.4 metres below ground surface in the Dalehurst Aquifer.

The weekly measured water levels in Obs WW No. 02-28 were compared to the daily measured water levels in the DeMonnin Dom Obs WW from June to August, 1999. On July 7, 1999, 40 mm of rain was recorded at the Red Deer meteorological station. In response, the water level in Obs WW No. 02-28 rose to the surface and was flowing during the July 9 and July 16 weekly water-level monitoring. A similar water-level fluctuation was also noted at the DeMonnin Dom Obs WW as shown on the adjacent figure; the DeMonnin Dom Obs WW is approximately 14 kilometres north of the Enerplus observation water well.

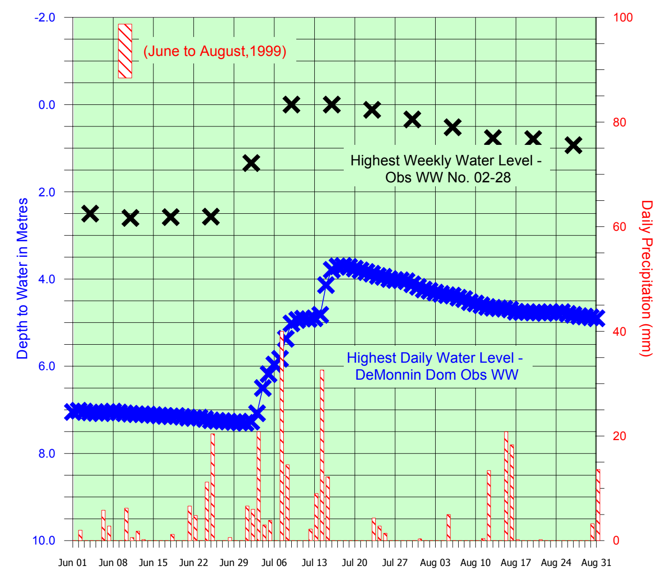


Figure 26. Obs WWs Water Levels and June to August, 1999 Precipitation

AENV Obs WW No. 95 (Raven Trout Brooding Station) in SW 05-036-05 W5M was drilled in May 1981 and completed open hole from 35.7 to 36.6 metres below ground surface in the Dalehurst Aquifer.

Because a water-level measurement reference was not provided by Alberta Environment for AENV Obs WW No. 95, changes in water levels were referenced to the non-pumping water level of 21.1 metres measured on May 27, 1981. The hydrograph for AENV Obs WW No. 95 shows annual cycles of rise and decline throughout the monitoring period (see page A-42).

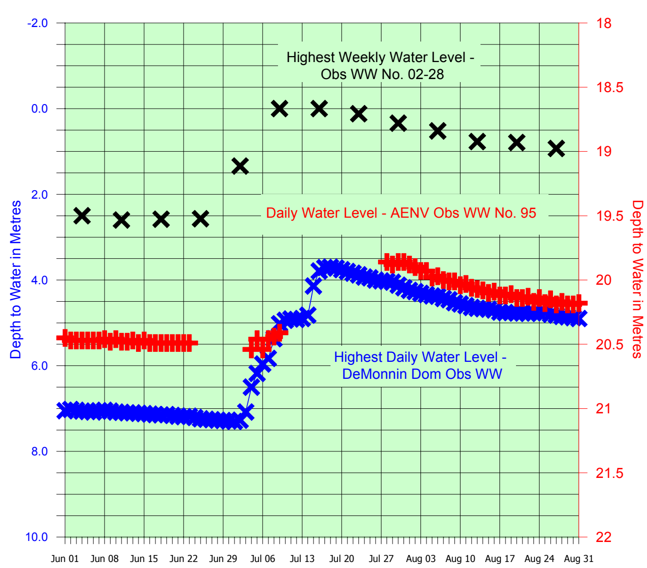


Figure 27. Water-Level Comparions – AENV Obs WW No. 95, Obs WW No. 02-28 and DeMonnin Obs WW - 1999

AENV Obs WW No. 95 is located 28 kilometres southwest of the Enerplus Obs WW No. 02-28. The daily measured water-level fluctuations in AENV Obs WW No. 95 were compared to the daily measured water levels in the DeMonnin Dom Obs WW and the weekly measured water levels in Obs WW No. 02-28 from June to August, 1999. Although water-level data are not available from June 10 to June 27, 1999 in AENV Obs WW No. 95, the water-level rise beginning on July 7 and the following water-level decline parallel the water-level trends in Obs WW No. 02-28 and the DeMonnin Dom WW.

6.2 Estimated Groundwater Use in Clearwater County

An estimate of the quantity of groundwater removed from each geologic unit in Clearwater County must include both the licensed and/or registered groundwater diversions. As stated previously on page 7 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 12,137 cubic metres. As of January 2003, AENV has licensed the use of 4,221 m³/day for livestock, which includes both surface water and groundwater. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 7,916 m³/day of water required for livestock watering is obtained from water wells for which there is no licence and/or registration.

There are 1,719 water wells that are used for stock or domestic/stock purposes. There are 1,358 licensed and registered water wells giving 424 stock water wells for which there is no licence and/or registration. By dividing the number of stock and domestic/stock water wells (424) into the quantity required for stock purposes for which it is not licensed and/or registered (7,916 m³/day), the average water well with a licence and/or registration diverts 18.7 m³/day per stock water well.

Groundwater for household use does not require a licence if the use is less 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 5,484 domestic or domestic/stock water wells in Clearwater County serving a population of 11,505, the domestic use per water well is 0.5 m³/day.

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

Domestic 0.5 m³/day
Stock 18.7 m³/day
Domestic/stock 19.2 m³/day

Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells.

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. Table 7 shows a breakdown of the 6,118 (4,418+616+1,084) water wells for which there is no licence and/or registration used for domestic, stock, or domestic/stock purposes by the geologic unit in which each water well is completed. The final column in the table equals the total amount of groundwater that is being used for both domestic and stock purposes from water wells for which there is no licence and/or registration. The data provided in Table 7 indicate that most of the 36,376 m³/day, estimated to be diverted from domestic, stock, or domestic/stock water wells for which there is no licence and/or registration, is from the Dalehurst Aquifer.

	Groundwater Diversions from Water Wells With or Without Licences and/or Registrations							*Groundwater Diversions With Licences and/or Registrations*	*Groundwater Diversions Without Licences and/or Registrations*
Aquifer Designation	Number of Domestic	Daily Use (0.5 m³/day)	Number of Stock	Daily Use (21.3 m³/day)	Number of Domestic and Stock	Daily Use (22.4 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Multiple Surficial Completions	133	70	19	417	41	921	1407	171	1236
Upper Sand/Gravel	74	39	7	154	12	269	462	125	337
Lower Sand/Gravel	99	52	28	614	68	1527	2,193	142	2,051
Multiple Bedrock Completions	474	249	84	1,842	104	2,335	4,426	0	4,426
Disturbed	494	259	46	1009	78	1751	3,019	125	2,894
Dalehurst	2,791	1,464	428	9,386	761	17,087	27,937	2,998	24,939
Upper Lacombe	1	1	0	0	1	22	23	0	23
Unknown	352	185	4	88	19	427	699	228	471
Totals [1]	4,418	2,317	616	13,508	1,084	24,340	40,165	3,789	36,376

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

Table 7. Total Groundwater Diversions by Aquifer

By assigning 0.5 m³/day for domestic use, 18.7 m³/day for stock use and 19.2 m³/day for domestic/stock use, and using the total maximum diversion associated with any water well with a licence and/or registration, a map has been prepared that shows the estimated groundwater use in terms of volume per section per day for the County (not including springs).

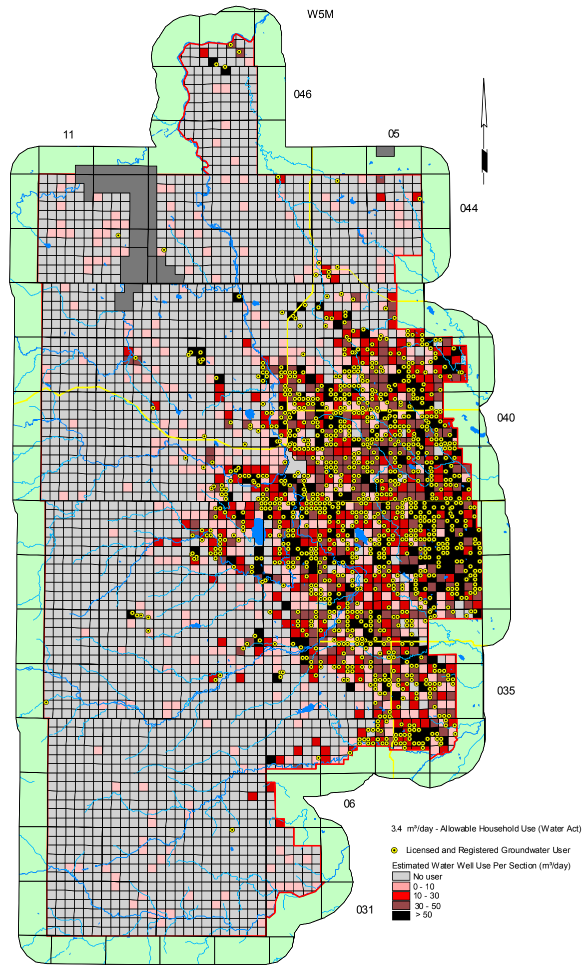


Figure 28. Estimated Water Well Use Per Section

There are 3,632 sections in the County. In 66% (2,391) of the sections in the County, there is no domestic, stock or licensed and/or registered groundwater water well. The range in groundwater use for the remaining 1,241 sections is from 0.5 m³/day to 1,000 m³/day (industrial), with an average use per section of 30 m³/day (4.5 igpm). The estimated water well use per section can be more than 50 m³/day in 241 of the 1,241 sections. There are 480 of the total 1,461 groundwater users with a licence and/or registration in areas of greater than 50 m³/day. The most notable areas where water well use of more than 50 m³/day is expected to occur is in townships 037 and 038, range 04, W5M, as shown on Figure 28.

Groundwater Use within Clearwater County (m³/day)		%
Domestic/Stock (including agriculture and registrations)	40,165	76
Municipal (licensed)	301	1
Commercial/Industrial/Recreation et al (licensed)	12,145	23
Total	52,611	100

Table 8. Total Groundwater Diversions

In summary, the estimated total groundwater use within Clearwater County is 52,611 m³/day, with the breakdown as shown in the above table. An estimated 46,448 m³/day is being withdrawn from a specific aquifer. The remaining 624 m³/day or 1% is being withdrawn from unknown aquifer units. Of the 46,448 m³/day, 91% is being diverted from bedrock aquifers and 8% from surficial aquifers. Approximately 30% of the total estimated groundwater use is from water wells without a licence and/or registration.

6.3 Groundwater Flow

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

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer; flow through the aquifers takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 9.

Table 9 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 Table 9 are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed and Registered (m^3/day)	Without Licences and Registrations (m^3/day)	Total (m^3/day)
Surficial					55,015	494	3,624	4,118
Drayton Valley								
	186	0.004	6,400	4,650				
Swan Creek								
North	115	0.210	6,000	14,375				
South	71	0.210	14,000	20,708				
Clearwater River								
	107	0.006	10,000	6,688				
Raven River								
	110	0.008	10,000	8,594				
Springs								
	54	0.006	14,000	4,725				
Disturbed Belt					6,800	3,861	2,894	6,755
North Saskatchewan River sub-basin					3,500			
North Saskatchewan River	4.2	0.010	30	1,313				
Swan Creek	4.2	0.017	15	1,094				
Clearwater River	4.2	0.010	25	1,094				
Red Deer River sub-basin					3,300			
Red Deer River	4.2	0.018	30	2,250				
Raven River	4.2	0.013	20	1,050				
Dalehurst					36,851	11,615	24,939	36,554
Red Deer River sub-basin					13,726			
Raven River								
NE	8	0.007	25	1,458				
SW	8	0.003	12	300				
SE	8	0.002	20	250				
Leshill Creek								
SW	8	0.003	18	450				
NE	8	0.009	25	1,875				
East	8	0.006	20	1,000				
East	8	0.015	9	1,080				
SW	8	0.020	18	2,925				
SE	8	0.013	5	500				
Lobstick Creek								
NE	8	0.010	40	3,250				
SE	8	0.005	17	638				
North Saskatchewan River sub-basin					23,125			
North Saskatchewan River								
West side of river								
ENE	8	0.012	25	2344				
ENE	8	0.023	20	3667				
Brazeau River								
North	8	0.015	25	2917				
Baptiste River								
NE	8	0.011	20	1833				
East	8	0.010	6	471				
South	8	0.025	15	3000				
East side of river								
West	8	0.006	10	500				
South	8	0.016	8	1000				
West	8	0.017	25	3375				
North	8	0.008	10	650				
West	8	0.008	18	1157				
North	8	0.004	9	253				
Clearwater River								
Northeast	8	0.007	25	1458				
Southwest	8	0.006	10	500				

Table 9. Groundwater Budget

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers is 0.4 to 2.4 cubic kilometres. This volume is based on an areal extent of 2,700 square kilometres and a saturated thickness of three metres. The variation in the total volume is based on the value of porosity that is used for the surficial deposits. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared from water levels associated with water wells completed to depths of less than 20 metres in aquifers in the surficial deposits. The water levels from these water wells were used for the calculation of the saturated thickness of the surficial deposits 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 a flow direction northeast toward the North Saskatchewan River.

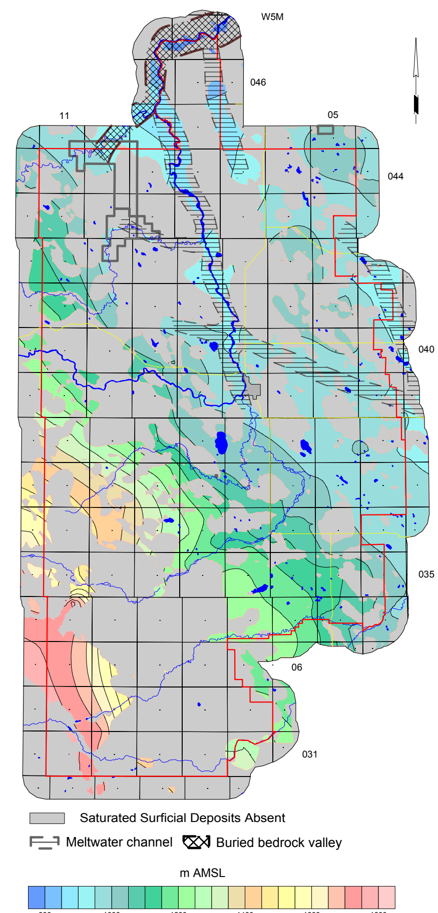


Figure 29. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

6.3.2 Recharge/Discharge

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

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

6.3.2.1 Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data.

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

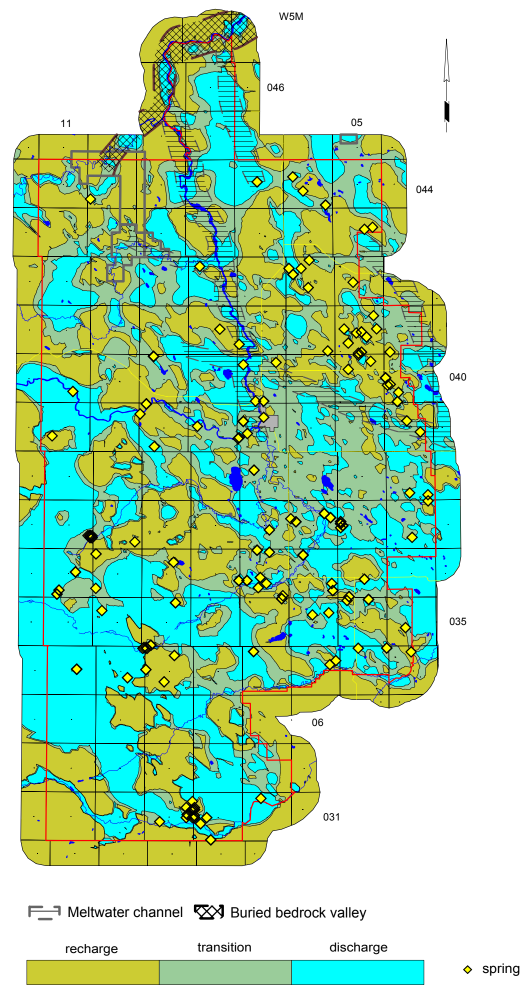


Figure 30. Bedrock Recharge/Discharge Areas

Figure 35 shows that, in more than 40% of the County, there is a downward hydraulic gradient from the bedrock surface toward the upper bedrock aquifer(s) (i. e. recharge). Areas where there is an upward hydraulic gradient from the bedrock to the bedrock surface (i. e. discharge) are mainly in the vicinity of river valleys. The remaining parts of the County are areas where there is a transition condition.

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

With 40% of the County land area being one of recharge to the bedrock, and the average precipitation being 522 mm per year, one percent of the annual precipitation is sufficient to provide the total calculated quantity of groundwater flowing through the upper bedrock aquifer(s).

6.4 Areas of Groundwater Decline

In order to determine the areas of possible water-level decline in the sand and gravel aquifer(s) and in the upper bedrock aquifer(s), the following approach was attempted. 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 were required to differ by at least 365 days. Only the earliest and latest control points at a given location were used. The method of calculating changes in water levels is at best an estimate. Additional data would be needed to verify water-level change.

Of the 399 surficial water wells with a non-pumping water level and date in the County and buffer area, there are 36 water wells with sufficient control to prepare 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 water-level control points are present. Most of the areas where the map suggests that there has been a decline in NPWL may be a result gridding a limited number of control points. The adjacent map, where sufficient control exists, indicates that there may have been a decline in the NPWL in parts of township 036 and 037, ranges 04 to 06 and townships 040 to 042, ranges 07 to 09, W5M.

Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different surficial aquifer. Of the 141 groundwater users completed in surficial aquifers that are authorized to divert groundwater, most occur in areas where insufficient control exists.

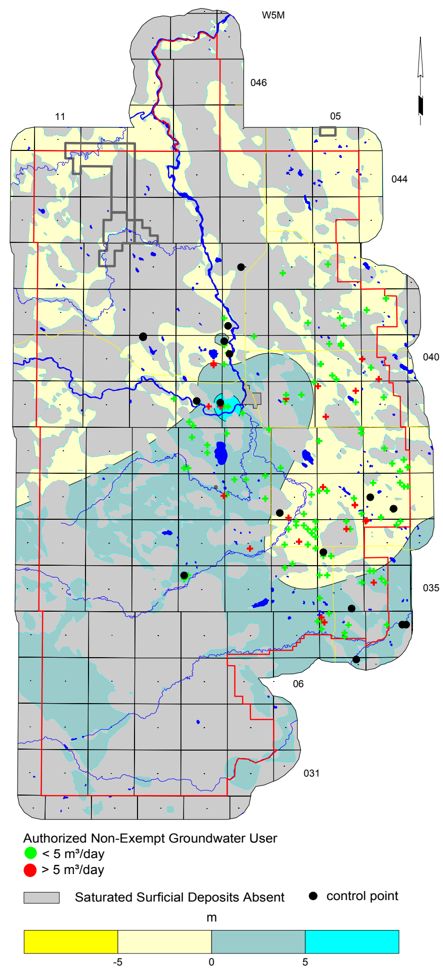


Figure 31. Changes in Water Levels in Surficial Deposits

Estimated Water Well Use Per Section (m³/day)	% of Area with More than a 5-Metres Projected Decline
<30	28
30 to 50	11
>50	12
no use	49

Table 10. Water-Level Decline in Sand and Gravel Aquifer(s)

Figure 31 indicates that in 45% of the County where surficial deposits are present, it is possible that the non-pumping water level has declined. The areas of groundwater decline in the sand and gravel aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact and that the decline may be due to variations in recharge to the aquifer or because the water wells are not on file with Alberta Environment.

In areas where a water-level decline exists, 49% of the areas has no estimated water well use; 28% of the use is less than 30 m³/day; 11% of the use is between 30 and 50 m³/day per section; and the remaining 12% of the declines occurred where the estimated groundwater use per section is greater than 50 m³/day, as shown above in Table 10.

Of the 6,232 bedrock water wells with a non-pumping water level and date in the County and buffer area, there are 1,960 water wells with sufficient control to prepare the adjacent map. The adjacent map indicates that in the yellow areas where there is sufficient data control, it is possible that the NPWL has declined.

The water level in Obs WW No. 10-07 in 10-07-041-08 W5M was monitored by Mow-Tech Ltd. from 1990 to 1999. The observation water well is completed from 56.7 to 96.9 metres below ground surface in the Dalehurst Aquifer. The location of Obs WW No. 10-07 is in an area where it is possible that a water-level decline has occurred. The water level in Obs WW No. 10-07 has declined in the order of three metres, as shown below in Figure 32.

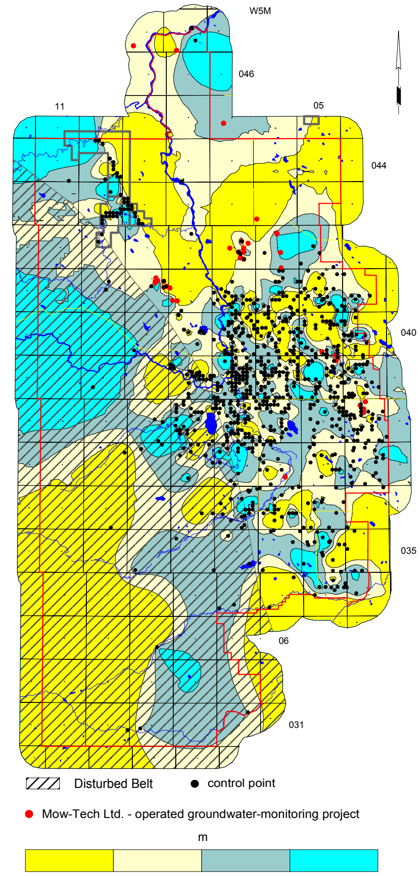


Figure 32. Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)

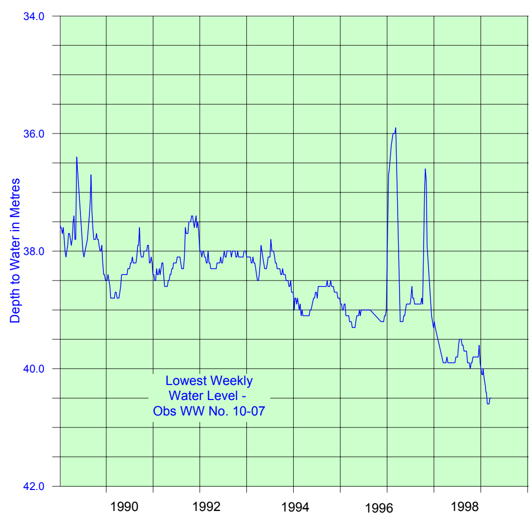


Figure 33. Water Levels in Obs WW No. 10-07

The areas of groundwater decline in the upper bedrock aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact.

In areas where a water-level decline of more than five metres is indicated, 75% of the area has no estimated water well use; 16% is less than 30 m³/day; 4% is between 30 and 50 m³/day per section; and the remaining 5% of the declines occurred where the estimated groundwater use per section is greater than 50 m³/day, as shown below in Table 11. In the County where a water-level decline is indicated, most of the areas of no estimated water well use are in areas where there is not sufficient control.

Estimated Water Well Use Per Section (m³/day)	*% of Area with More than a 5-Metre Projected Decline*
<10	*11*
10 to 30	*5*
30 to 50	*4*
>50	*5*
no use	*75*

Table 11. Water-Level Decline of More than 5 Metres in Upper Bedrock Aquifer(s)

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

6.5 Discussion of Specific Study Areas

6.5.1 Area 1 – Township 037, Range 06 W5M

What is the approximate extent and potential (yield and water quality) of the aquifers in this area? What comments can be made on whether or not there is any evidence of water-level decline in the aquifer underlying township 037, range 06 W5M?

Groundwater resources in Area 1 are mainly being utilized for domestic and stock purposes. There are 44 authorized groundwater users in Area 1, of which one is for agricultural purposes and 43 are registrations, for a total authorized use of 85 m³/day. Groundwater production data are available for a water source well in 12-03-037-06 W5M in 1998 and 1999 and for a water source well in SE 10-037-06 W5M. The water source well in 12-03-037-06 W5M diverted an average of less than two m³/day during its main producing months of May to November in 1998 and 1999. The water source well in SE 10-037-06 W5M (WSW No. SE 10) has diverted an average of 225 m³/day since groundwater production began in December 2001. Clearwater County anticipates that further development in Area 1 may be limited due to groundwater availability.

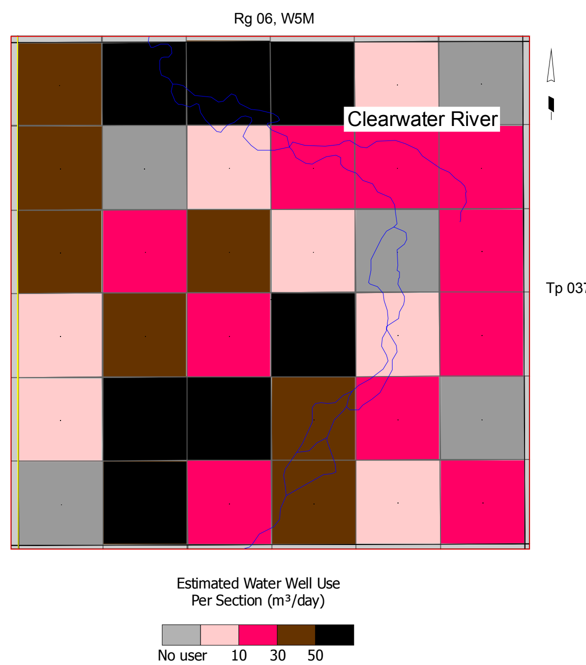


Figure 34. Estimated Water Well Use Per Section – Area 1

The flow through the Sand and Gravel Aquifer in Area 1 is estimated to be 820 m³/day and the flow through the Dalehurst Aquifer is estimated to be 650 m³/day. Figure 34 indicates that the estimated water well use per section in township 037, range 06, W5M ranges from less than one to more than 50 m³/day, with groundwater use of more than 30 m³/day per section determined to be in the western two-thirds of the township. In Area 1, there are records for 212 water wells, with 70% drilled for domestic/stock purposes. Ninety-five percent of the 212 water wells have sufficient data to determine the completion aquifer.

Where the Sand and Gravel Aquifer(s) are present in Area 1, the apparent yields for water wells completed in the Sand and Gravel Aquifer(s) are expected to be mainly more than 100 m³/day (see page A-53). Of the 44 groundwater authorizations, four are for water wells completed in the Sand and Gravel Aquifer(s) for a total of 8 m³/day.

Groundwaters from water wells completed in Area 1 in the surficial deposits are expected to be a calcium-magnesium-bicarbonate-type and have TDS concentrations that are less than 1,000 mg/L (see page A-54).

There are indications that there has been a continual decline of less than five metres in the water-level surface in the surficial deposits in most of township 037, range 06, W5M, as shown in Figure 35. Of the 212 water wells in Area 1, 32 (15%) are completed in surficial deposits and only two surficial water wells have sufficient data for determining changes in water levels in surficial deposits.

Water Source Well No. SE 10 is located in the area where a water-level decline may be occurring. The water level in WSW No. SE 10 has been monitored by Mow-Tech Ltd. since December 2001.

Water Source Well No. SE 10 drilled in October 2000, is located adjacent to the Clearwater River, as shown on Figure 35, and is completed from 4.1 to 5.6 metres below ground surface in sand and gravel deposits. The highest and lowest water-level fluctuations in WSW No. SE 10 from November 2002 to August 2003 have been compared to the discharge rate in the Clearwater River recorded near Dovercourt.

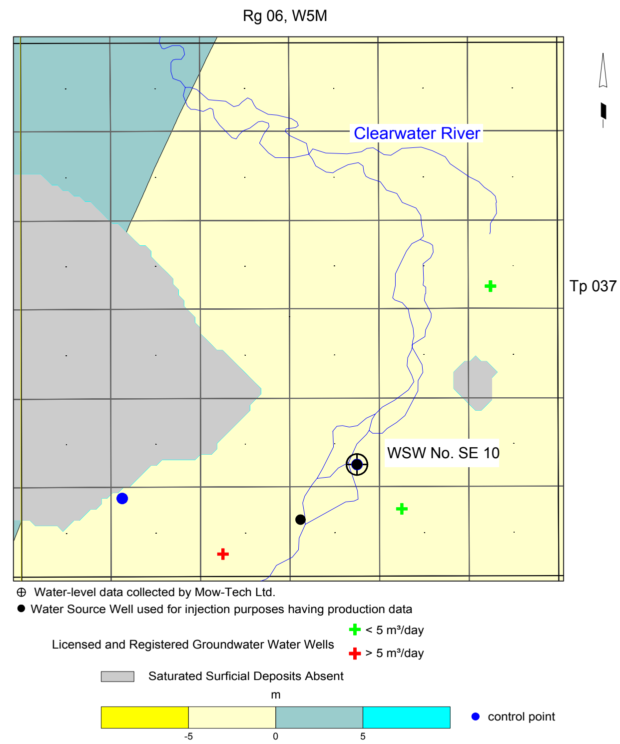


Figure 35. Changes in Water Levels in Surficial Deposits – Area 1

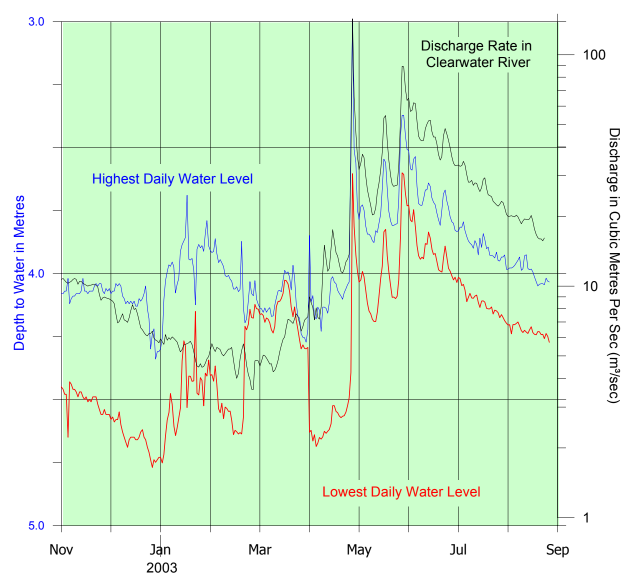


Figure 36. Discharge Rate in Clearwater River and Water-Level Measurements in WSW No. SE 10 – Area 1

The water levels in WSW No. SE 10 mainly mimic the changes in discharge in the Clearwater River except during the winter months of January and February when the discharge continues to decline. On March 31, 2003 there is water-level declne of 0.34 metres as a result of increased groundwater production in WSW No. SE 10. Near the end of April, there is a sharp rise in water levels in WSW No. SE 10, and in the discharge rate in the Clearwater River. This rise can be attributed to spring thaw.

The upper bedrock in Area 1 is the Dalehurst Member. The apparent yield for water wells completed through the Dalehurst Aquifer is expected to be more than ten m³/day (see page A-55).

Groundwaters from water wells completed in Area 1 in the Dalehurst Aquifer are expected to be a sodium-bicarbonate-type and have TDS concentrations that are mainly less than 1,000 mg/L (see page A-56).

There are indications that there has been a continual decline with the water-level surface in the upper bedrock aquifer(s) in most of the southern half and in the extreme northwestern part of township 037, range 06, W5M as shown in the adjacent figure. Of the 212 water wells in Area 1, 171 (80%) are completed in the Dalehurst Aquifer, and six bedrock water wells have sufficient data for determining areas of potential groundwater depletion in the Dalehurst Aquifer.

In the areas where a water-level decline may have occurred, the estimated use per section is mainly greater than 30 m³/day. In the areas where a water-level rise may have occurred, the estimated use per section is mainly less than 30 m³/day.

Of the 44 groundwater authorizations, 40 are for water wells completed in the Dalehurst Aquifer, having a total authorized diversion of 77 m³/day.

Additional groundwater monitoring data would need to be made available in order to provide a reasonable interpretation regarding the apparent water-level decline in Area 1.

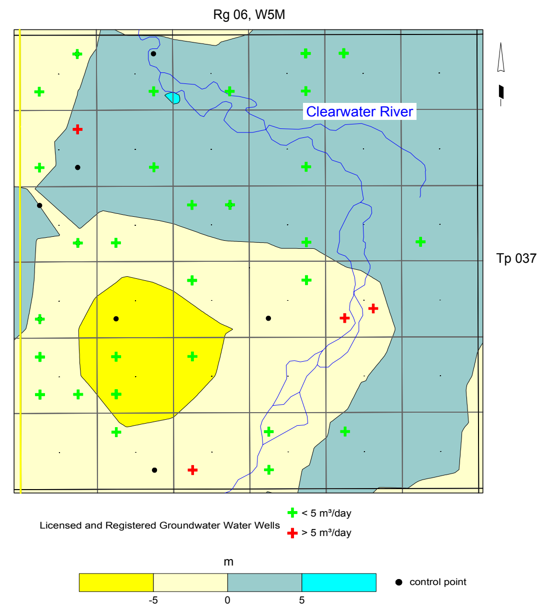


Figure 37. Areas of Potential Groundwater Depletion in Dalehurst Aquifer(s) – Area 1

6.5.2 Area 2 – Potable Water Injection by the Energy Industry

Members of the public have periodically expressed concern regarding the use of groundwater by the oil and gas industry in Alberta. Common concerns expressed by the public include the following:

- The volumes of potable groundwater being used for injection are large and once this water has been injected into an oil reservoir, it is lost forever.
- The use of groundwater by the oil industry negatively impacts the water wells used by the agricultural community and household users in rural residential subdivisions.
- The use of water by the oil industry can limit future agricultural expansion by having the water needed for the expansion licensed for industrial use and therefore not available for the local user.

Since the mid-1890s, the diversion and use of larger quantities of groundwater in Alberta has been the subject of prior approval. Initially the legislation that required licensing of the diversion and use of water was administered by the Dominion (federal) government, and was applied exclusively to surface water. The first Provincial water management legislation, the Water Resources Act, came into being in April 1931. The legislation continued to be directed toward the larger users of surface water.

The 1971 revision of the Water Resources Act specifically included clauses regarding the licensing of groundwater. The water management legislation underwent revisions from time to time. Largely in response to concerns by rural Albertans, from about mid-1981 the approval to divert groundwater for injection was a temporary permit rather than a permanent licence.

In March 1990, the Ground Water Allocation Policy for Oilfield Injection Purposes developed with input from various rural, agricultural and industrial groups took effect. The policy placed additional restrictions on the diversion and use of groundwater specifically for injection in the White (agricultural) Area of the province. The policy was to manage the groundwater resources of the province of Alberta in such a way as to provide continuing protection to the existing and future domestic, municipal, agricultural and industrial users while maintaining the important principle of multi-purpose use of water. The Policy was to substantially reduce the conflicts over the use of potable water for oilfield injection.

6.5.2.1 Diversion and Use of Groundwater for Injection

There are 60 permits and licences allowing the diversion of up to 4,308,460 cubic metres of groundwater per year for injection in the County. The adjacent graph indicates that the total licensed quantity has been gradually increasing over the years. Although the total licensed quantity can be diverted each year, it often is not.

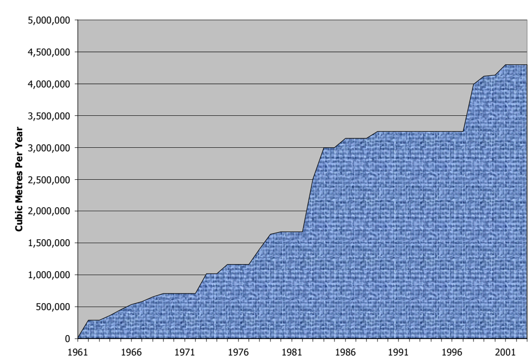


Figure 38. Licensed Groundwater Diversion for Injection Purposes

6.5.2.2 Licensed Allocations of Groundwater Versus Actual Diversion and Use

It has been possible to compare the quantity of groundwater licensed for diversion and use for injection by AENV, to the quantity actually being diverted and used based on the data collected by the Alberta Energy and Utilities Board (EUB).

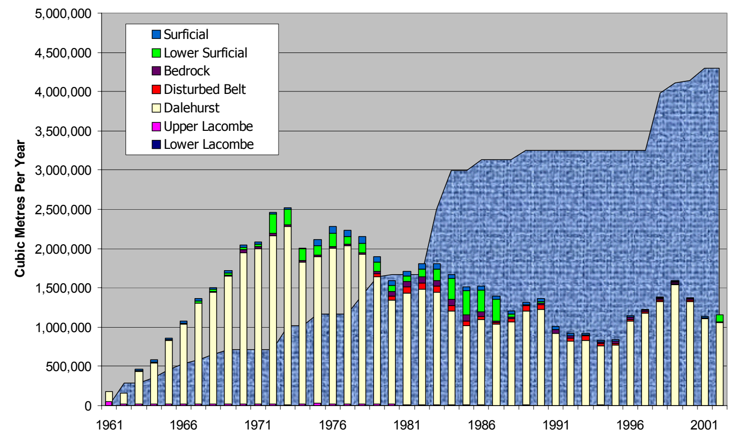


Figure 39. Licensed Groundwater Versus Diversion Reported

The adjacent graph indicates the yearly quantity of groundwater diverted by aquifer for injection in the County. The quantity of groundwater approved for diversion by AENV is also indicated. Nearly 90% of the total groundwater diverted is from the Dalehurst Aquifer. The total quantity of groundwater used in the County increased between 1961 and 1973 and has generally, with few exceptions, been gradually decreasing ever since. The total diverted in 2002, 1.15 million cubic metres, is only 45% of what it was in 1971 when the total diversion reached 2.54 million cubic metres. Based on the volumes reported to the EUB, the quantity of groundwater actually diverted in 2002, the most recent year for which data are available, is 27% of the total quantity licensed.

6.5.2.3 Future Trends in Groundwater Use for Injection

It is difficult to obtain statistics on future trends for the use of groundwater for injection in the County. Where new injection schemes require water, groundwater generally continues to be the most sustainable and reasonable cost-effective alternative, especially where smaller quantities of water are required. Based on the water-level data available from most approvals, the diversion and use of the groundwater for secondary recovery projects is NOT having a negative effect on the groundwater resource. In fact, the water-level data obtained from the oil industry for this project was significantly greater than the water-level data provided by Alberta Environment.

6.5.3 Area 3 – Shallow Groundwater Nitrate Levels

Clearwater County has concerns with regard to nitrate contamination of water wells completed in shallow sandstones and/or in surficial sand and gravel aquifers.

In Clearwater County, there were two groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) for the surficial aquifers and 12 groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ for the upper bedrock aquifer(s). The range for the Nitrate + Nitrite (as N) concentrations in the groundwaters is higher in the water wells completed in the surficial deposits than in the water wells completed in the bedrock, ranging from 31.5 to 84.3 mg/L for the surficial aquifers and from 10.5 to 27.34 mg/L for the bedrock aquifers.

The 14 groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ represent only one percent of the total number of groundwater samples (1,095) for which analyses were available. The locations for the water wells with the elevated values are scattered and do not indicate the problem is area specific. The water well completion depths range from 6.1 to 47.2 metres below ground level. None of the chemical analyses are more recent than 1985 and at least five are for water wells completed in 1975 or earlier.

Aquifer	Nitrate + Nitrite (as N)	Chloride (mg/L)	Analysis Date	Water Well Completed Depth (m)	Water Well Completion Date	Legal	Proposed Use
Bedrock	10.5	30	05-Oct-77	11.3	10-May-64	NE 14-039-07 W5M	Domestic
Dalehurst Member	12	20	04-Oct-85	16.8		NW 09-039-05 W5M	Domestic
Dalehurst Member	14.1	23	18-Jan-84	42.7		NH 19-036-05 W5M	Domestic
Dalehurst Member	14.3	0.12	13-Jul-77	30.5		NE 05-043-06 W5M	Domestic
Dalehurst Member	14.9	42	30-Dec-76	20.4	01-Jan-48	SE 04-038-06 W5M	Domestic
Dalehurst Member	15.4	22	20-Aug-76	29.0		··- 21-039-07 W5M	Domestic
Dalehurst Member	17.9	176	14-Jun-77	18.3		NW 09-039-05 W5M	Domestic
Dalehurst Member	19	64	24-Sep-85	47.2	01-Oct-80	SW 23-037-04 W5M	Domestic
Dalehurst Member	19.5	22	26-Jul-78	21.3		SE 01-039-05 W5M	Domestic
Dalehurst Member	24.6	47	09-Mar-84	21.3		16-09-038-04 W5M	Domestic & Stock
Dalehurst Member	27.3	122	17-Jul-78	30.5	12-Nov-75	SW 25-038-06 W5M	Domestic
Disturbed Belt	19.5	26	20-May-75	22.9		SE 19-031-07 W5M	Domestic
Surficial	31.5	120	29-Sep-72	18.3		SE 35-039-05 W5M	Domestic
Surficial	84.3	70	09-Jan-76	6.1	1966	SE 14-035-04 W5M	Domestic

Table 12. Concentrations of Nitrate + Nitrite (as N) in Groundwaters

A review of the corresponding chloride concentrations for the 14 water wells indicated the chloride concentrations range from a low of 0.12 to a high of 176 mg/L, all below the SGCDWQ aesthetic guideline of 250 mg/L. However, the two higher chloride values of 120 mg/L for one of the surficial water well completions and 176 mg/L for one of the bedrock water well completions suggest surface contamination is a possibility.

Good groundwater management practices involve monitoring and recommend periodic analysis of a groundwater sample, especially where human consumption is involved.

7 RECOMMENDATIONS

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

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

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a “super” database, which includes only verified data. The first step would be to field-verify the 180 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. There is one water well for which the County has responsibility; the County-operated water well is included in Appendix E. It is recommended that the County-operated water well plus the 180 water wells be field-verified, water levels be measured, a water sample be collected for analysis, and a short aquifer test be conducted. An attempt to update the quality of the entire database is not recommended.

The most notable areas where surficial water wells are completed in the Sand and Gravel Aquifer(s) are where the thickness of the Sand and Gravel Aquifer(s) is greater than five metres, particularly in the southeastern part of the County, and in association with the meltwater channel north of Rocky Mountain House. The median apparent yield value from surficial water wells in these areas is greater than 100 m³/day (15 igpm).

The results of the present study indicate the following recommendations:

- **Improve the Data**

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

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

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

A list of the 181 water wells (180 plus 1 County) that could be considered for the above program is given in Appendix E and on the CD-ROM.

- **Link AENV Groundwater and Licensing Databases**

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

- **Monitor Groundwater Use and Water Levels**

While there are a few areas where water-level data are available at different times, on the overall, there are an insufficient number of water levels to set up a groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View and in Flagstaff County, water well owners were being provided with a tax credit if they accurately measured the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells. Monitoring of water levels in domestic and stock water wells is a practice that is recommended by PFRA in the “Water Wells That Last for Generations” manual and accompanying videos (Buchanan, Bob (editor). Alberta Agriculture, Food and Rural Development, 1996).

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

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

- **Provide Water Well Driller with Feedback**

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.

- **Partnership with the Petroleum Industry**

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

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

Groundwater is a renewable resource and it must be managed.

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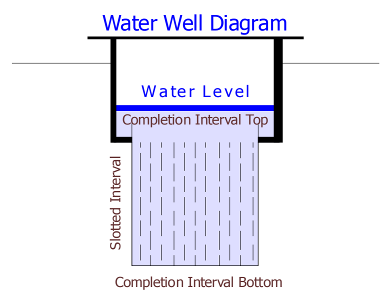
9 GLOSSARY

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
Borehole	includes all "work types" except springs
Completion Interval	see diagram
Deltaic	a depositional environment in standing water near the mouth of a river
Dewatering	the removal of groundwater from an aquifer for purposes other than use
Dfb	one of the Köppen climate classifications; a Dfb climate consists of warm to cool summers, severe winters, and no dry season. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month.
Evapotranspiration	a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants (Freeze and Cherry, 1979)
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957)
Fluvial	produced by the action of a stream or river
Friable	poorly cemented
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
km	kilometre
Kriging	a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990)
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits
Lithology	description of rock material
Lsd	Legal Subdivision
m	metres



Completion Interval

mm — millimetres

m²/day — metres squared per day

m³ — cubic metres

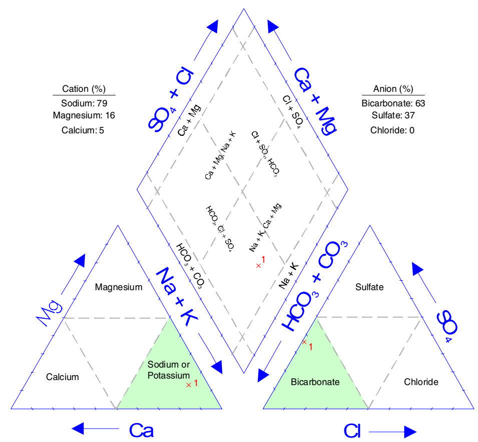
m³/day — cubic metres per day

mg/L — milligrams per litre

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

Obs WW — Observation Water Well

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



Piper Tri-Linear Diagram

Rock — earth material below the root zone

Surficial Deposits — includes all sediments above the bedrock

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

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

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

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

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

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

Water Well	a hole in the ground for the purpose of obtaining groundwater; “work type” as defined by AENV includes test hole, chemistry, deepened, well inventory, federal well survey, reconditioned, reconstructed, new, old well-test
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer
	Apparent Yield: based mainly on apparent transmissivity
	Long-Term Yield: based on effective transmissivity
AAFC-PFRA	Prairie Farm Rehabilitation Administration Branch of Agriculture and Agri-Food Canada
AENV	Alberta Environment
AMSL	above mean sea level
BGP	Base of Groundwater Protection
DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
GCDWQ	Guidelines for Canadian Drinking Water Quality
IAAM	*Infinite Aquifer Artesian Model.* The mathematical model is used to calculate water levels at a given location. The model has been used for more than 17 years by HCL for several hundred groundwater monitoring projects. The model aquifer is based on a solution of the well function equation. The simulation calculates drawdown by solving the well function equation using standard approximation methods. The drawdown at any given point at any given time uses the method of superposition.
NPWL	non-pumping water level
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

10 CONVERSIONS

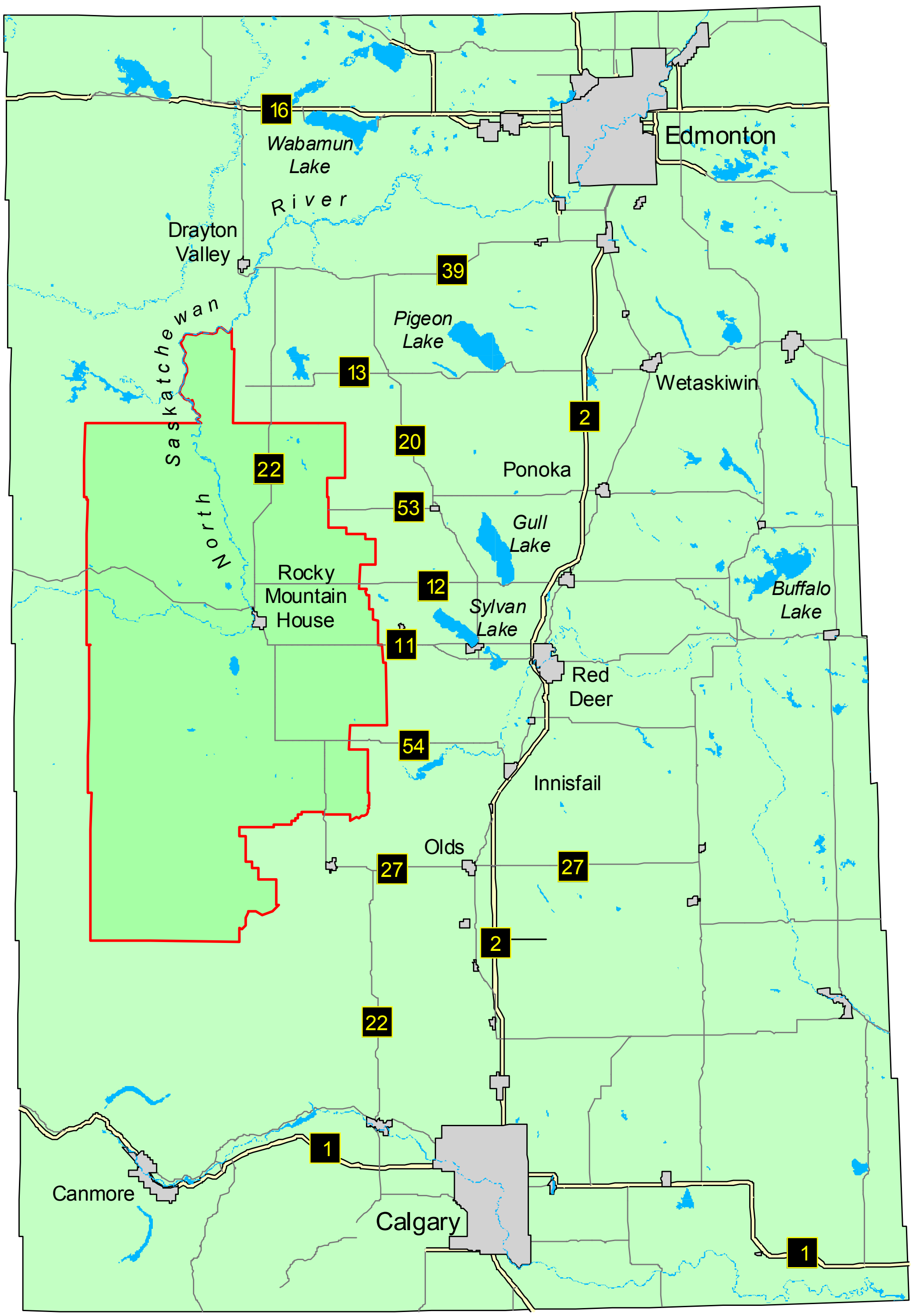
Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092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

CLEARWATER COUNTY

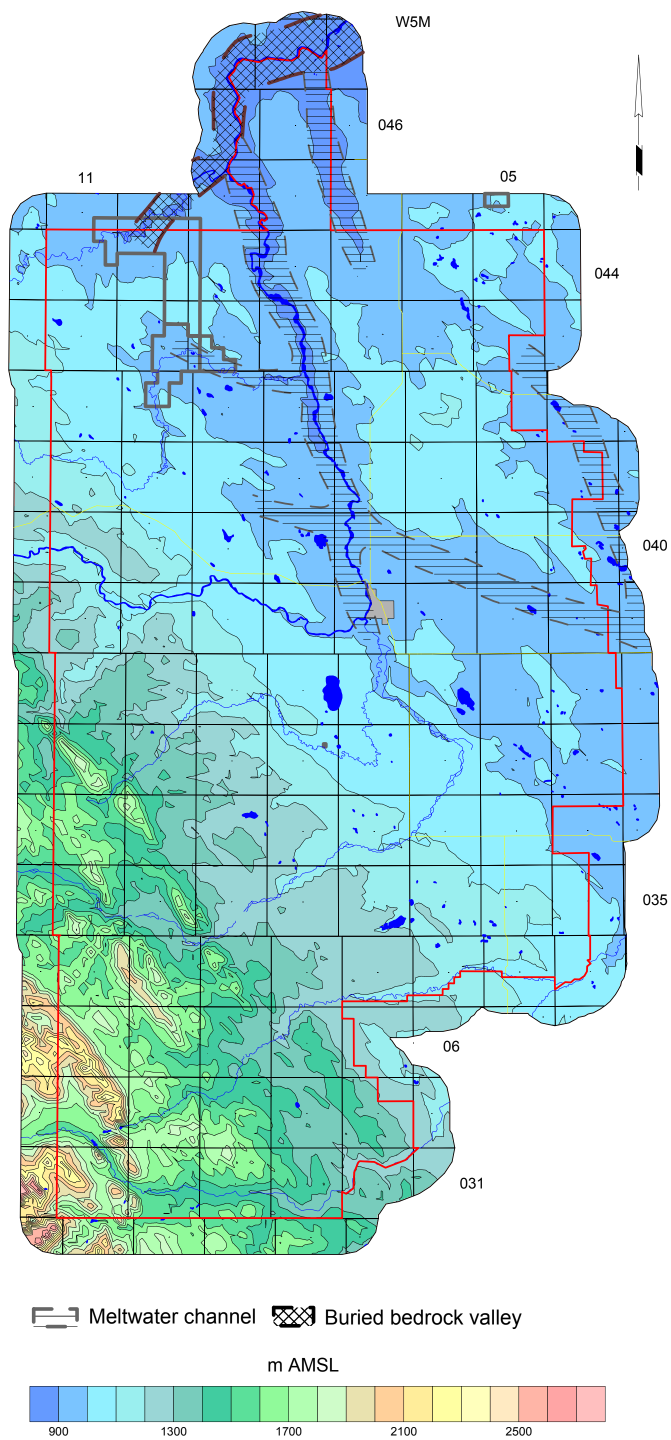
Appendix A

Hydrogeological Maps and Figures

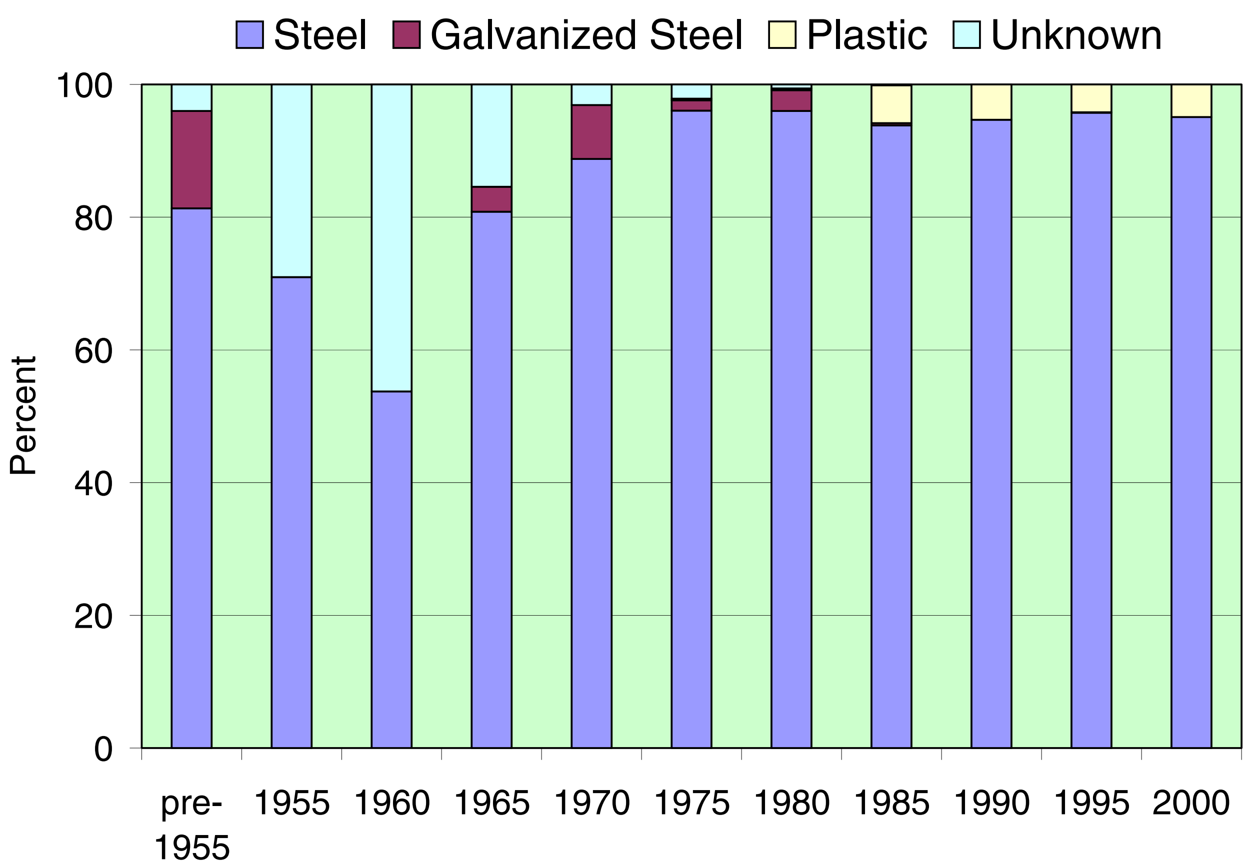
Index Map


16
Wabamun Lake
Edmonton
River
Drayton Valley
39
Pigeon Lake
North Saskatchewan
13
Wetaskiwin
2
20
22
Ponoka
53
Gull Lake
Rocky Mountain House
12
Buffalo Lake
Sylvan Lake
11
Red Deer
54
Innisfail
Olds
27
27
2
22
1
Canmore
Calgary
1

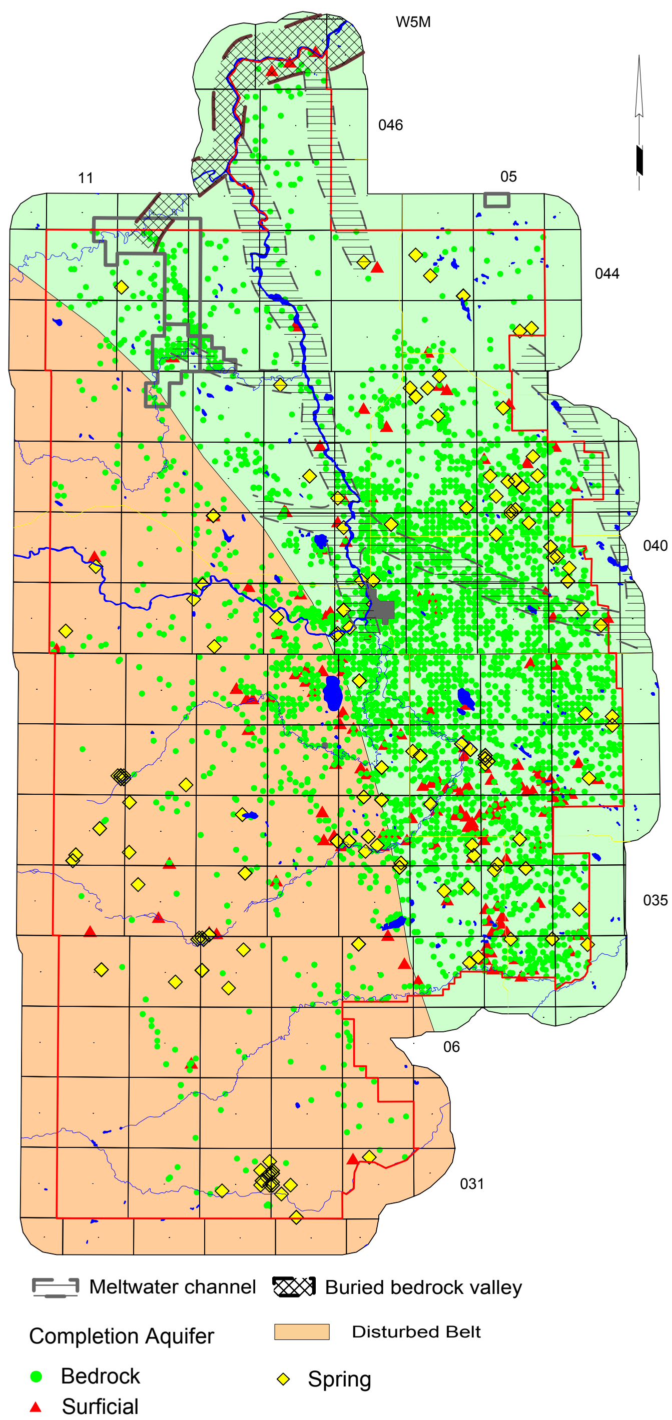
Surface Topography



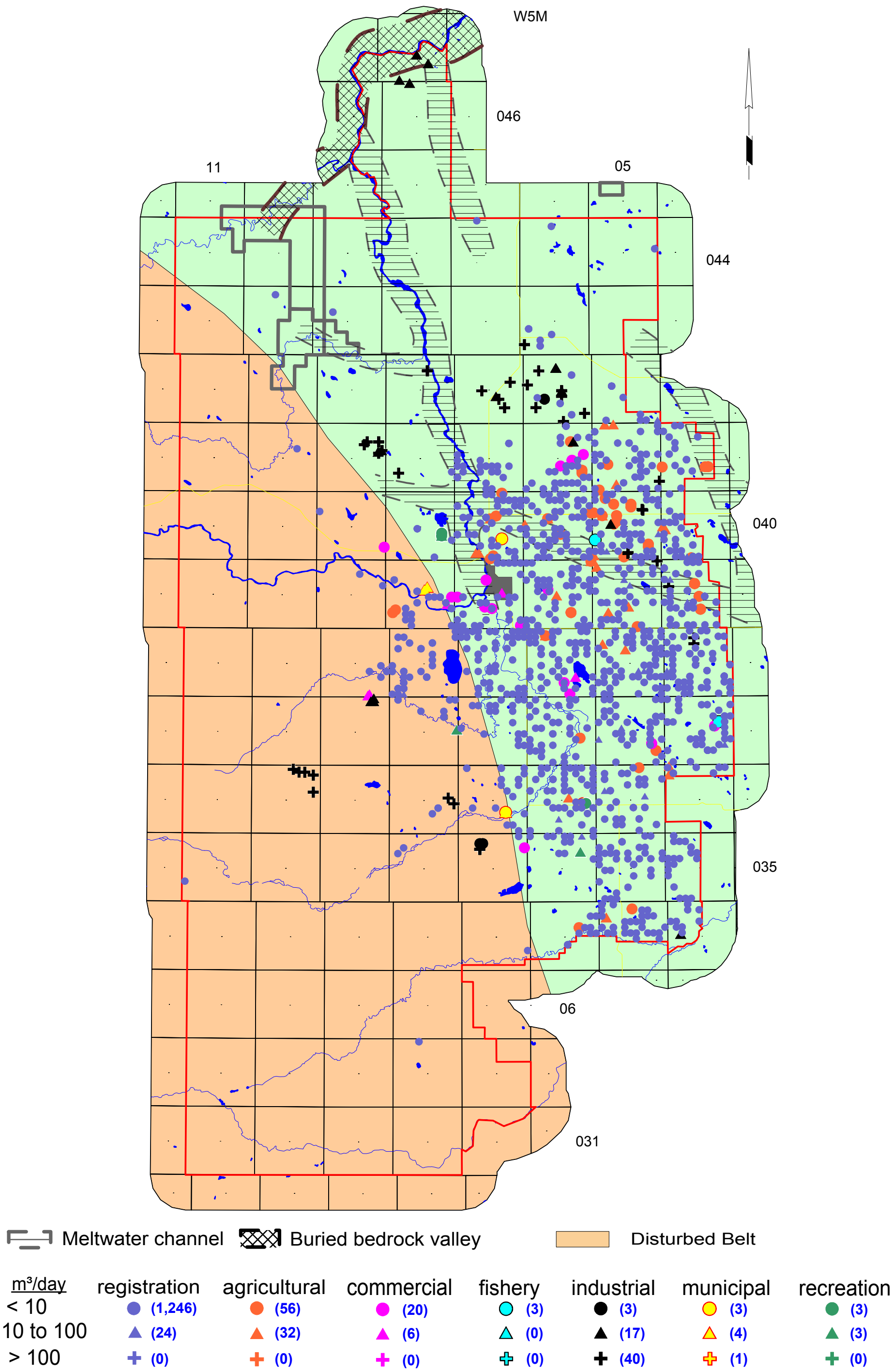
Surface Casing Types Used in Drilled Water Wells



Location of Water Wells and Springs

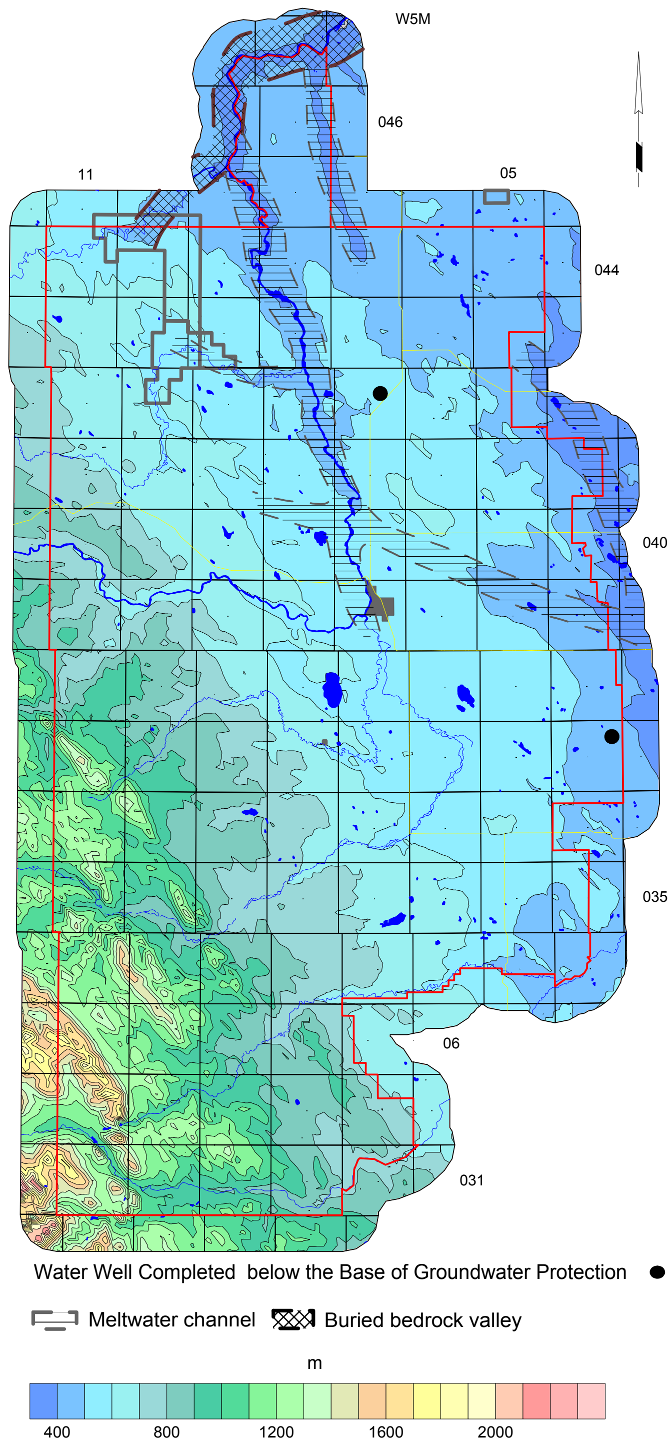


Licensed and Registered Groundwater Water Wells



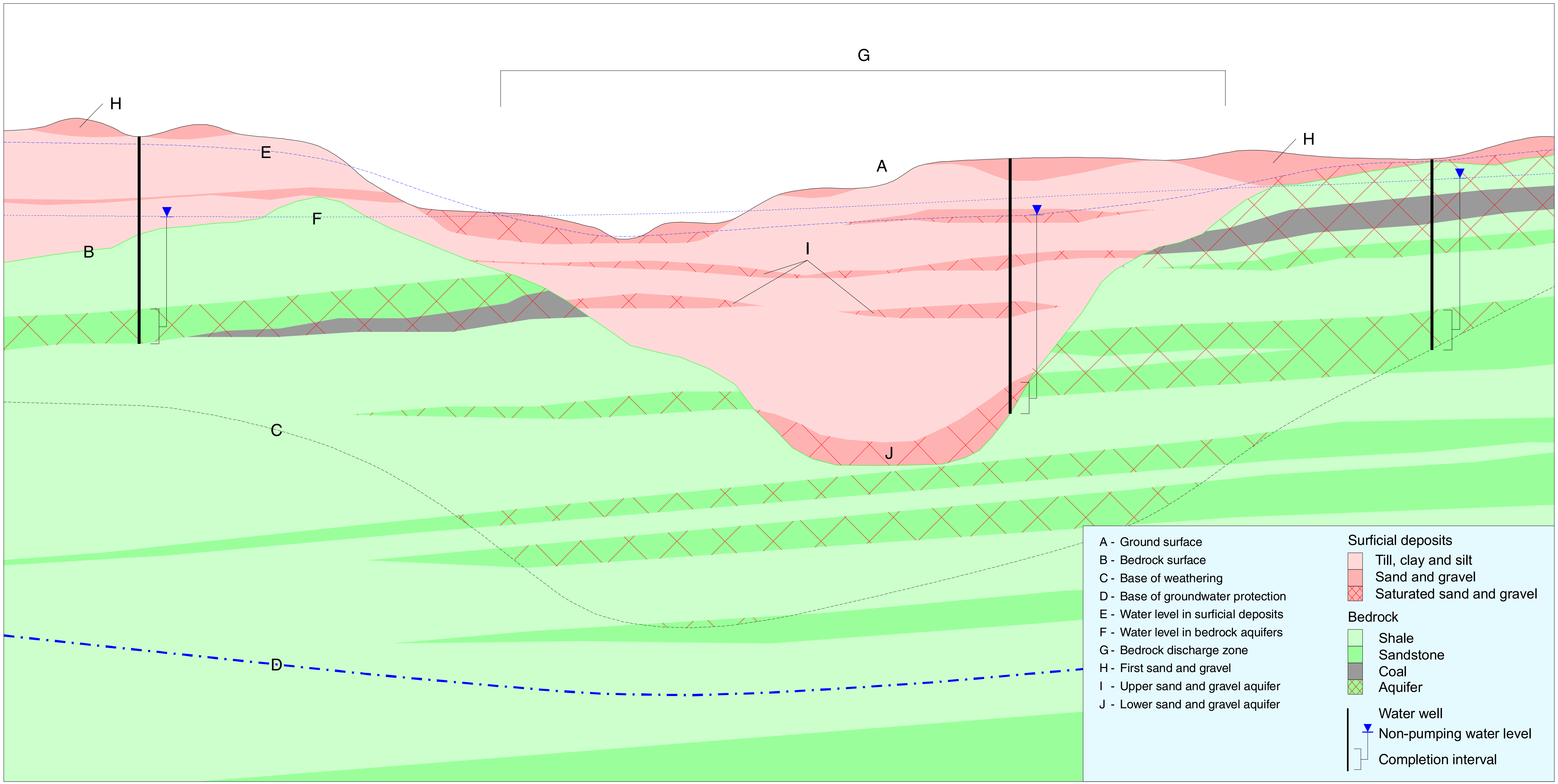
Depth to Base of Groundwater Protection

(modified after EUB, 1995)

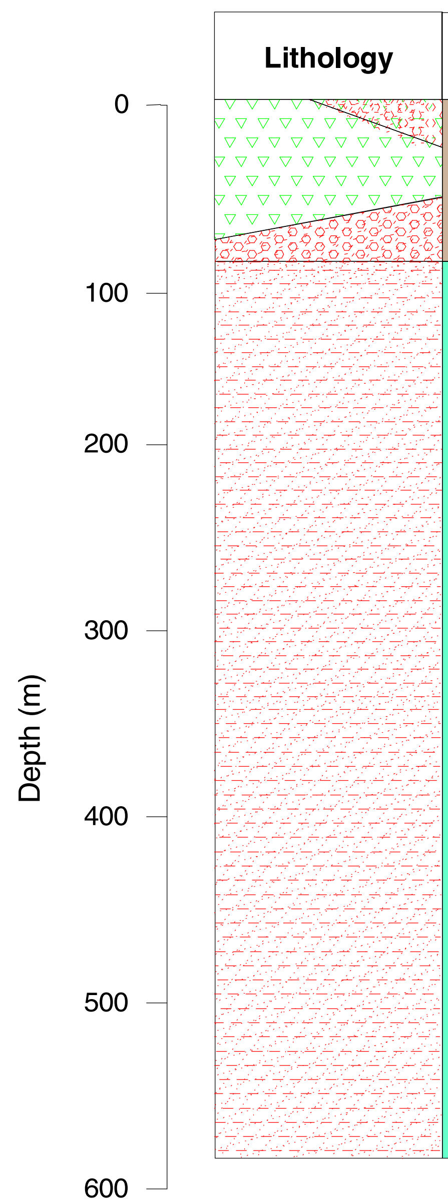


Generalized Cross-Section

(for terminology only)

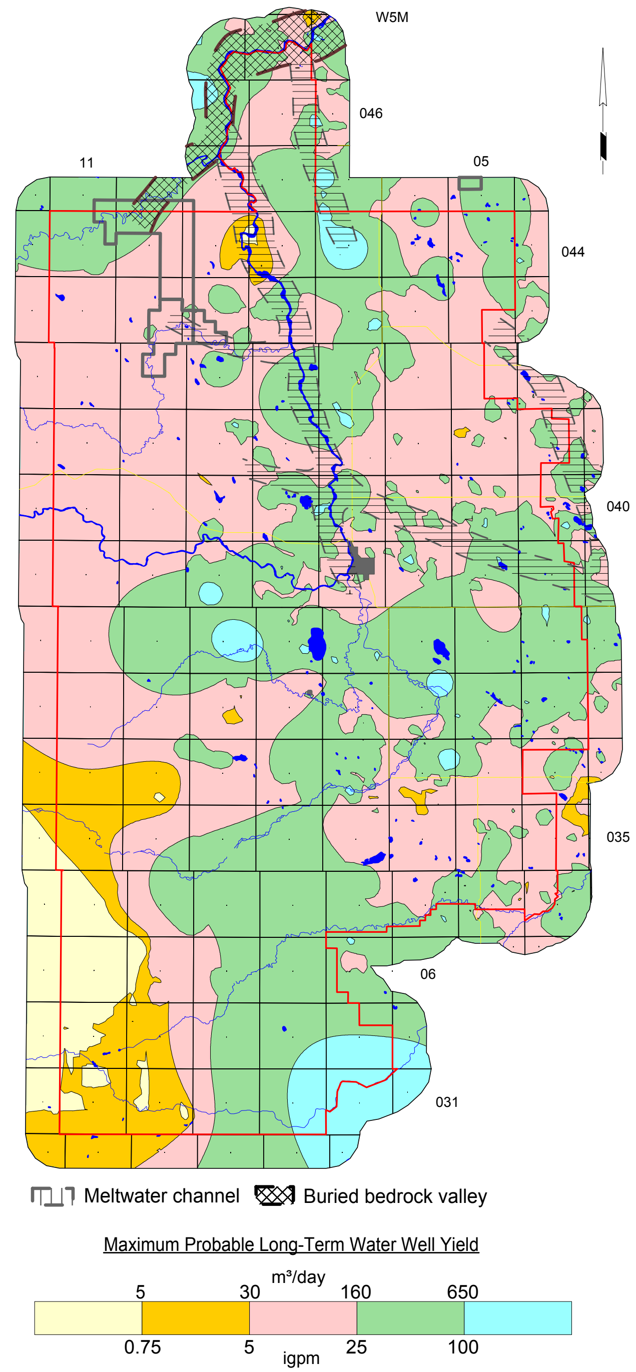


Geologic Column

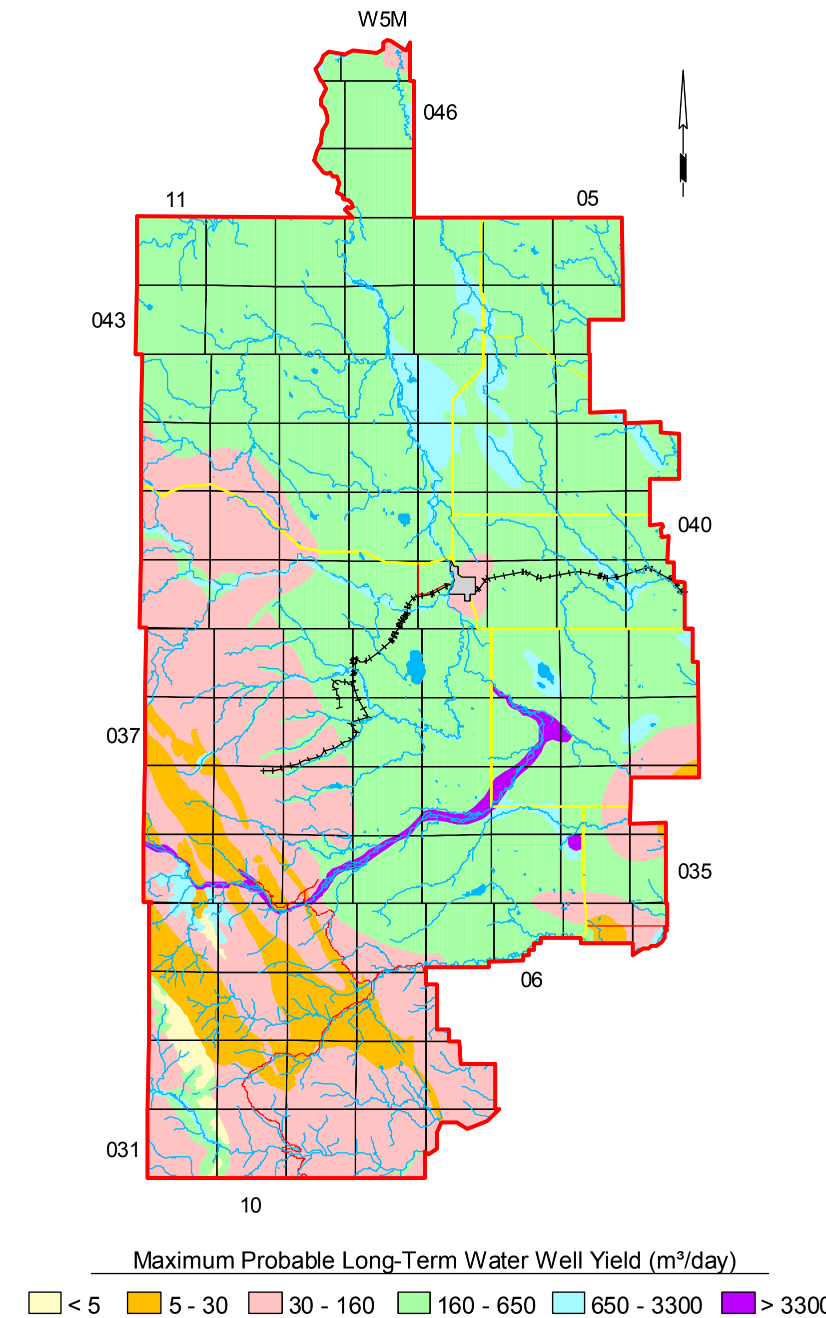


Lithologic Description	Group and Formation: Average Thickness (m)	Group and Formation: Designation	Member: Average Thickness (m)	Member: Designation	Zone: Designation	
sand, gravel, till, clay, silt	<50	Surficial Deposits	<50	Upper		
			<20	Lower		
sandstone, shale, coal	<800	Paskapoo Formation	<300	Dalehurst Member		Obed-Marsh Coal Zone
						Lower Dalehurst Coal Zone
			100-300	Lacombe Member	Upper	Upper Sandstone
						Middle Sandstone
						Lower Sandstone
			30-100		Lower	Lower Lacombe Coal Zone
			20-100	Haynes Member		

Hydrogeological Maps

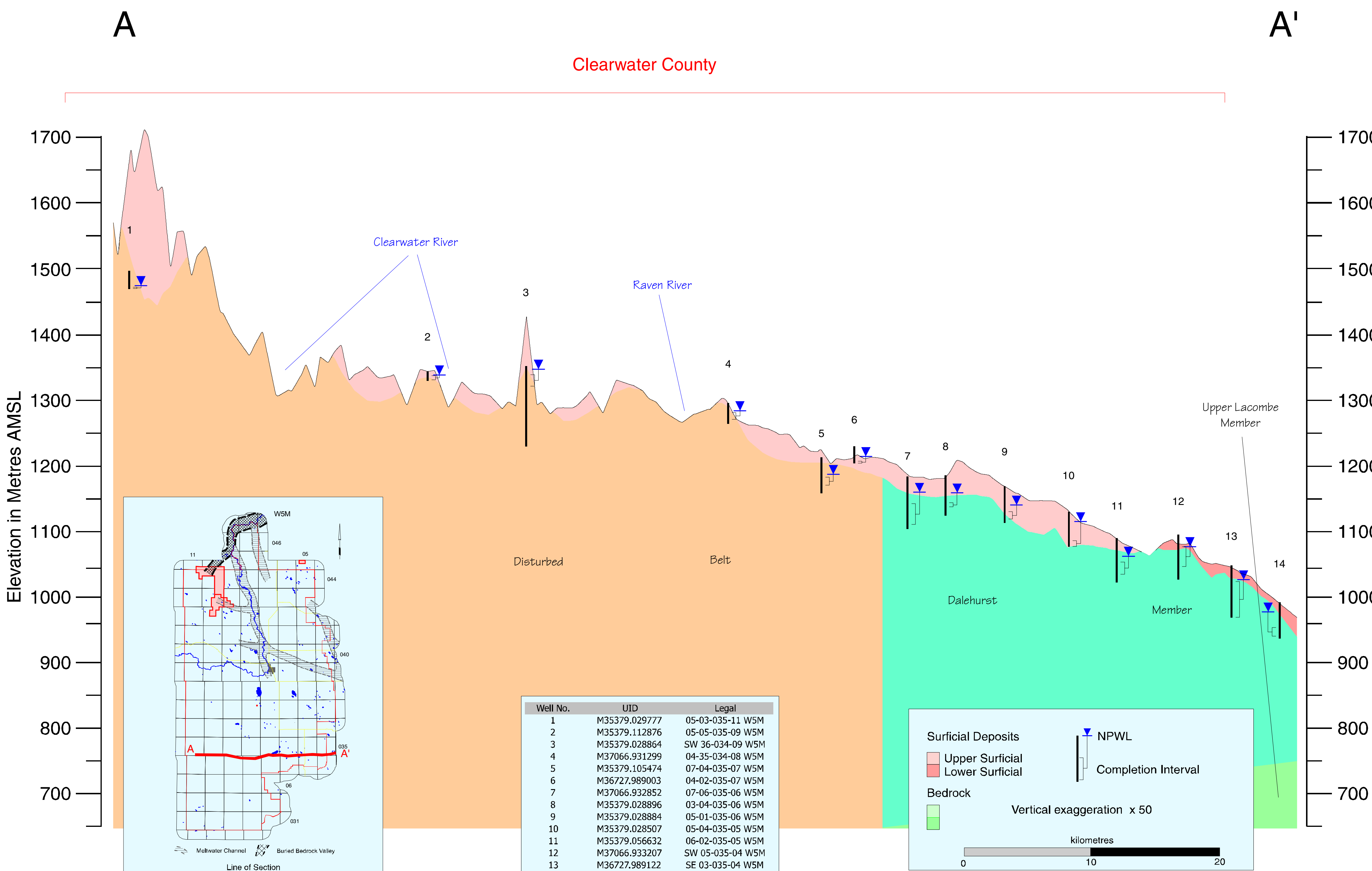


2003 HCL



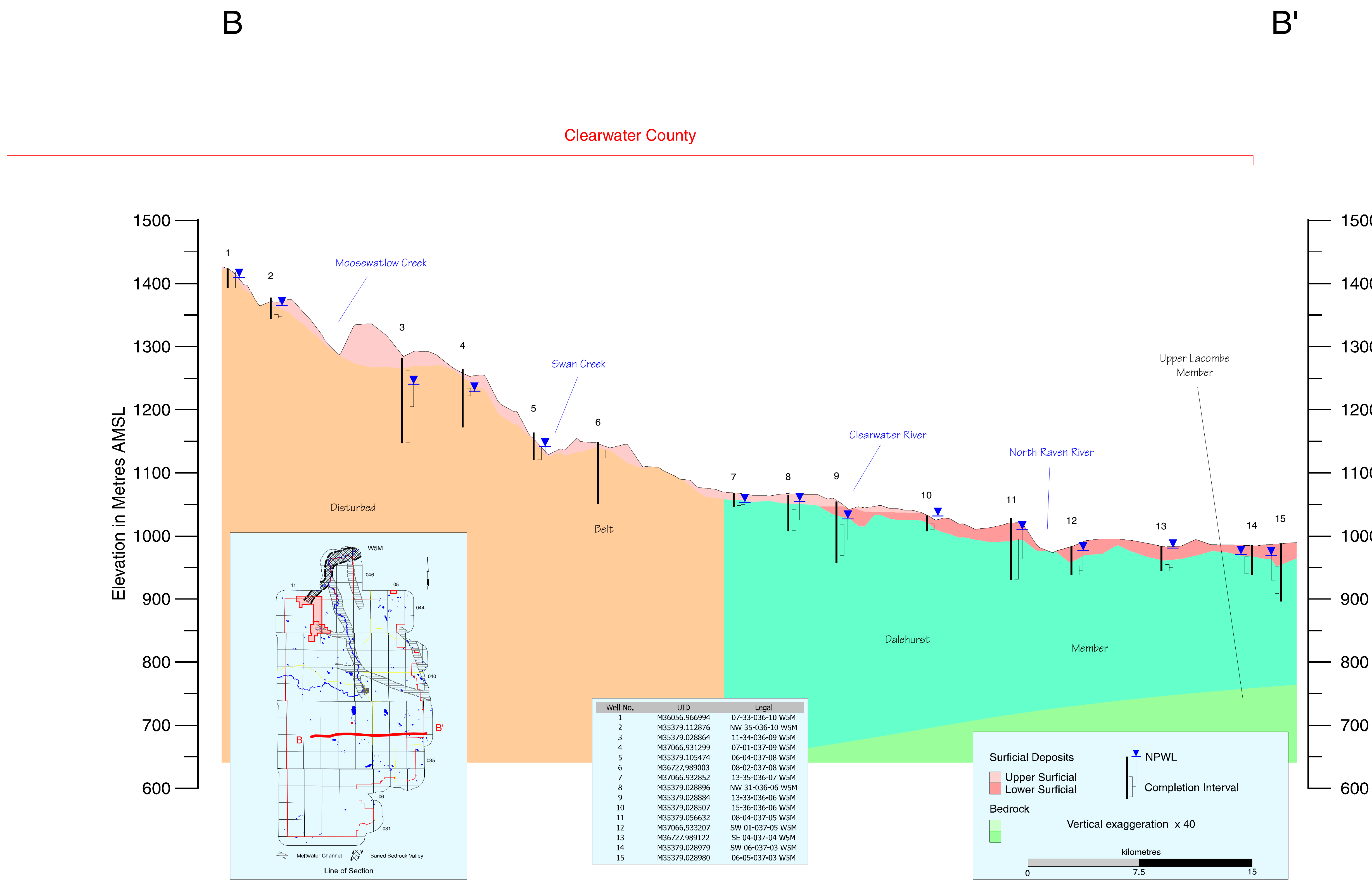
1971 Alberta Research Council

Cross-Section A - A'



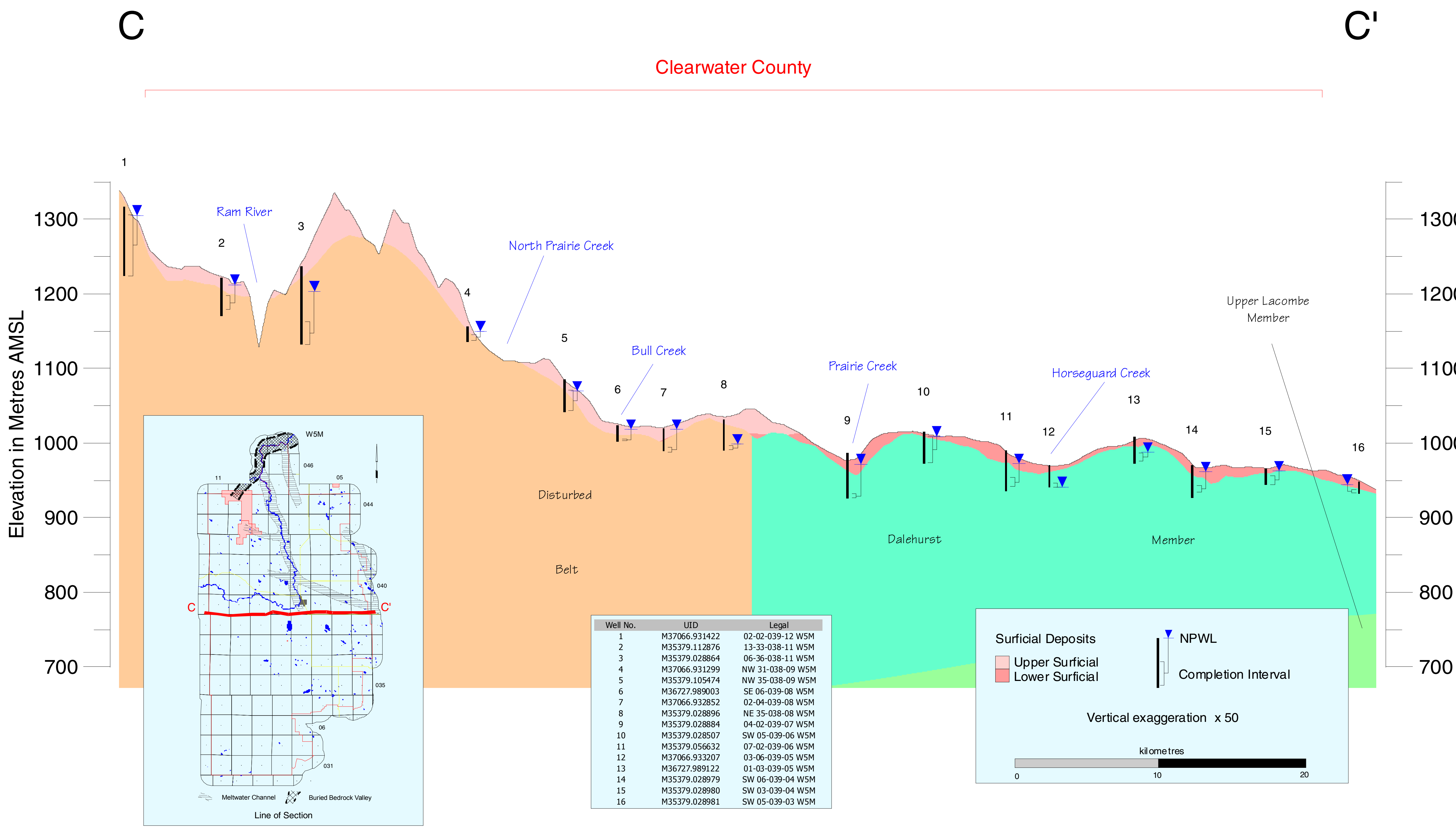
Well No.	UID	Legal
1	M35379.029777	05-03-035-11 W5M
2	M35379.112876	05-05-035-09 W5M
3	M35379.028864	SW 36-034-09 W5M
4	M37066.931299	04-35-034-08 W5M
5	M35379.105474	07-04-035-07 W5M
6	M36727.989003	04-02-035-07 W5M
7	M37066.932852	07-06-035-06 W5M
8	M35379.028896	03-04-035-06 W5M
9	M35379.028884	05-01-035-06 W5M
10	M35379.028507	05-04-035-05 W5M
11	M35379.056632	06-02-035-05 W5M
12	M37066.933207	SW 05-035-04 W5M
13	M36727.989122	SE 03-035-04 W5M
14	M35379.028979	16-01-035-04 W5M

Cross-Section B - B'



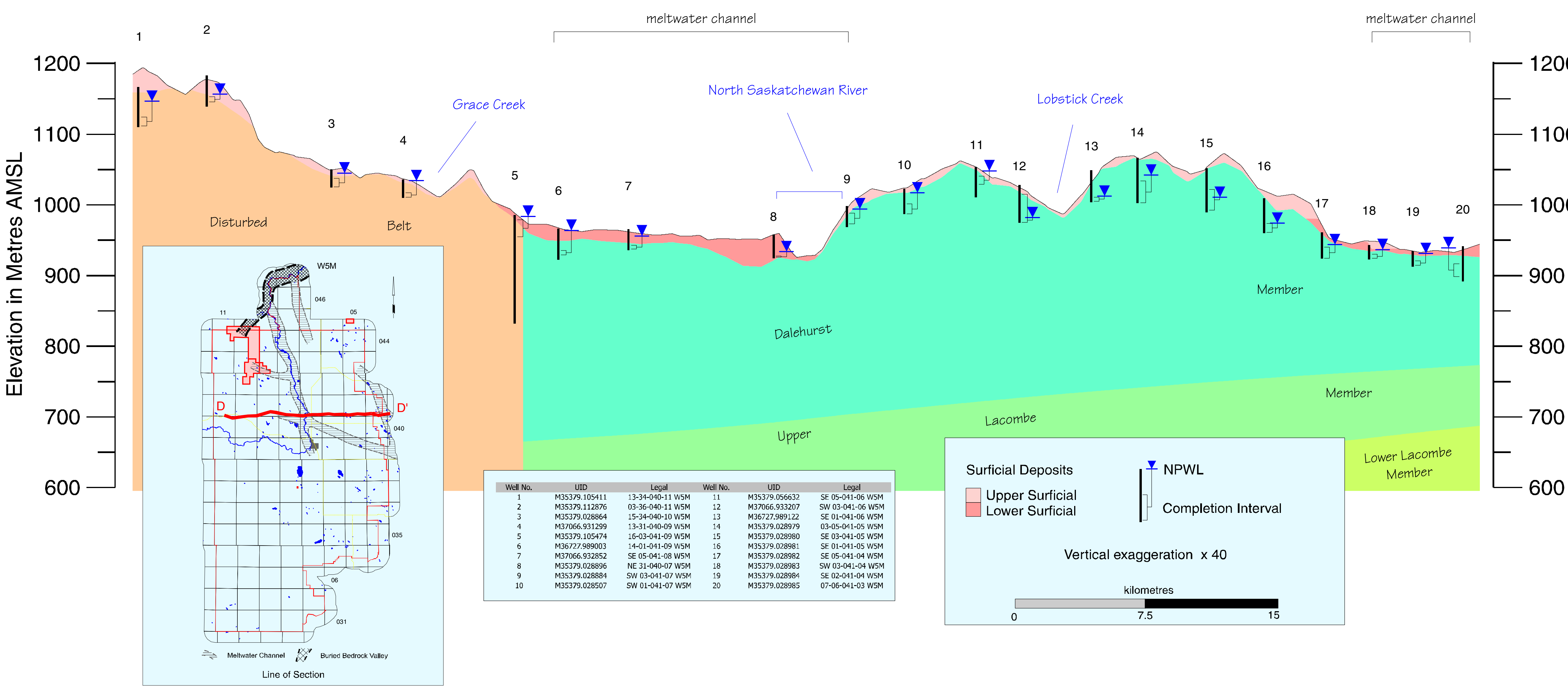
Well No.	UID	Legal
1	M36056.966994	07-33-036-10 W5M
2	M35379.112876	NW 35-036-10 W5M
3	M35379.028864	11-34-036-09 W5M
4	M37066.931299	07-01-037-09 W5M
5	M35379.105474	06-04-037-08 W5M
6	M36727.989003	08-02-037-08 W5M
7	M37066.932852	13-35-036-07 W5M
8	M35379.028896	NW 31-036-06 W5M
9	M35379.028884	13-33-036-06 W5M
10	M35379.028507	15-36-036-06 W5M
11	M35379.056632	08-04-037-05 W5M
12	M37066.933207	SW 01-037-05 W5M
13	M36727.989122	SE 04-037-04 W5M
14	M35379.028979	SW 06-037-03 W5M
15	M35379.028980	06-05-037-03 W5M

Cross-Section C - C'



Well No.	UID	Legal
1	M37066.931422	02-02-039-12 W5M
2	M35379.112876	13-33-038-11 W5M
3	M35379.028864	06-36-038-11 W5M
4	M37066.931299	NW 31-038-09 W5M
5	M35379.105474	NW 35-038-09 W5M
6	M36727.989003	SE 06-039-08 W5M
7	M37066.932852	02-04-039-08 W5M
8	M35379.028896	NE 35-038-08 W5M
9	M35379.028884	04-02-039-07 W5M
10	M35379.028507	SW 05-039-06 W5M
11	M35379.056632	07-02-039-06 W5M
12	M37066.933207	03-06-039-05 W5M
13	M36727.989122	01-03-039-05 W5M
14	M35379.028979	SW 06-039-04 W5M
15	M35379.028980	SW 03-039-04 W5M
16	M35379.028981	SW 05-039-03 W5M

Cross-Section D - D'



Well No.	UID	Legal	Well No.	UID	Legal
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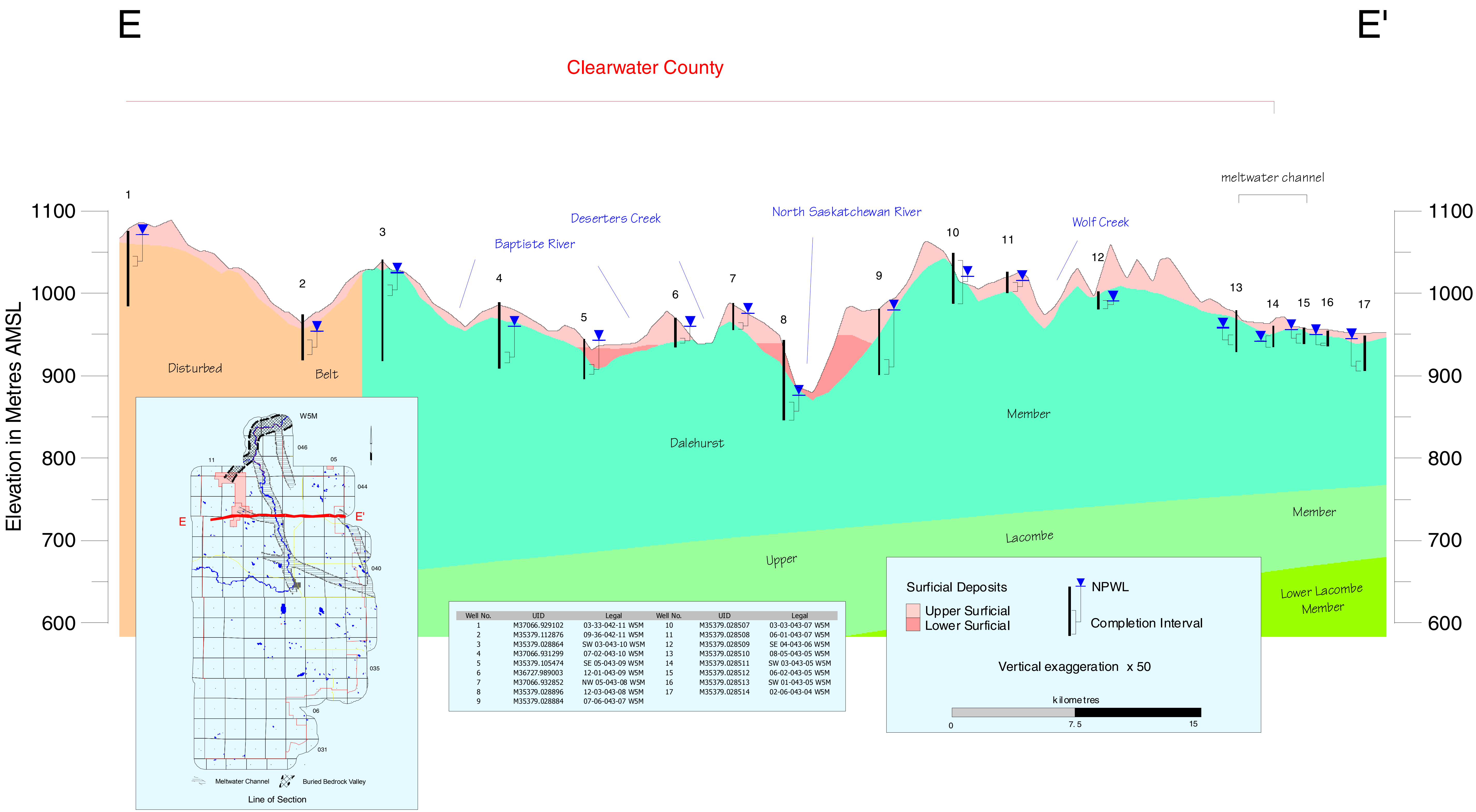
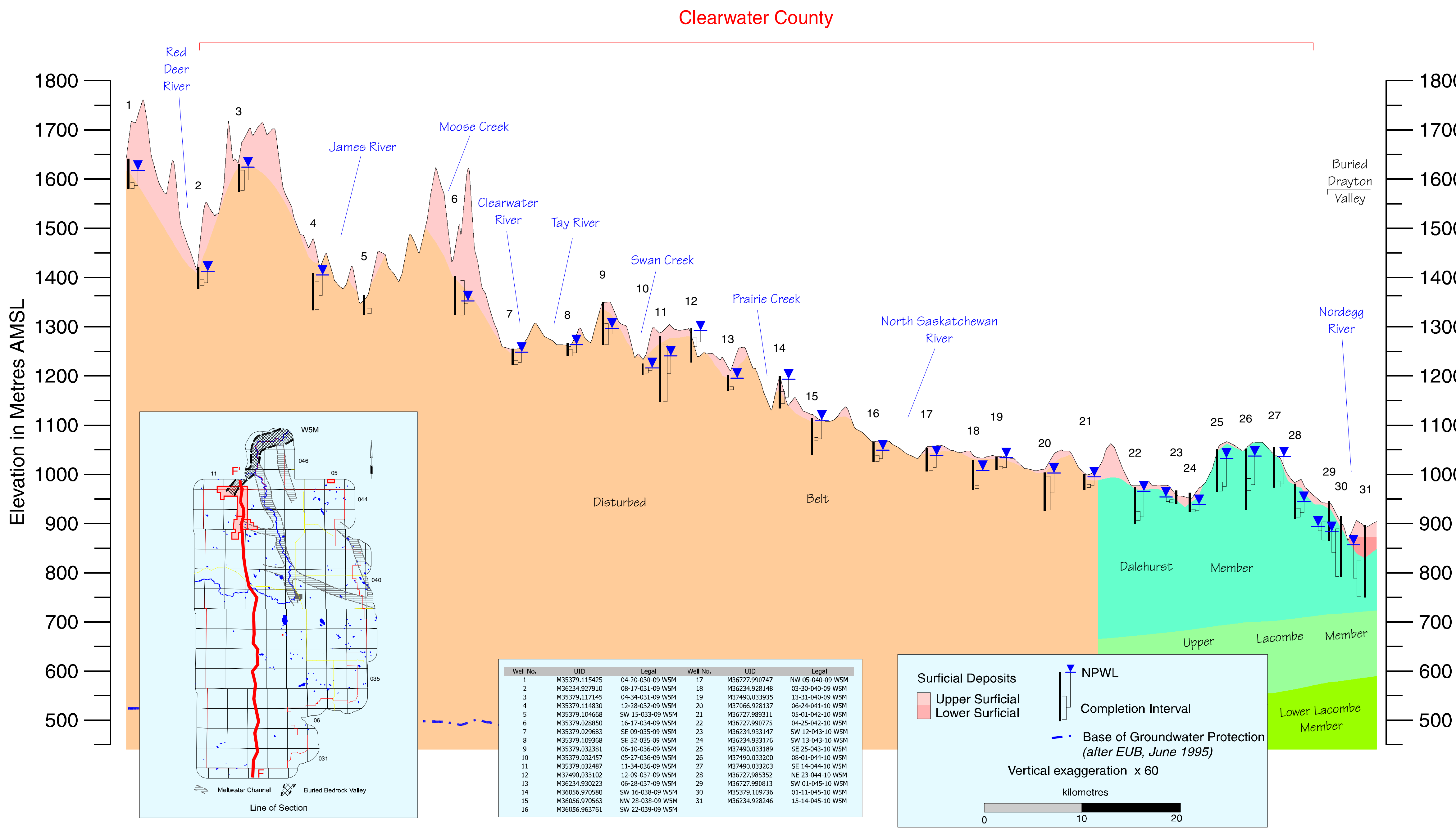
2	M35379.112876	03-36-040-11 W5M	12	M37066.933207	SW 03-041-06 W5M
3	M35379.028864	15-34-040-10 W5M	13	M36727.989122	SE 01-041-06 W5M
4	M37066.931299	13-31-040-09 W5M	14	M35379.028979	03-05-041-05 W5M
5	M35379.105474	16-03-041-09 W5M	15	M35379.028980	SE 03-041-05 W5M
6	M36727.989003	14-01-041-09 W5M	16	M35379.028981	SE 01-041-05 W5M
7	M37066.932852	SE 05-041-08 W5M	17	M35379.028982	SE 05-041-04 W5M
8	M35379.028896	NE 31-040-07 W5M	18	M35379.028983	SW 03-041-04 W5M
9	M35379.028884	SW 03-041-07 W5M	19	M35379.028984	SE 02-041-04 W5M
10	M35379.028507	SW 01-041-07 W5M	20	M35379.028985	07-06-041-03 W5M

Cross-Section E - E'



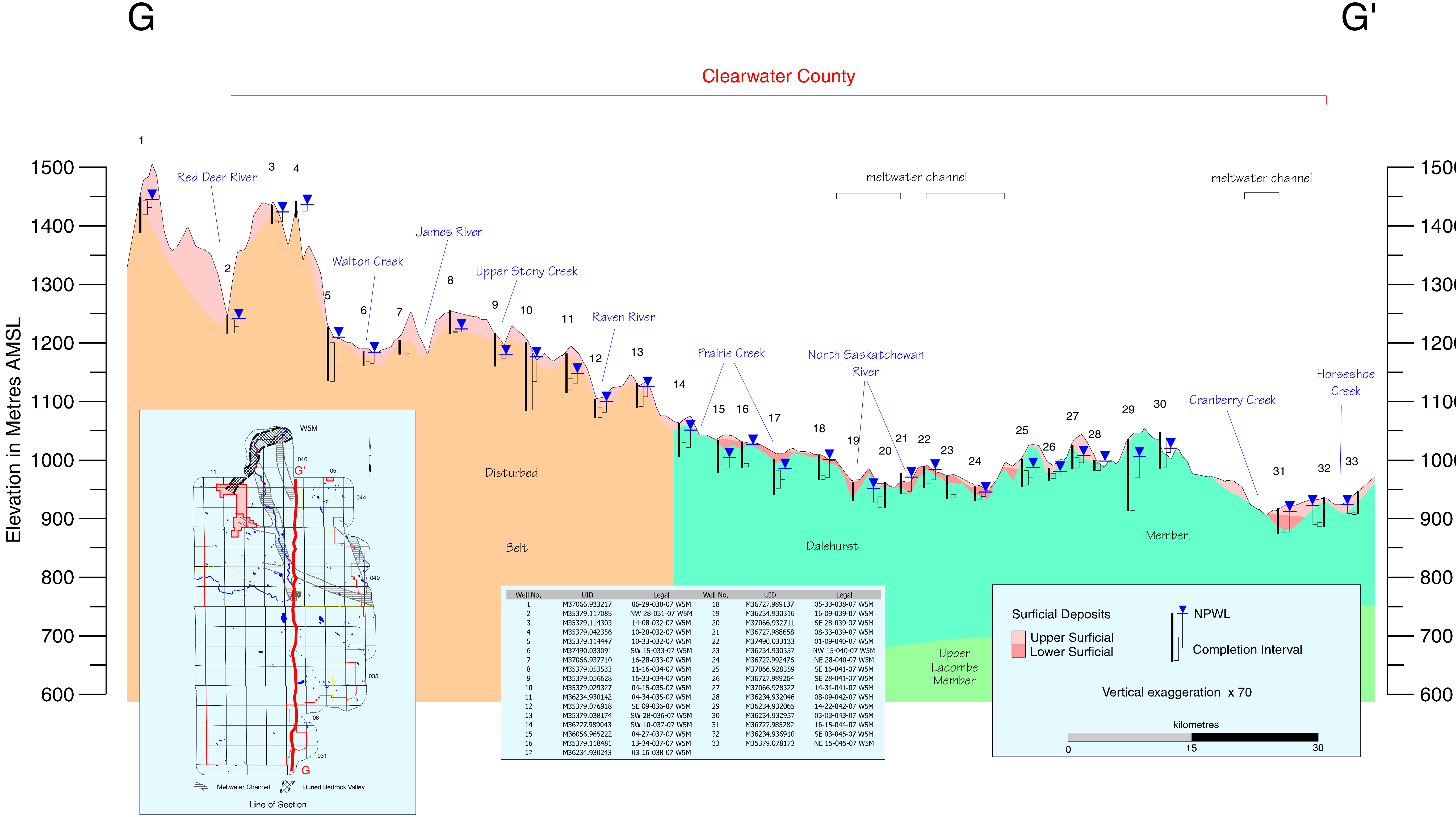
Well No.	UID	Legal	Well No.	UID	Legal
1	M37066.929102	03-33-042-11 W5M	10	M35379.028507	03-03-043-07 W5M
2	M35379.112876	09-36-042-11 W5M	11	M35379.028508	06-01-043-07 W5M
3	M35379.028864	SW 03-043-10 W5M	12	M35379.028509	SE 04-043-06 W5M
4	M37066.931299	07-02-043-10 W5M	13	M35379.028510	08-05-043-05 W5M
5	M35379.105474	SE 05-043-09 W5M	14	M35379.028511	SW 03-043-05 W5M
6	M36727.989003	12-01-043-09 W5M	15	M35379.028512	06-02-043-05 W5M
7	M37066.932852	NW 05-043-08 W5M	16	M35379.028513	SW 01-043-05 W5M
8	M35379.028896	12-03-043-08 W5M	17	M35379.028514	02-06-043-04 W5M
9	M35379.028884	07-06-043-07 W5M			

Cross-Section F - F'



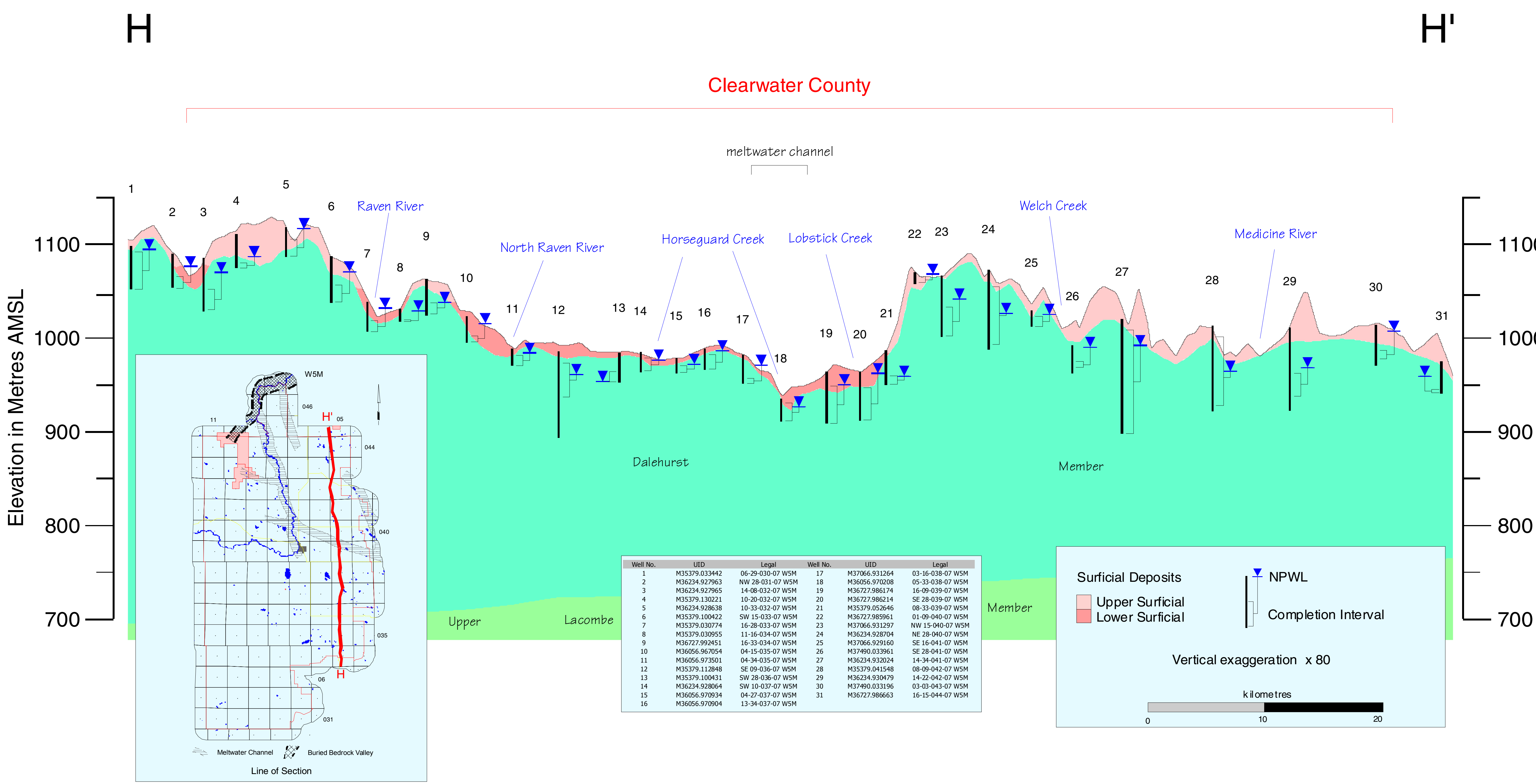
Well No.	UID	Legal	Well No.	UID	Legal
1	M35379.115425	04-20-030-09 W5M	17	M36727.990747	NW 05-040-09 W5M
2	M36234.927910	08-17-031-09 W5M	18	M36234.928148	03-30-040-09 W5M
3	M35379.117145	04-34-031-09 W5M	19	M37490.033935	13-31-040-09 W5M
4	M35379.114830	12-28-032-09 W5M	20	M37066.928137	06-24-041-10 W5M
5	M35379.104668	SW 15-033-09 W5M	21	M36727.989311	05-01-042-10 W5M
6	M35379.028850	16-17-034-09 W5M	22	M36727.990775	04-25-042-10 W5M
7	M35379.029683	SE 09-035-09 W5M	23	M36234.933147	SW 12-043-10 W5M
8	M35379.109368	SE 32-035-09 W5M	24	M36234.933176	SW 13-043-10 W5M
9	M35379.032381	06-10-036-09 W5M	25	M37490.033189	SE 25-043-10 W5M
10	M35379.032457	05-27-036-09 W5M	26	M37490.033200	08-01-044-10 W5M
11	M35379.032487	11-34-036-09 W5M	27	M37490.033203	SE 14-044-10 W5M
12	M37490.033102	12-09-037-09 W5M	28	M36727.985352	NE 23-044-10 W5M
13	M36234.930223	06-28-037-09 W5M	29	M36727.990813	SW 01-045-10 W5M
14	M36056.970580	SW 16-038-09 W5M	30	M35379.109736	01-11-045-10 W5M
15	M36056.970563	NW 28-038-09 W5M	31	M36234.928246	15-14-045-10 W5M
16	M36056.963761	SW 22-039-09 W5M			

Cross-Section G -G'



Well No.	UID	Legal	Well No.	UID	Legal
1	M37066.933217	06-29-030-07 W5M	18	M36727.989137	05-33-038-07 W5M
2	M35379.117085	NW 28-031-07 W5M	19	M36234.930316	16-09-039-07 W5M
3	M35379.114303	14-08-032-07 W5M	20	M37066.932711	SE 28-039-07 W5M
4	M35379.042356	10-20-032-07 W5M	21	M36727.988658	08-33-039-07 W5M
5	M35379.114447	10-33-032-07 W5M	22	M37490.033133	01-09-040-07 W5M
6	M37490.033091	SW 15-033-07 W5M	23	M36234.930357	NW 15-040-07 W5M
7	M37066.937710	16-28-033-07 W5M	24	M36727.992476	NE 28-040-07 W5M
8	M35379.053533	11-16-034-07 W5M	25	M37066.928359	SE 16-041-07 W5M
9	M35379.056628	16-33-034-07 W5M	26	M36727.989264	SE 28-041-07 W5M
10	M35379.029327	04-15-035-07 W5M	27	M37066.928322	14-34-041-07 W5M
11	M36234.930142	04-34-035-07 W5M	28	M36234.932046	08-09-042-07 W5M
12	M35379.076918	SE 09-036-07 W5M	29	M36234.932065	14-22-042-07 W5M
13	M35379.038174	SW 28-036-07 W5M	30	M36234.932957	03-03-043-07 W5M
14	M36727.989043	SW 10-037-07 W5M	31	M36727.985282	16-15-044-07 W5M
15	M36056.965222	04-27-037-07 W5M	32	M36234.936910	SE 03-045-07 W5M
16	M35379.118481	13-34-037-07 W5M	33	M35379.078173	NE 15-045-07 W5M
17	M36234.930243	03-16-038-07 W5M			

Cross-Section H -H'



Well No.	UID	Legal	Well No.	UID	Legal
1	M35379.033442	06-29-030-07 W5M	17	M37066.931264	03-16-038-07 W5M
2	M36234.927963	NW 28-031-07 W5M	18	M36056.970208	05-33-038-07 W5M
3	M36234.927965	14-08-032-07 W5M	19	M36727.986174	16-09-039-07 W5M
4	M35379.130221	10-20-032-07 W5M	20	M36727.986214	SE 28-039-07 W5M
5	M36234.928638	10-33-032-07 W5M	21	M35379.052646	08-33-039-07 W5M
6	M35379.100422	SW 15-033-07 W5M	22	M36727.985961	01-09-040-07 W5M
7	M35379.030774	16-28-033-07 W5M	23	M37066.931297	NW 15-040-07 W5M
8	M35379.030955	11-16-034-07 W5M	24	M36234.928704	NE 28-040-07 W5M
9	M36727.992451	16-33-034-07 W5M	25	M37066.929160	SE 16-041-07 W5M
10	M36056.967054	04-15-035-07 W5M	26	M37490.033961	SE 28-041-07 W5M
11	M36056.973501	04-34-035-07 W5M	27	M36234.932024	14-34-041-07 W5M
12	M35379.112848	SE 09-036-07 W5M	28	M35379.041548	08-09-042-07 W5M
13	M35379.100431	SW 28-036-07 W5M	29	M36234.930479	14-22-042-07 W5M
14	M36234.928064	SW 10-037-07 W5M	30	M37490.033196	03-03-043-07 W5M
15	M36056.970934	04-27-037-07 W5M	31	M36727.986663	16-15-044-07 W5M
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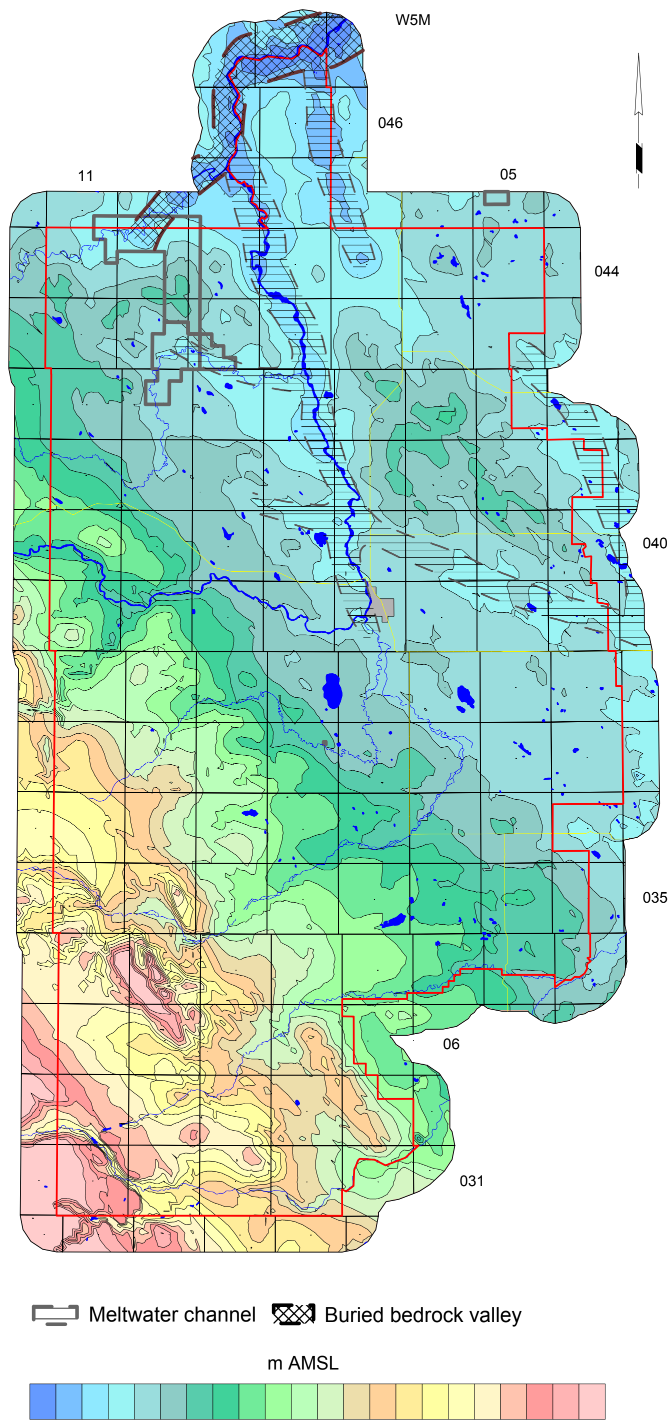
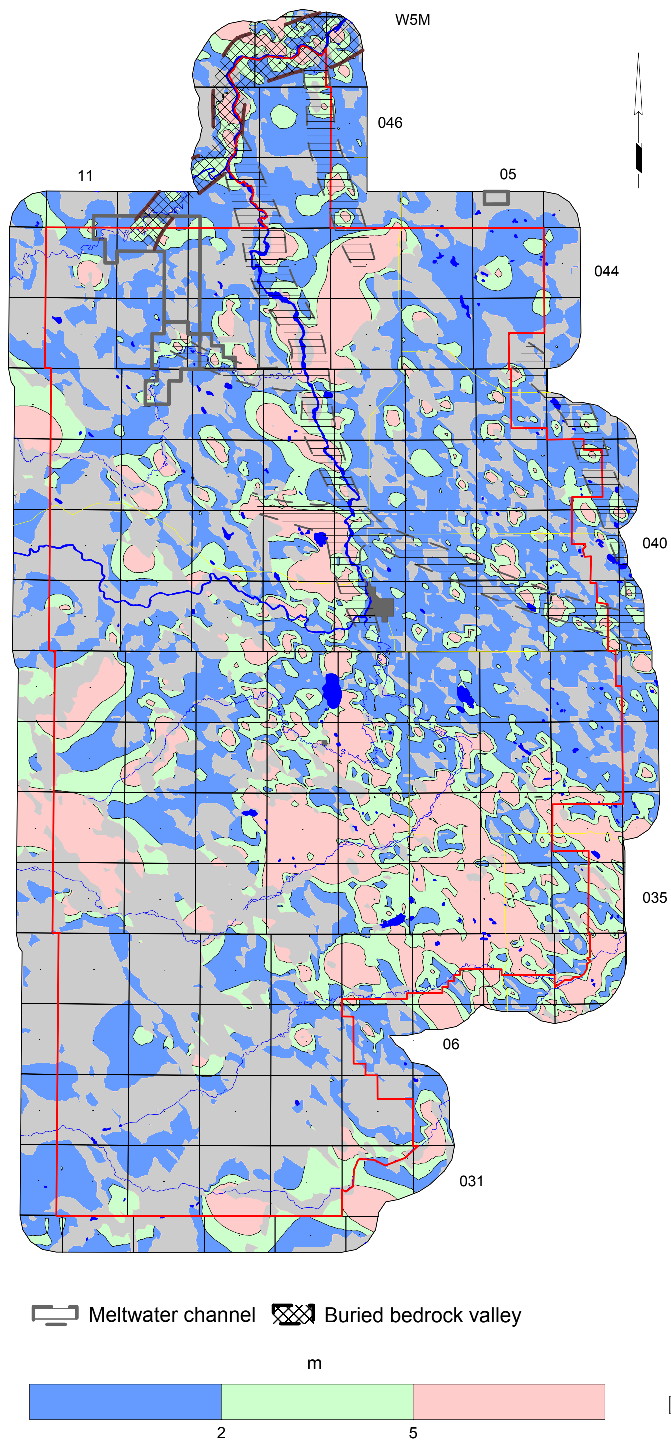
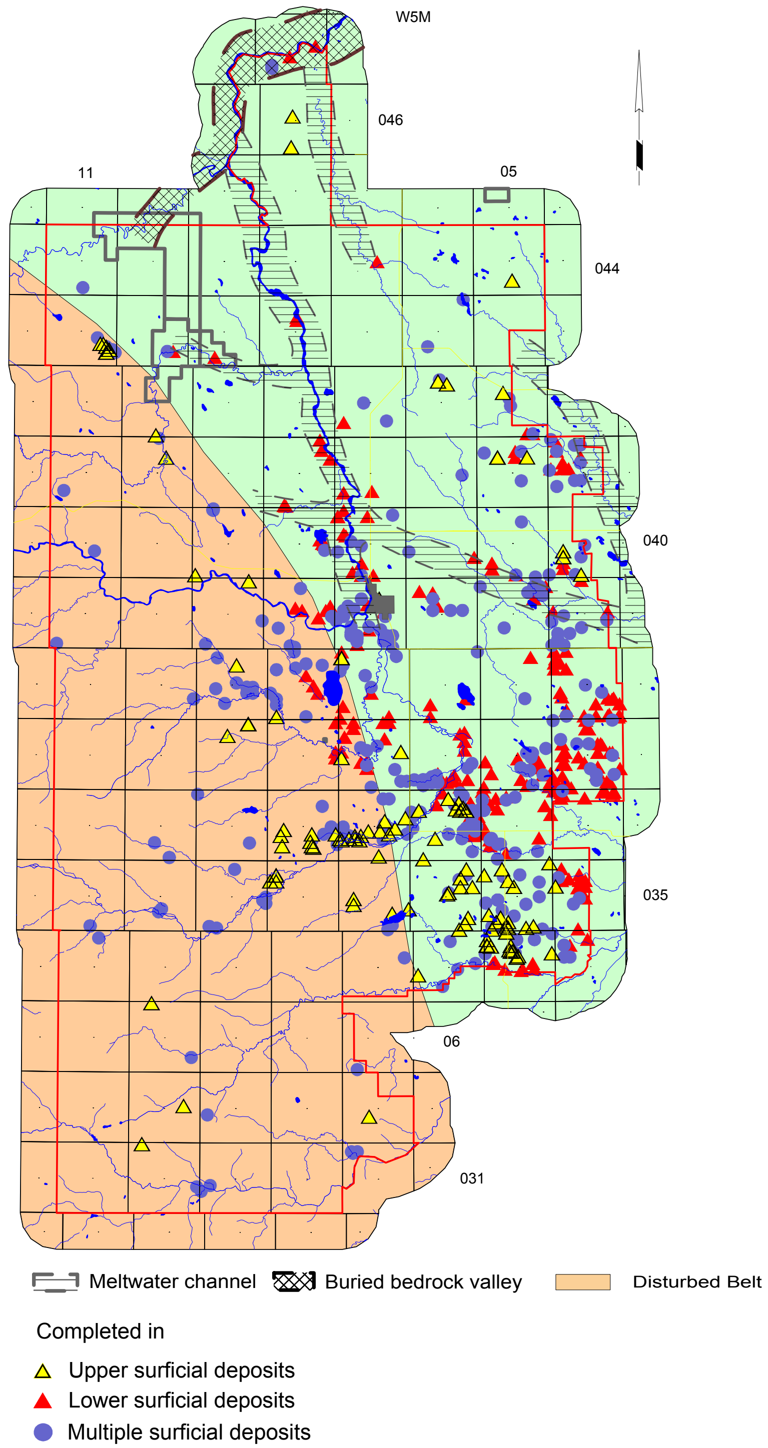
Bedrock Topography



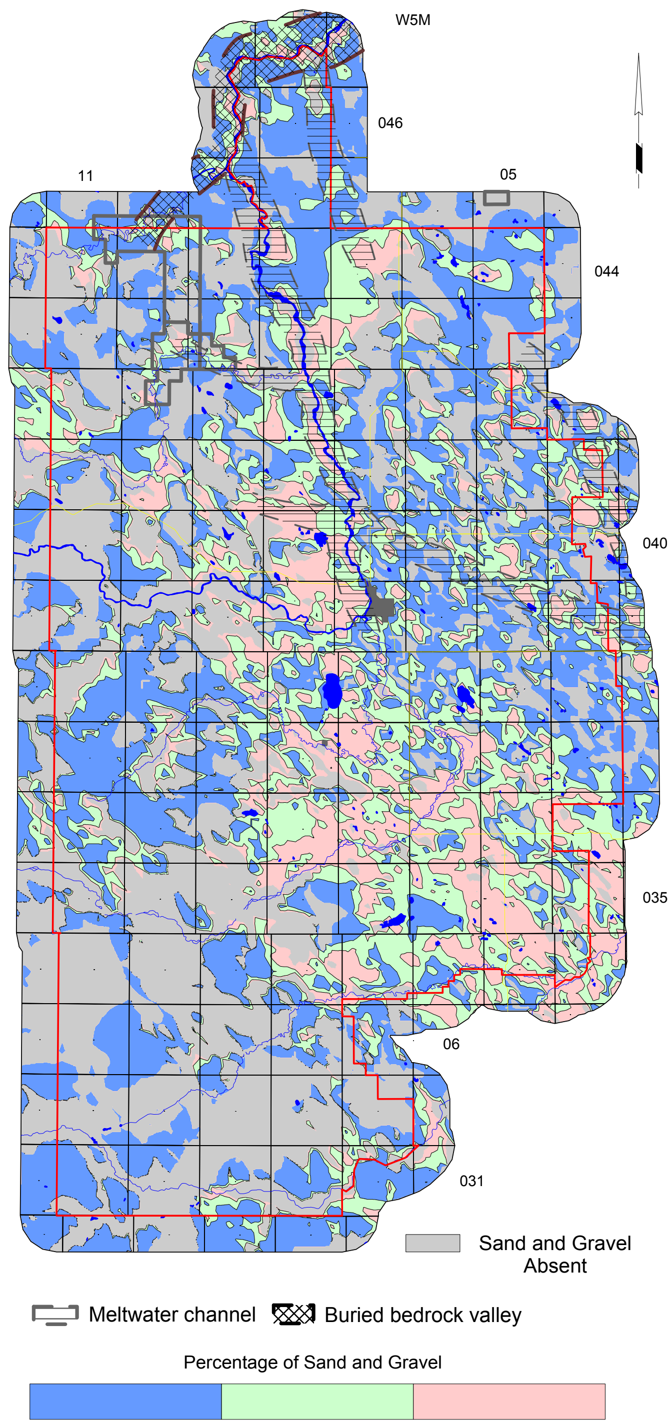
Thickness of Sand and Gravel Deposits



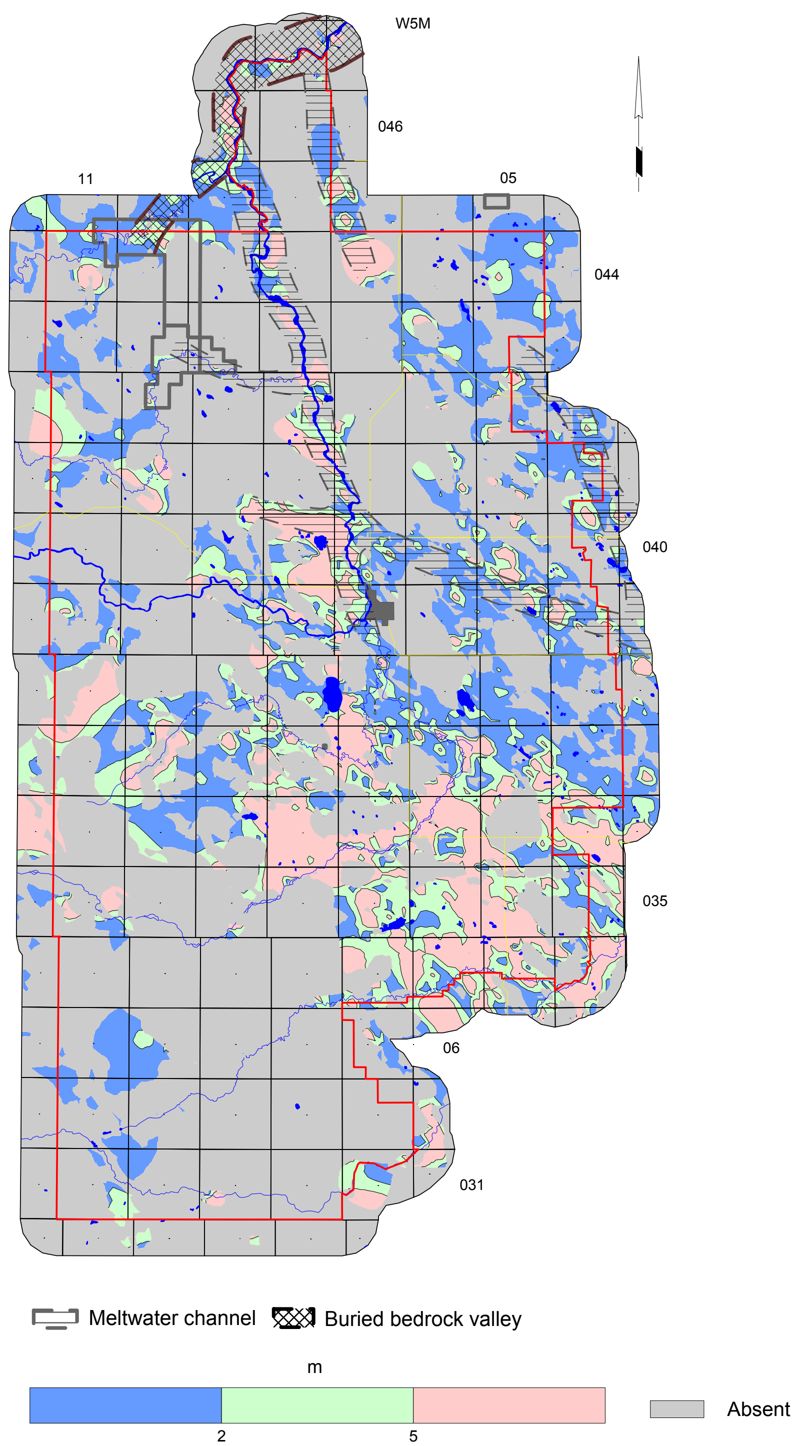
Water Wells Completed in Surficial Deposits



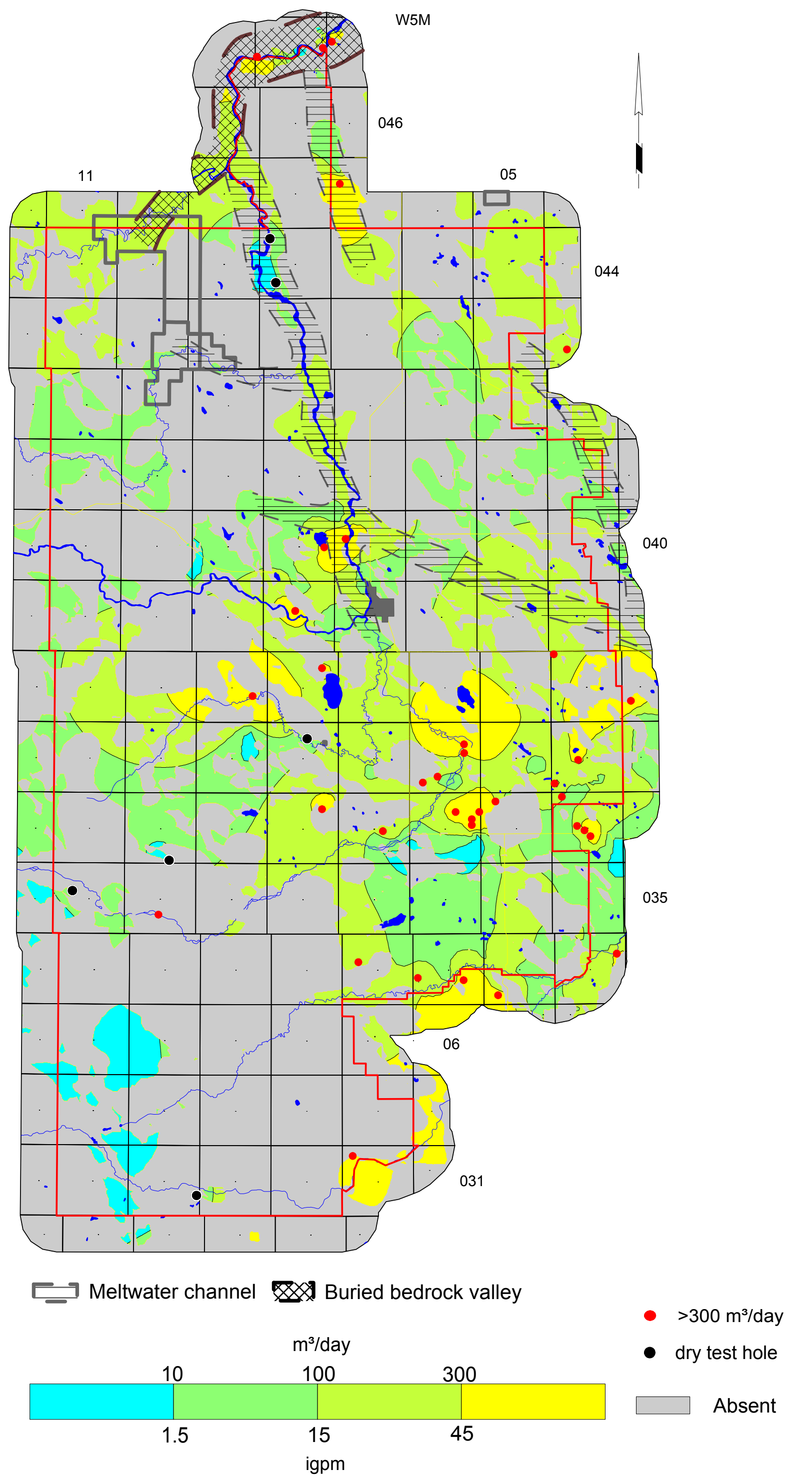
Amount of Sand and Gravel in Surficial Deposits



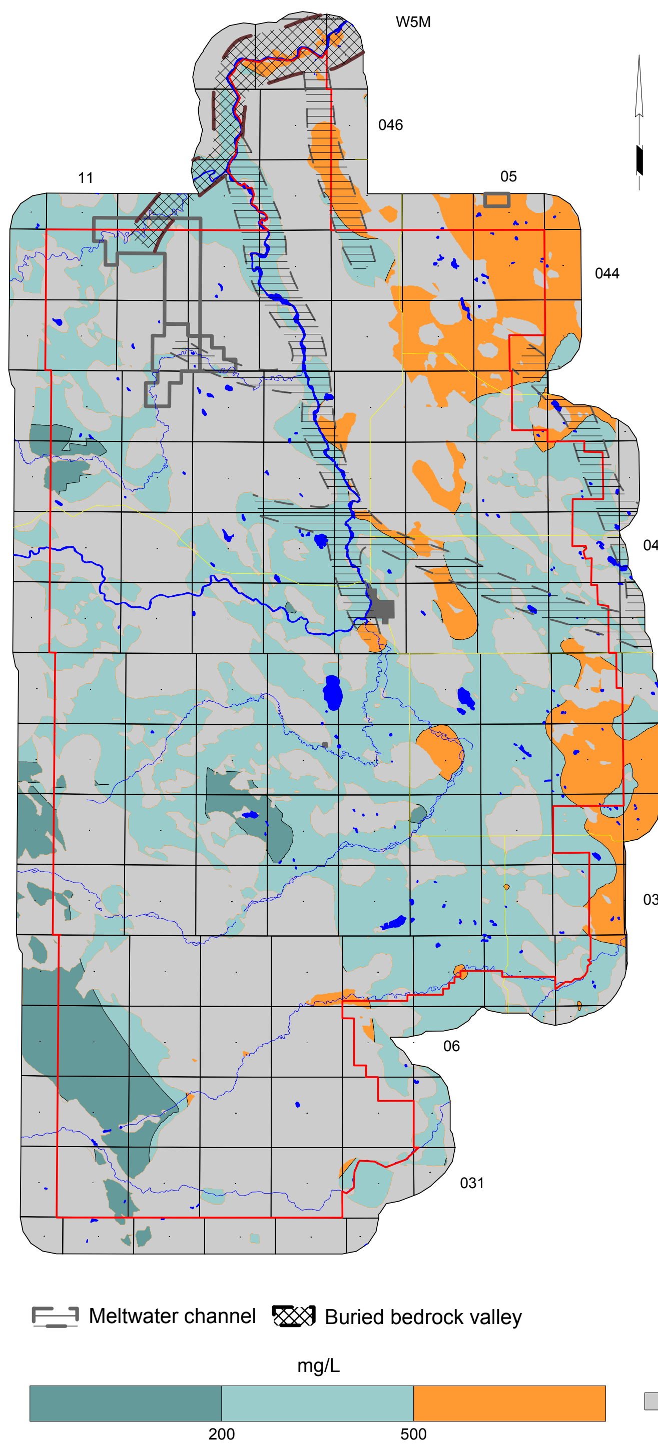
Thickness of Sand and Gravel Aquifer(s)



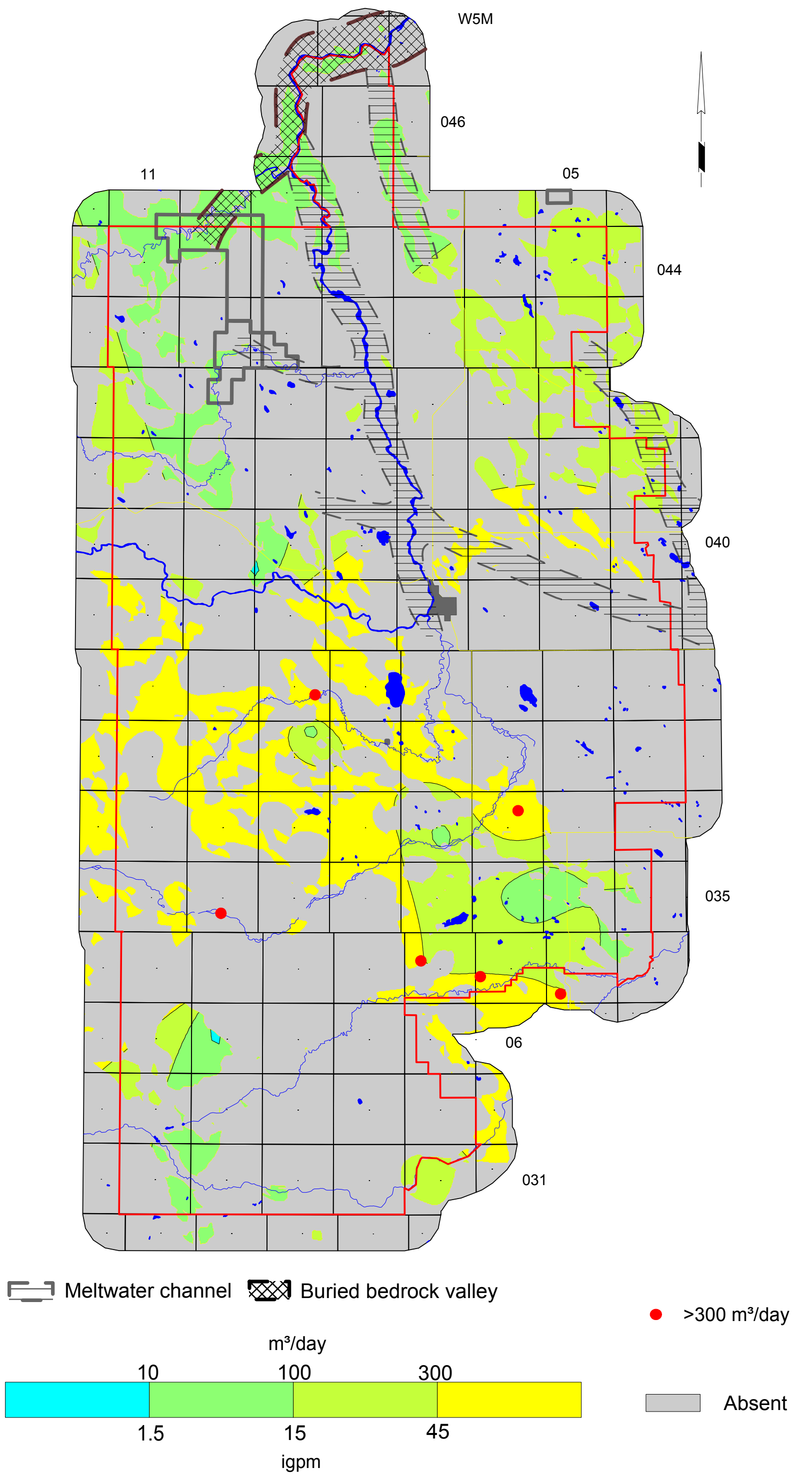
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



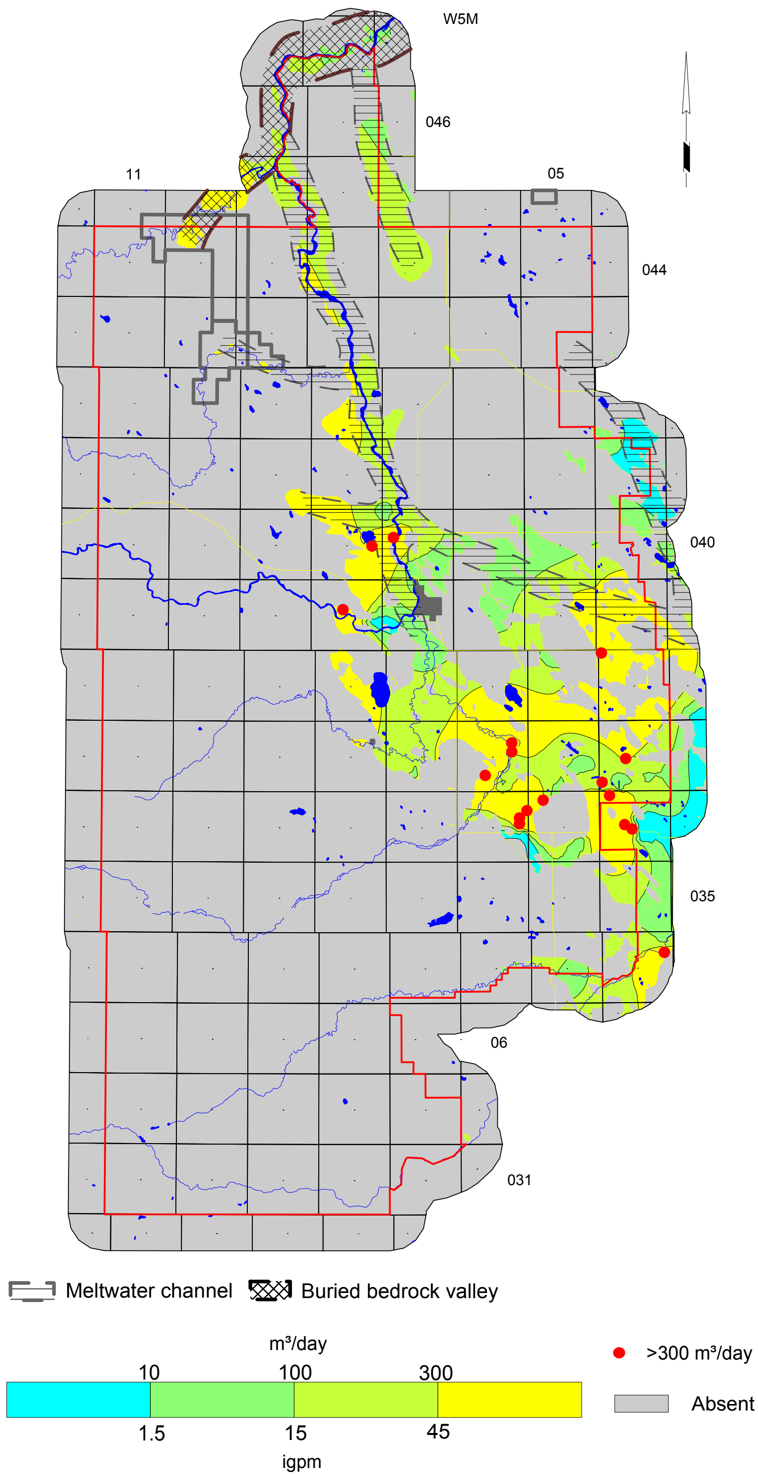
Total Dissolved Solids in Groundwater from Surficial Deposits



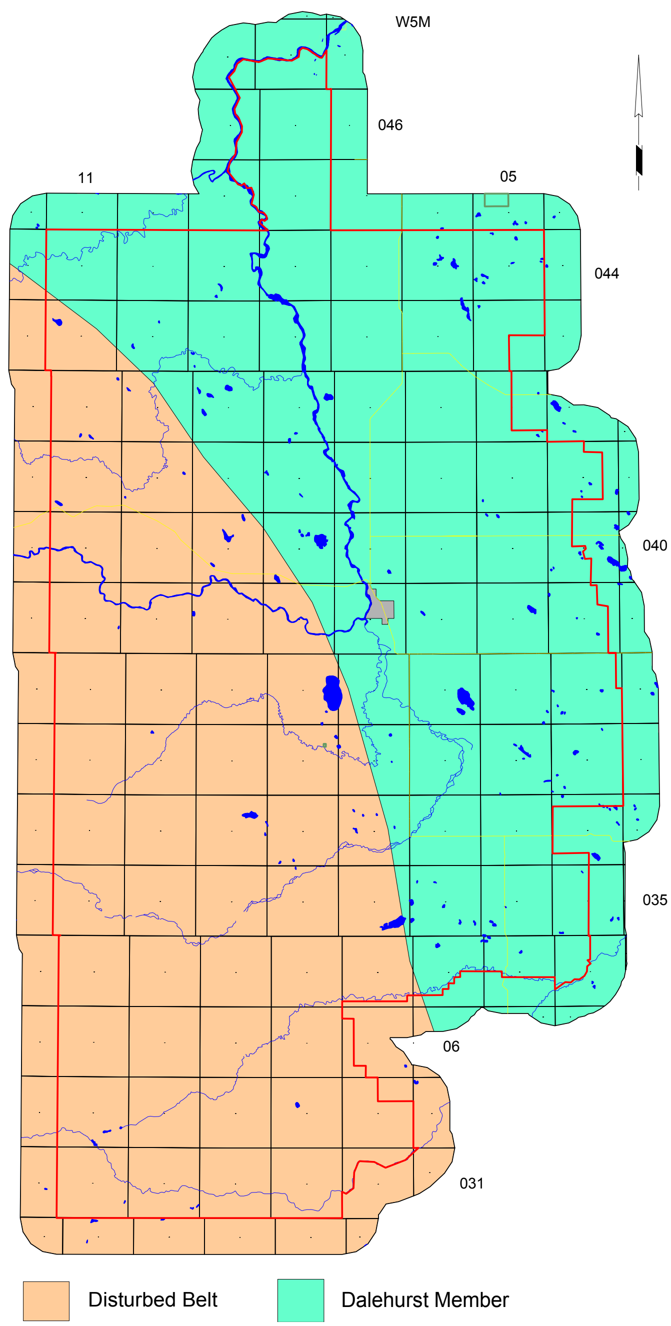
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



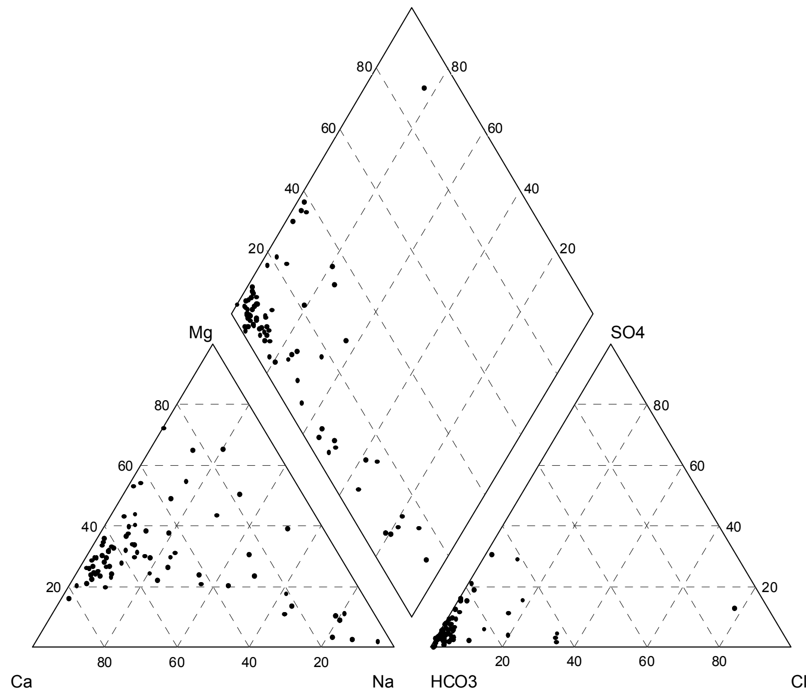
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



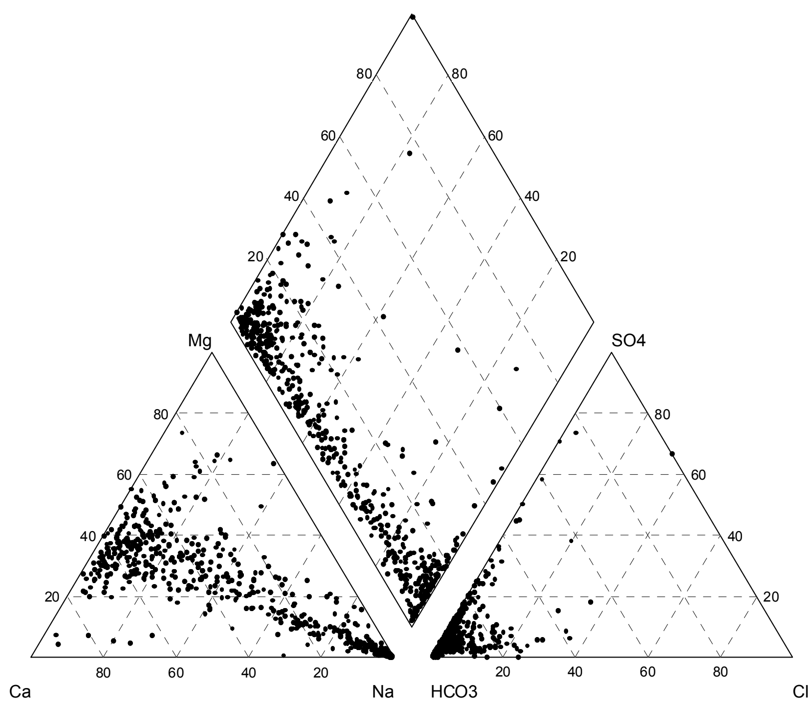
Bedrock Geology



Piper Diagrams

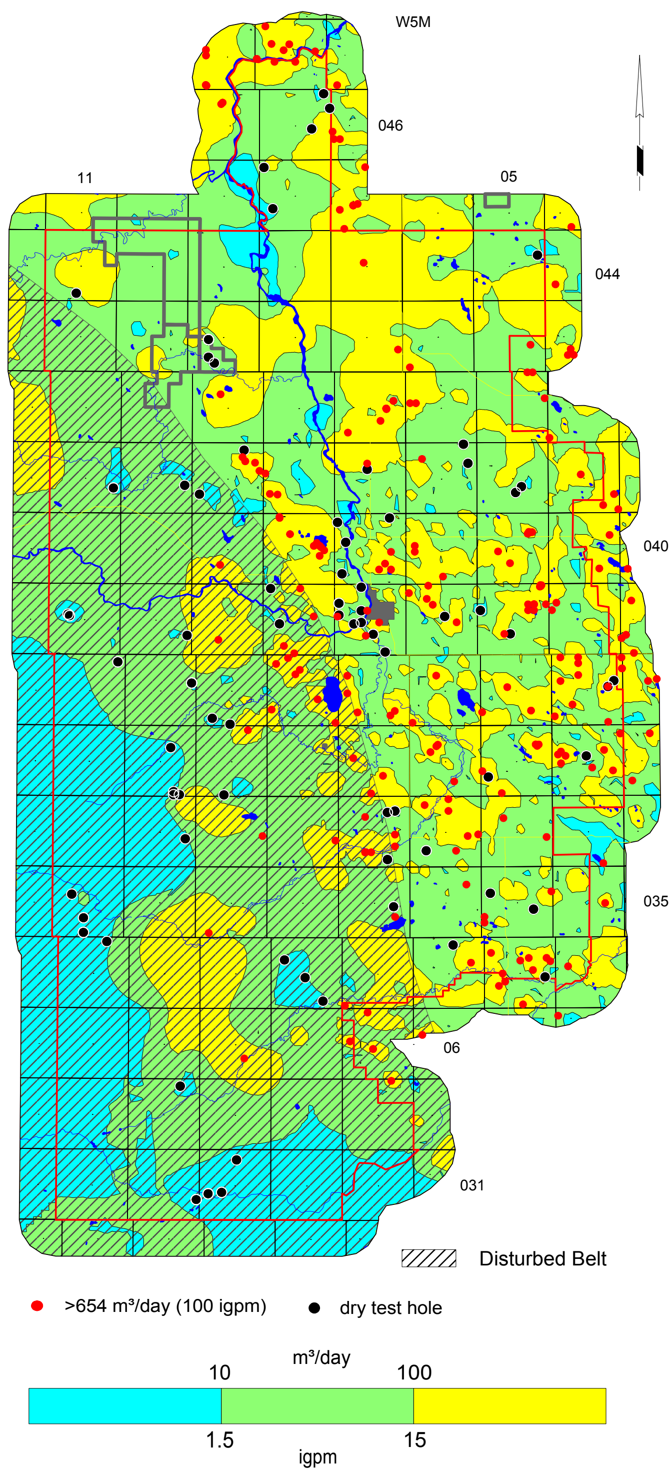


Surficial Deposits

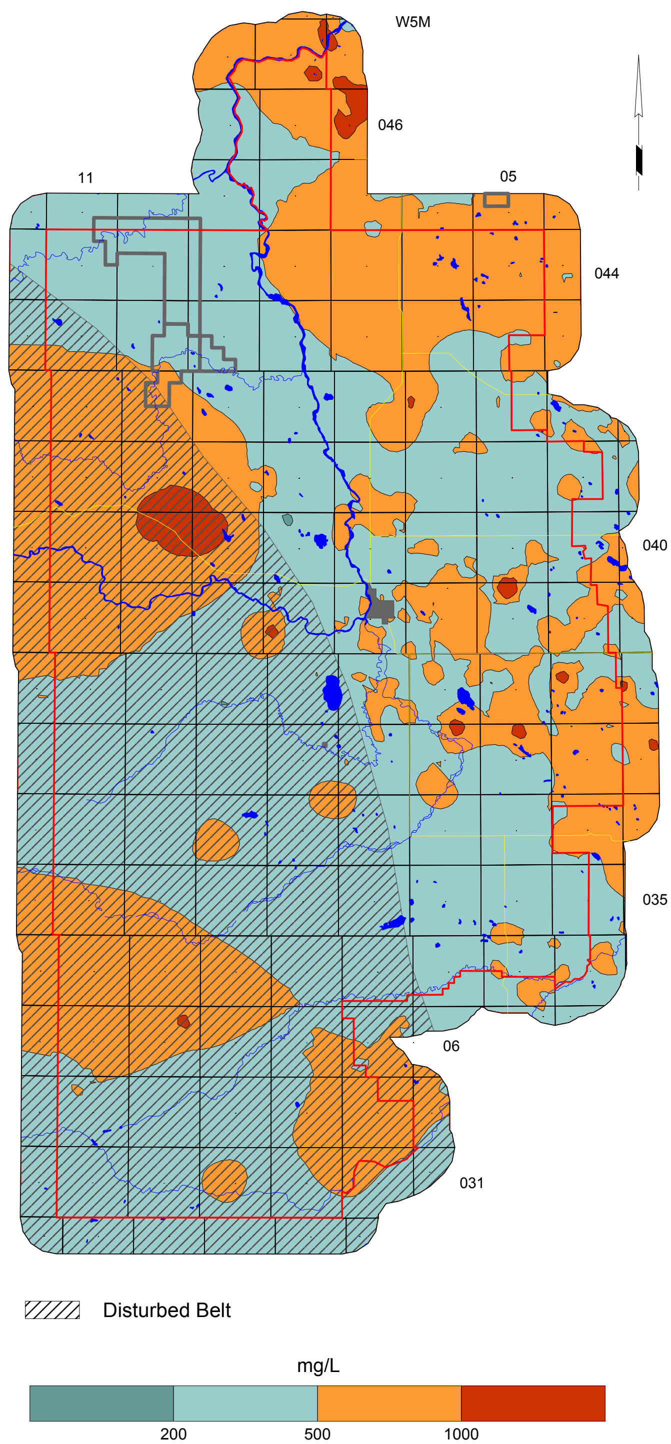


Bedrock Aquifers

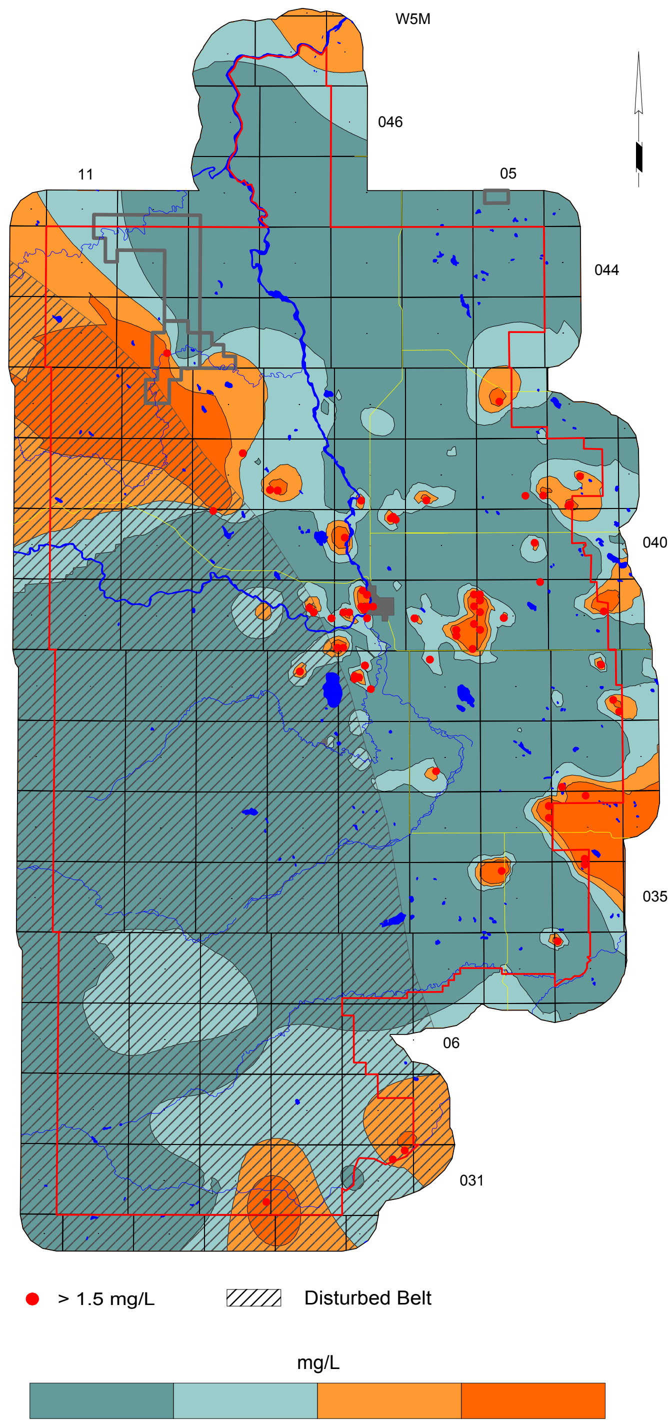
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



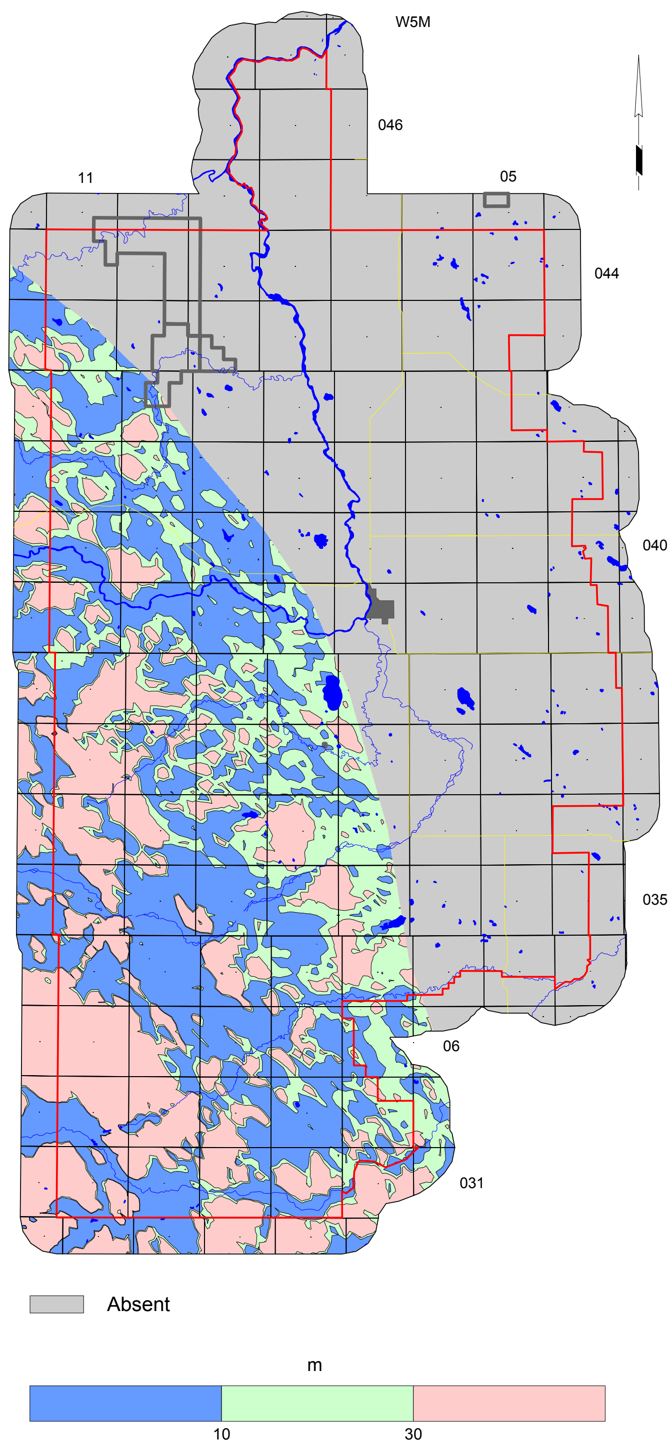
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



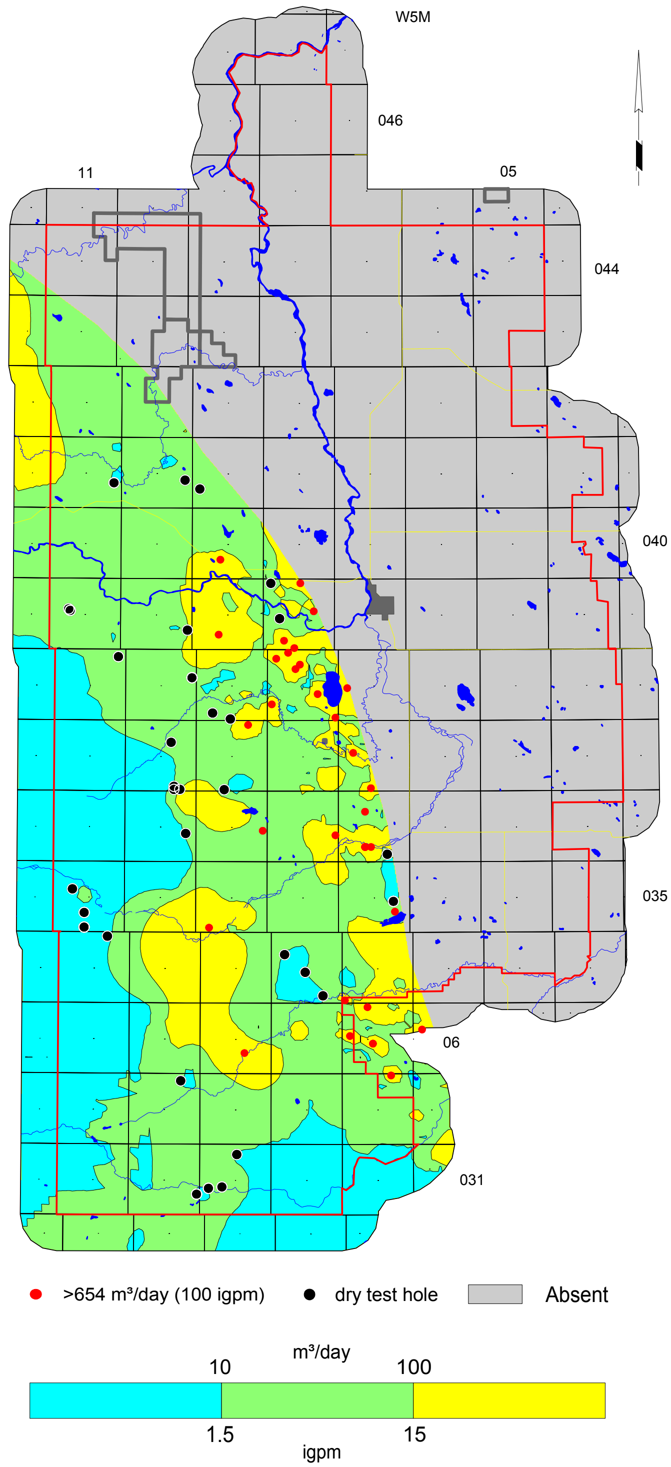
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



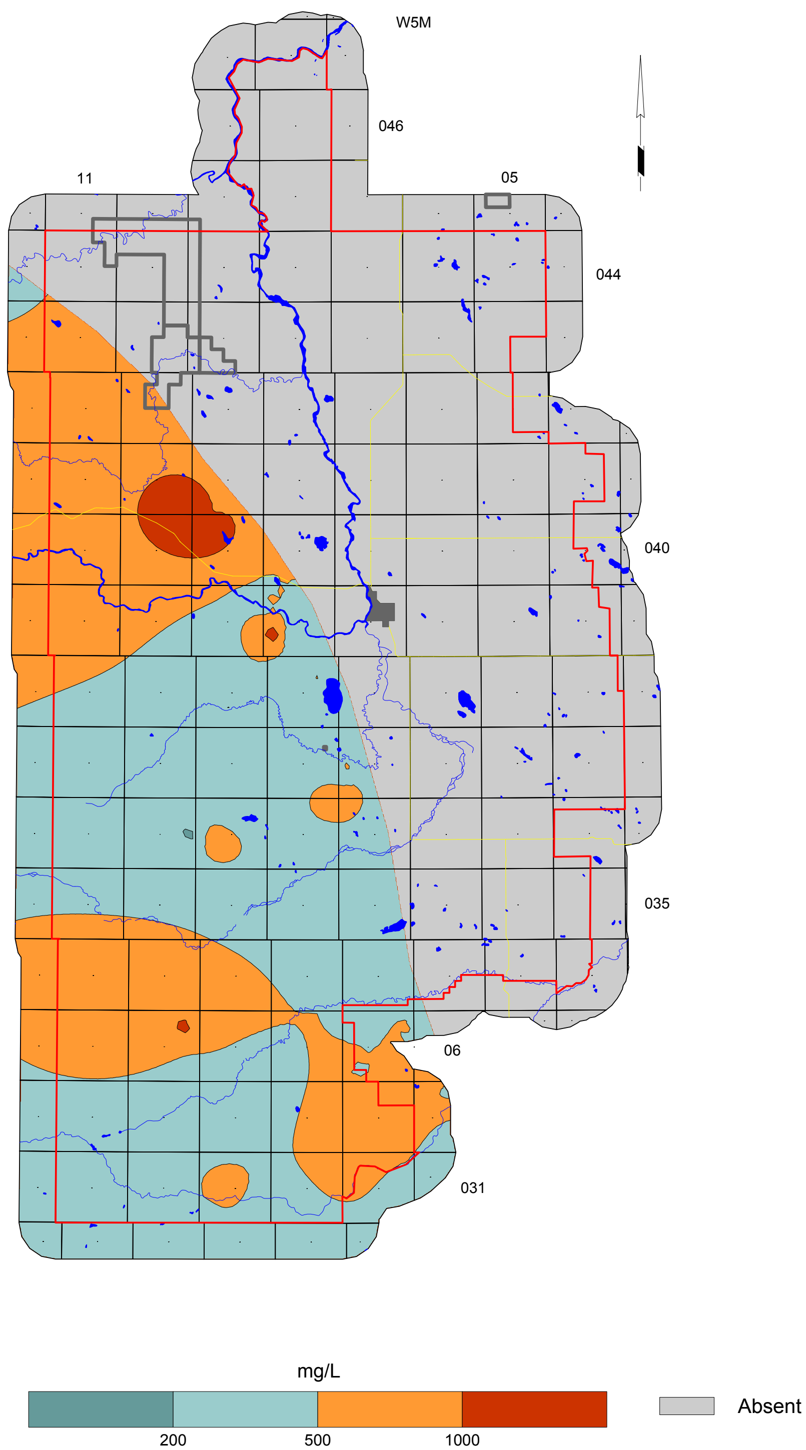
Depth to Top of Disturbed Belt



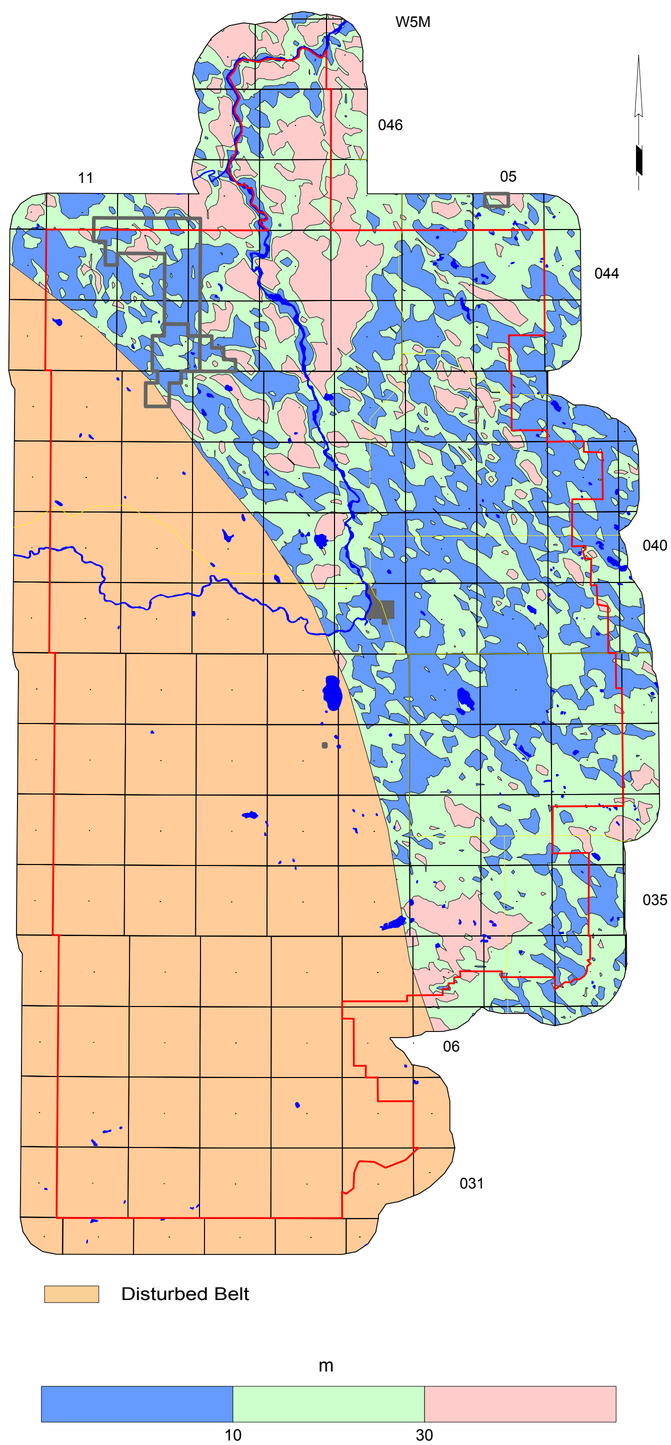
Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer



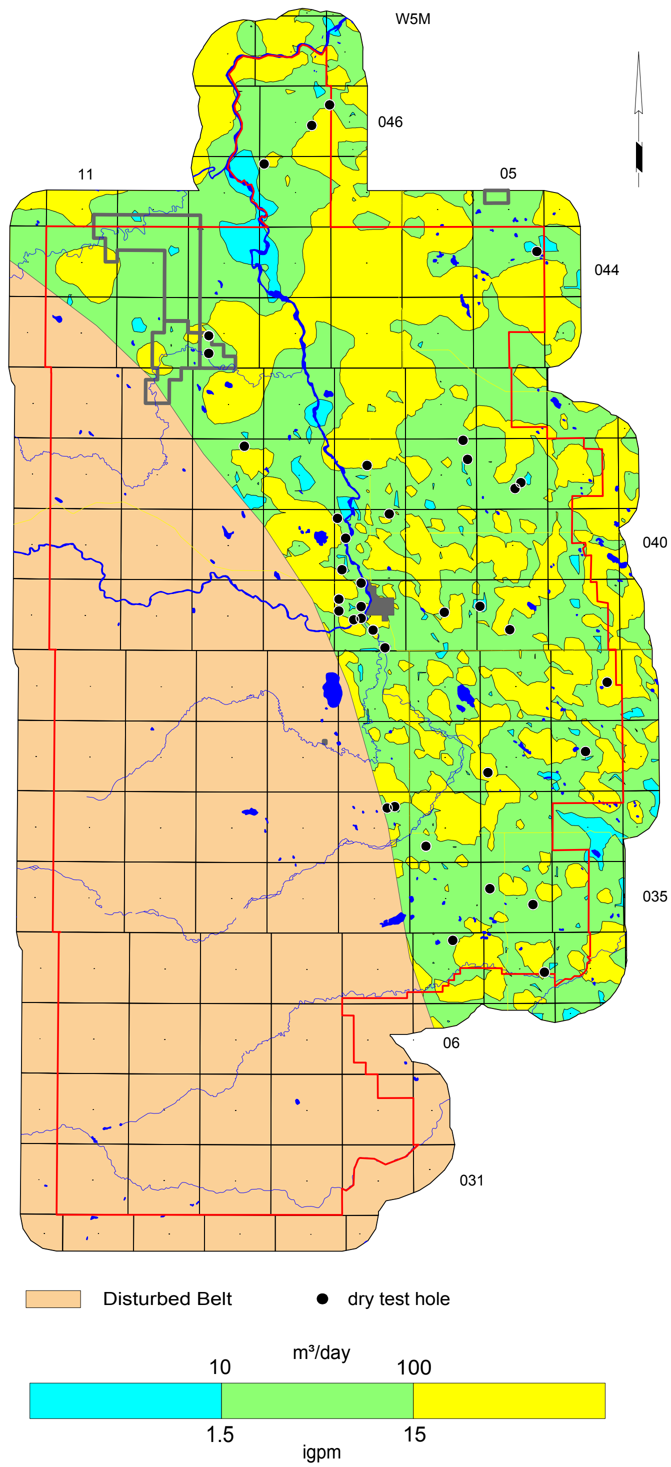
Total Dissolved Solids in Groundwater from Disturbed Belt Aquifer



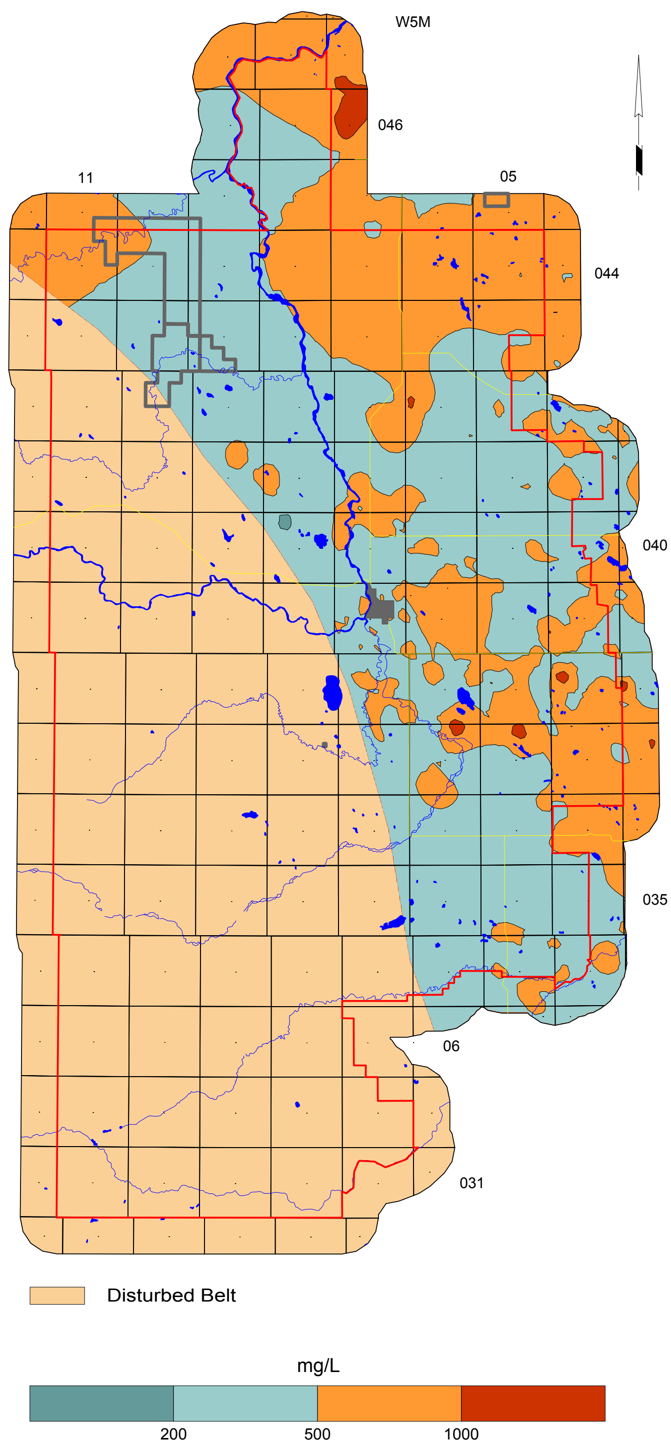
Depth to Top of Dalehurst Member



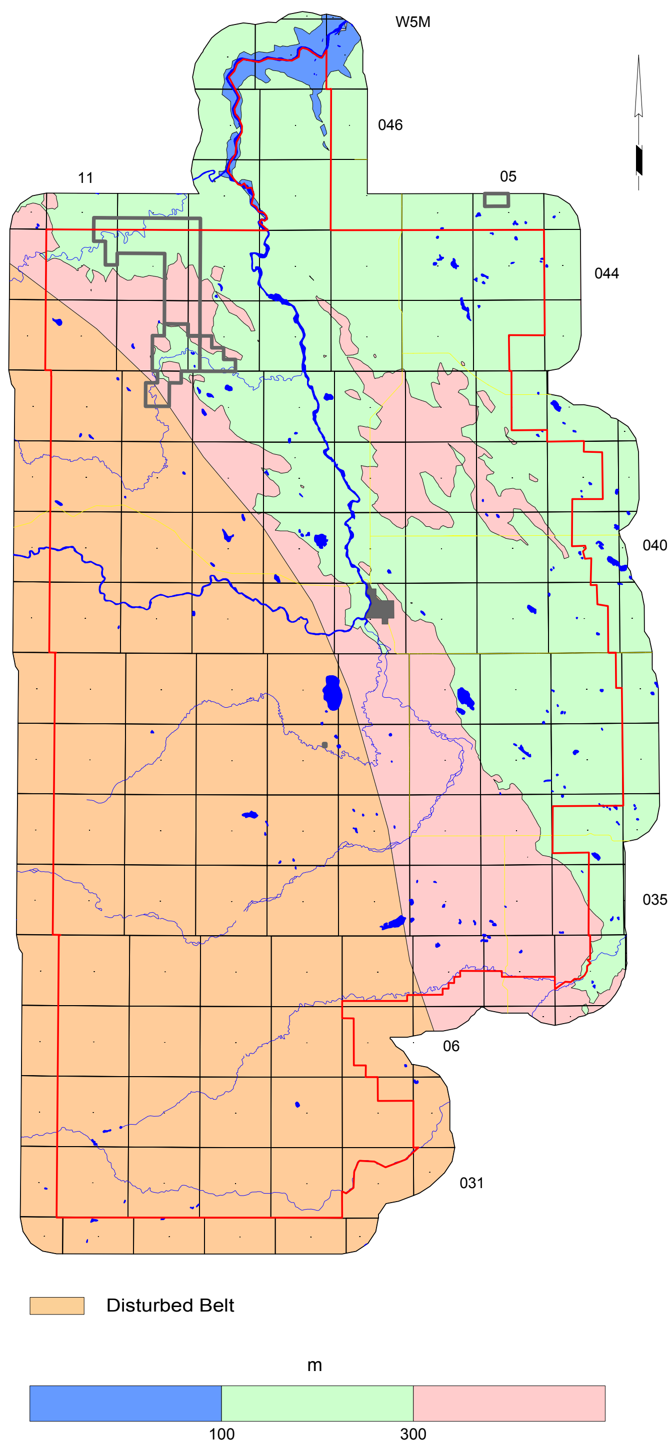
Apparent Yield for Water Wells Completed through Dalehurst Aquifer



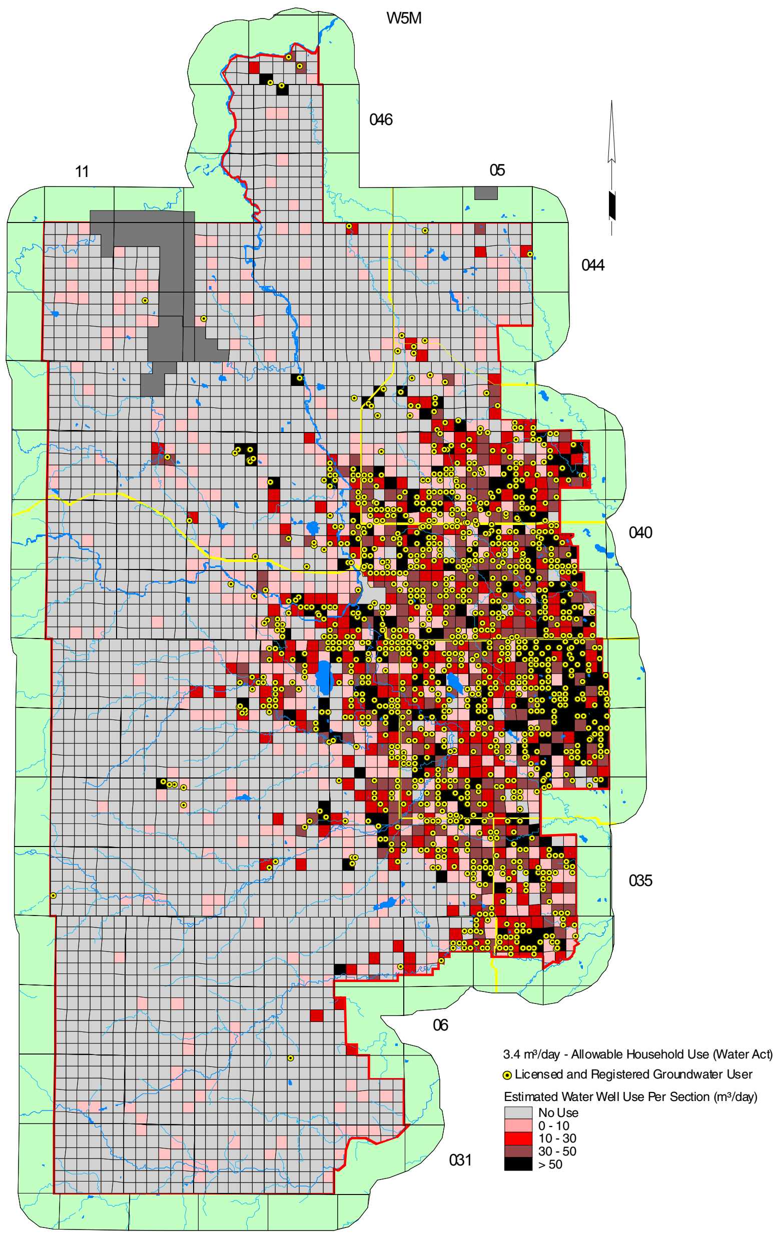
Total Dissolved Solids in Groundwater from Dalehurst Aquifer



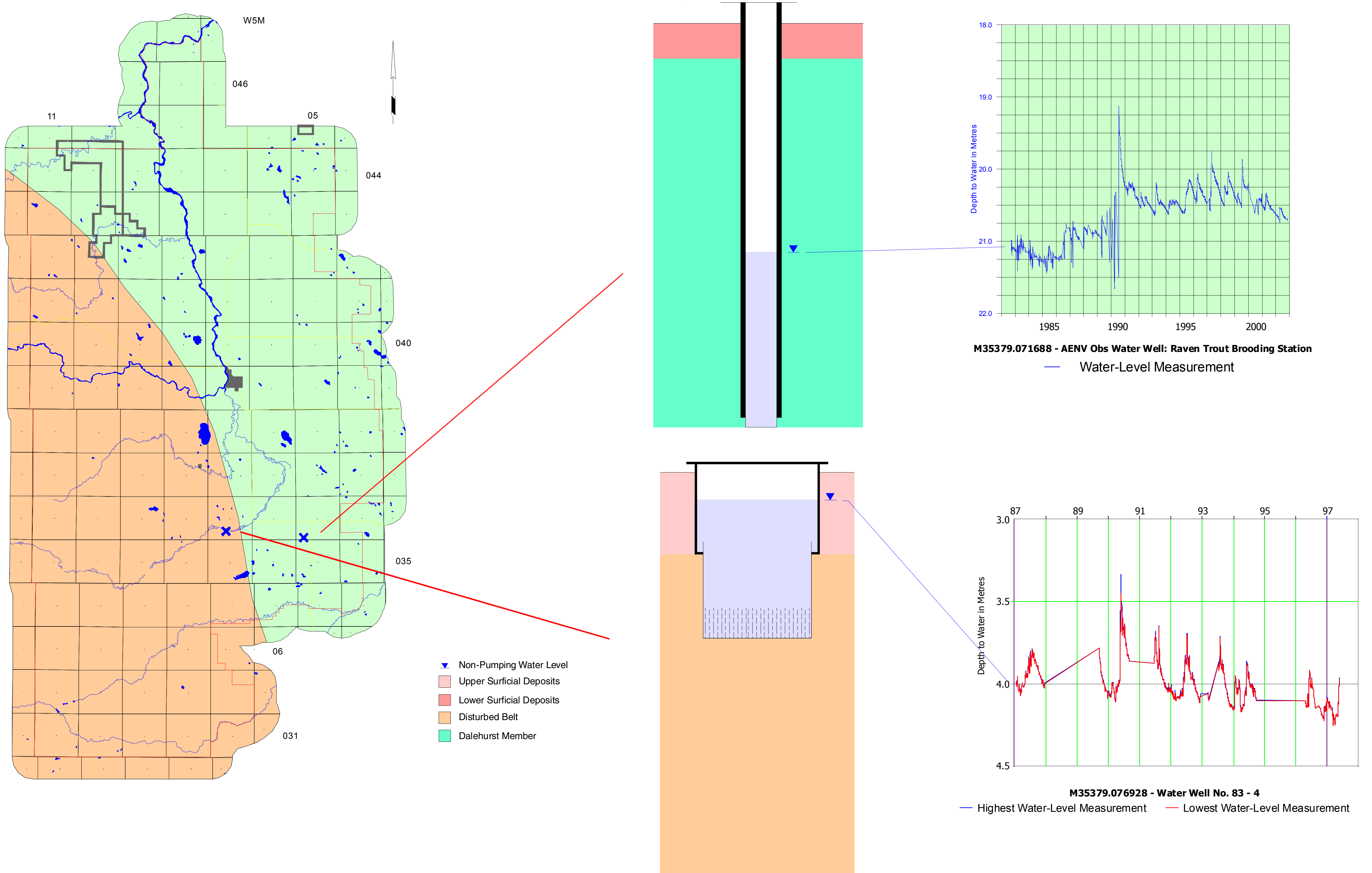
Depth to Top of Upper Lacombe Member



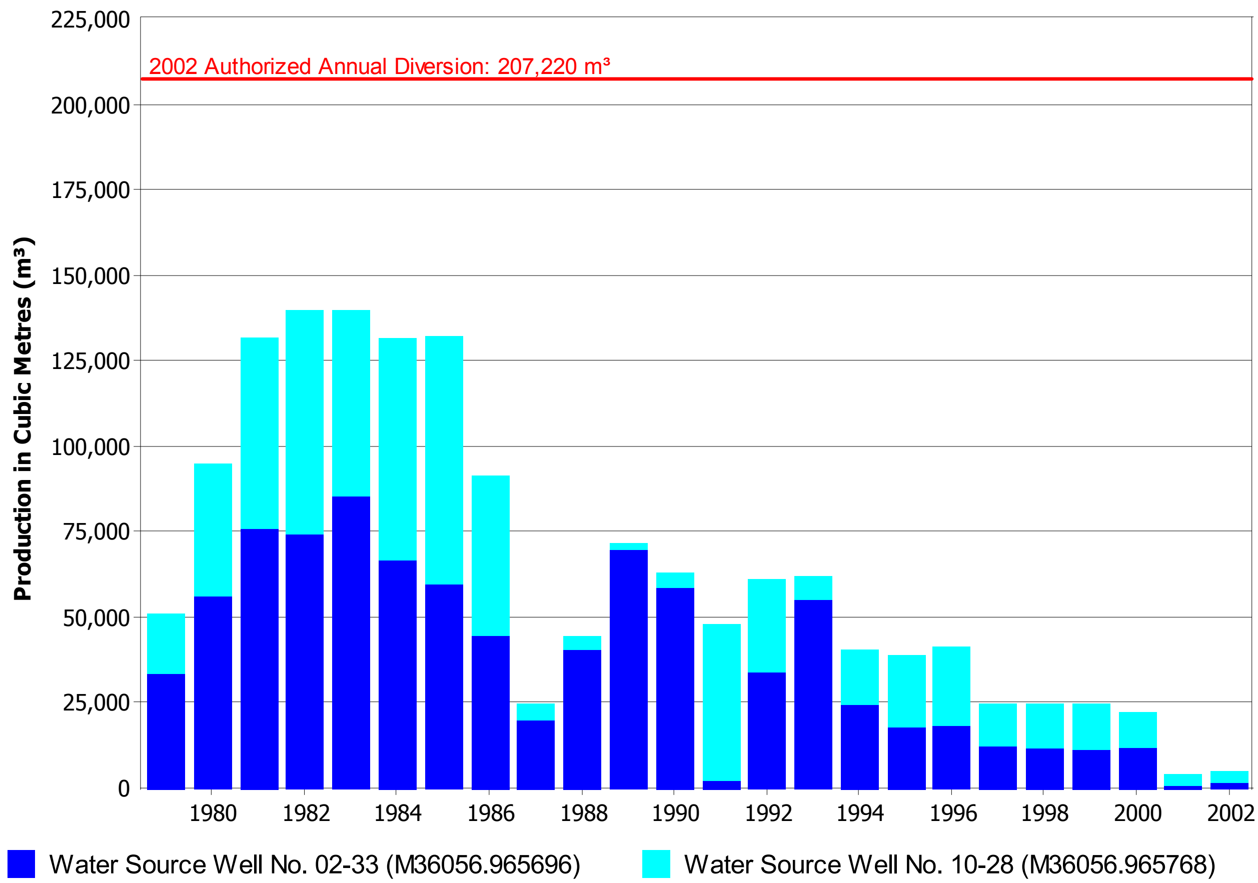
Estimated Water Well Use per Section



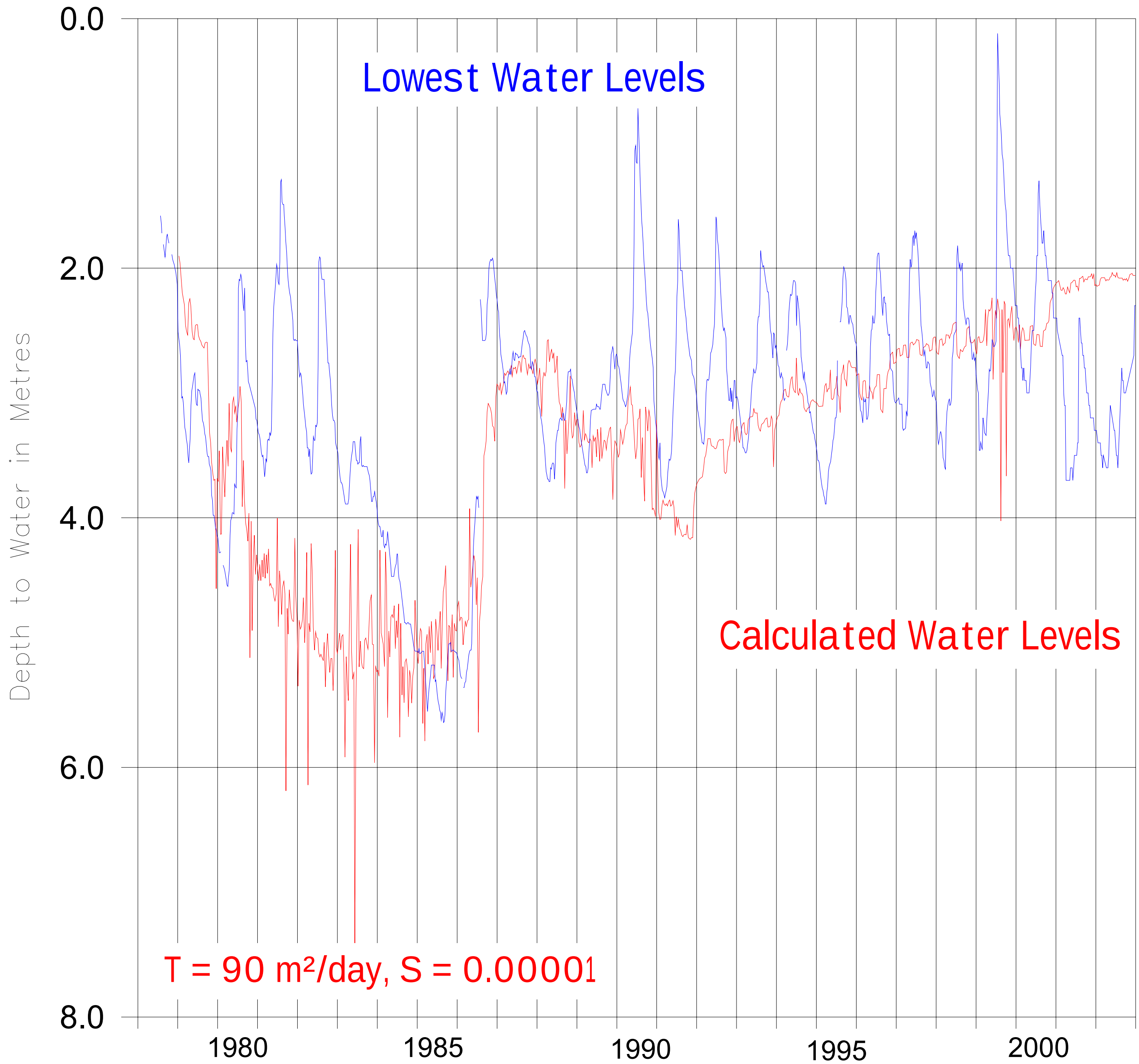
Hydrographs



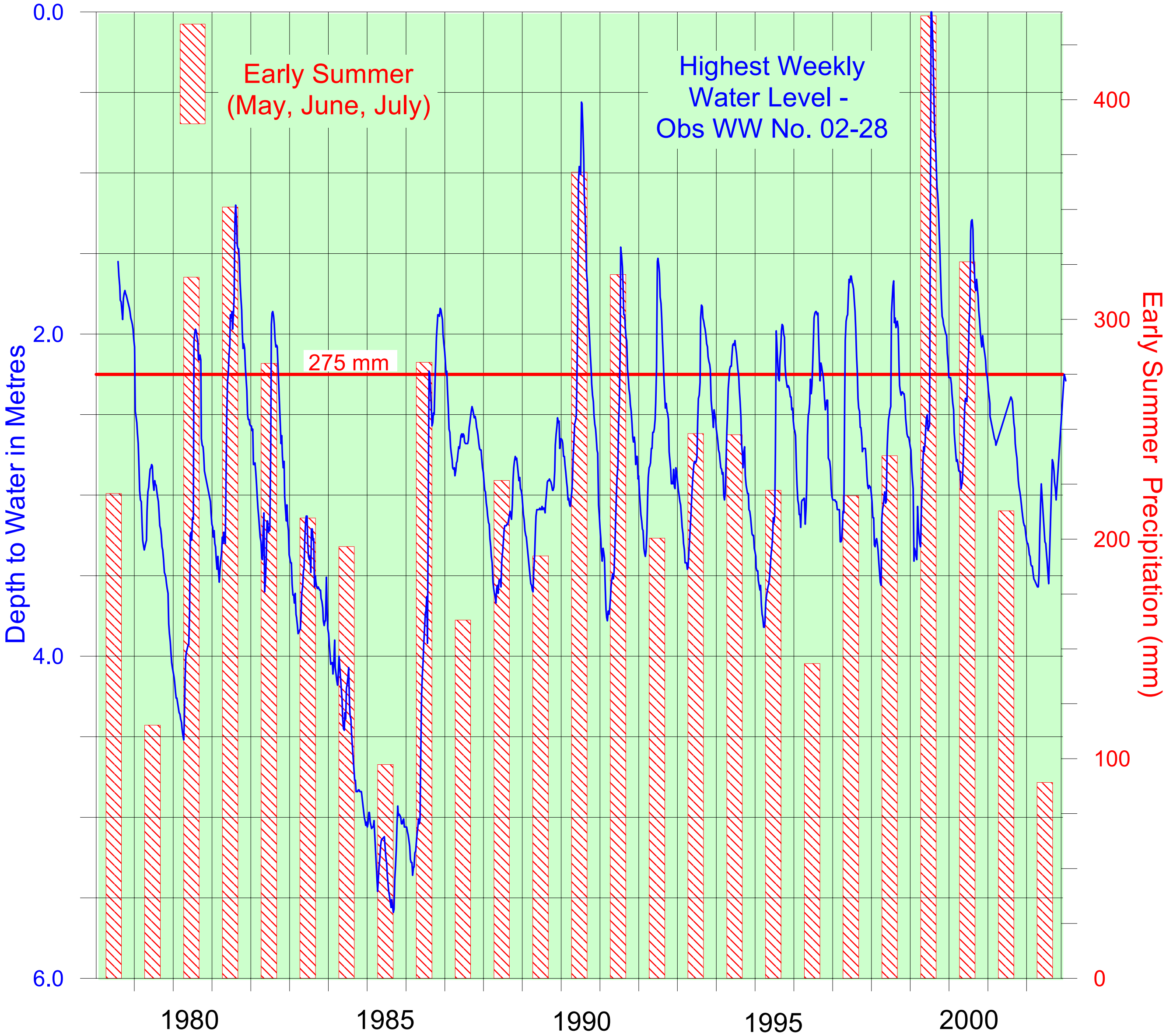
Annual Production from WSW Nos. 02-33 and 10-28

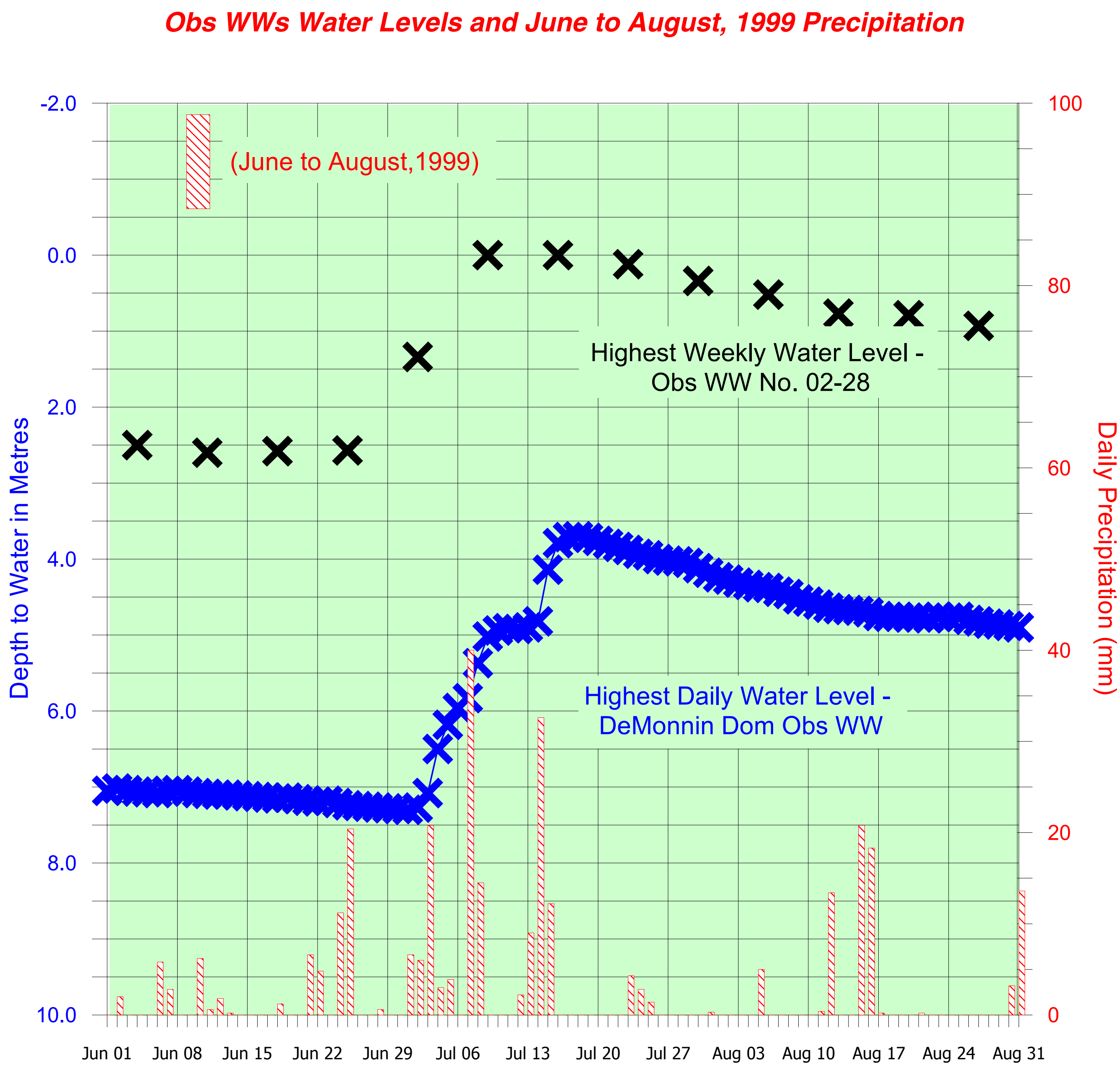


Water-Level Comparison - Obs WW No. 02-28



Obs WW No. 02-28 Measured Water Level and Early Summer Precipitation




Obs WWs Water Levels and June to August, 1999 Precipitation
(June to August,1999)
Highest Weekly Water Level -
Obs WW No. 02-28
Highest Daily Water Level -
DeMonnin Dom Obs WW
Depth to Water in Metres
Daily Precipitation (mm)
-2.0
0.0
2.0
4.0
6.0
8.0
10.0
100
80
60
40
20
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
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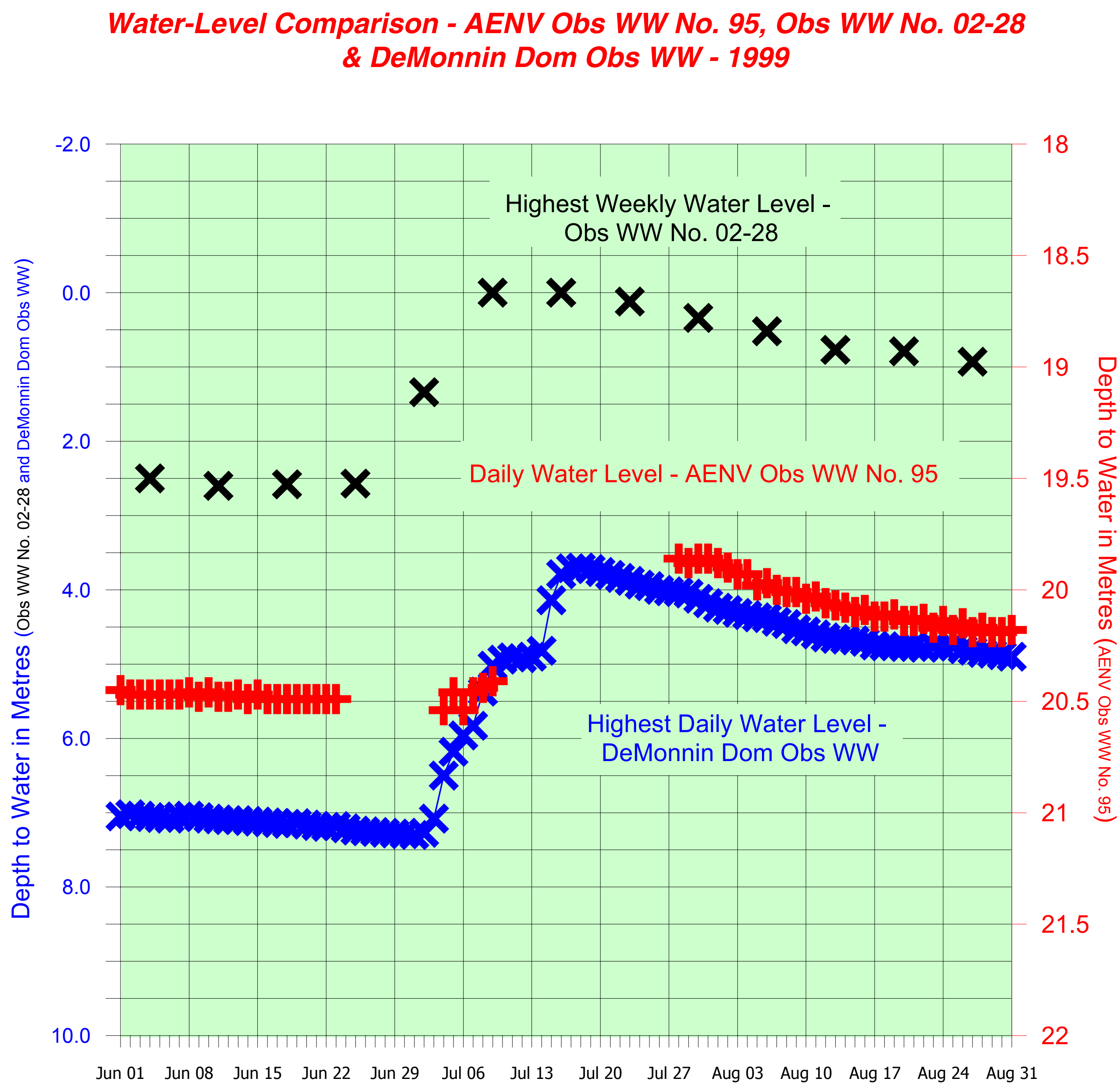
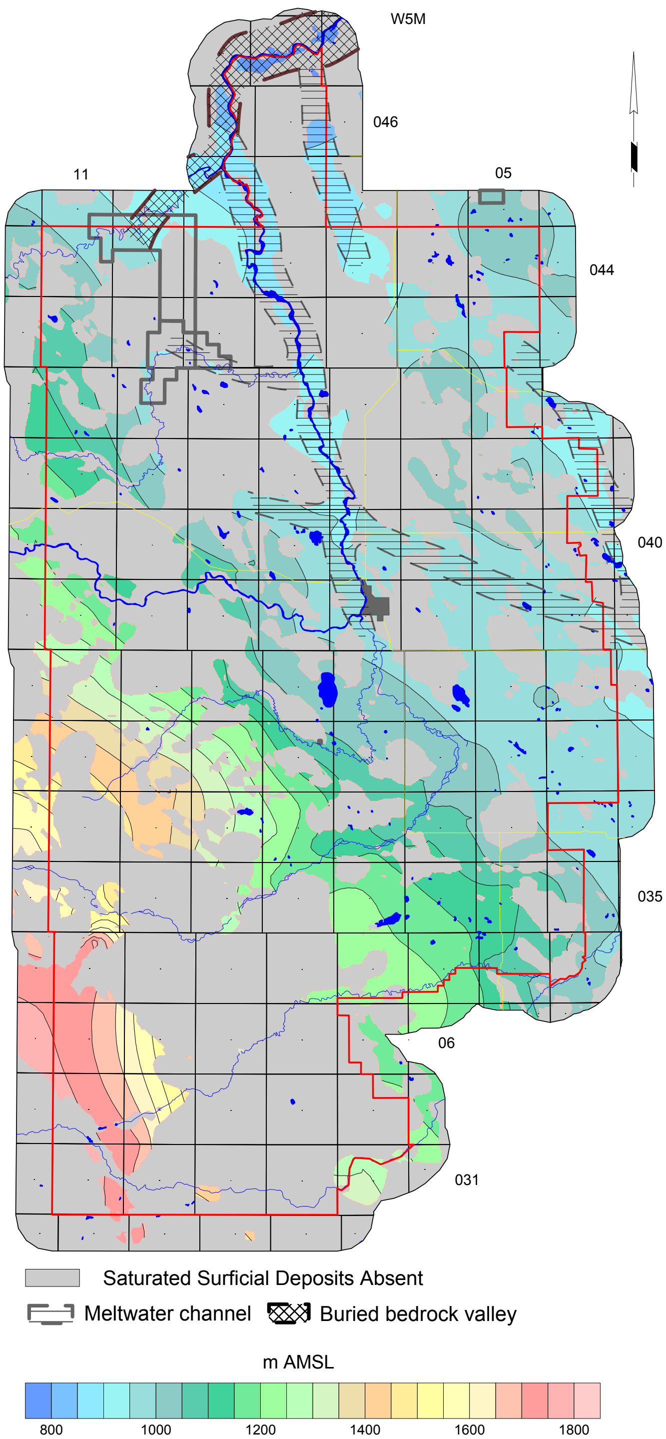
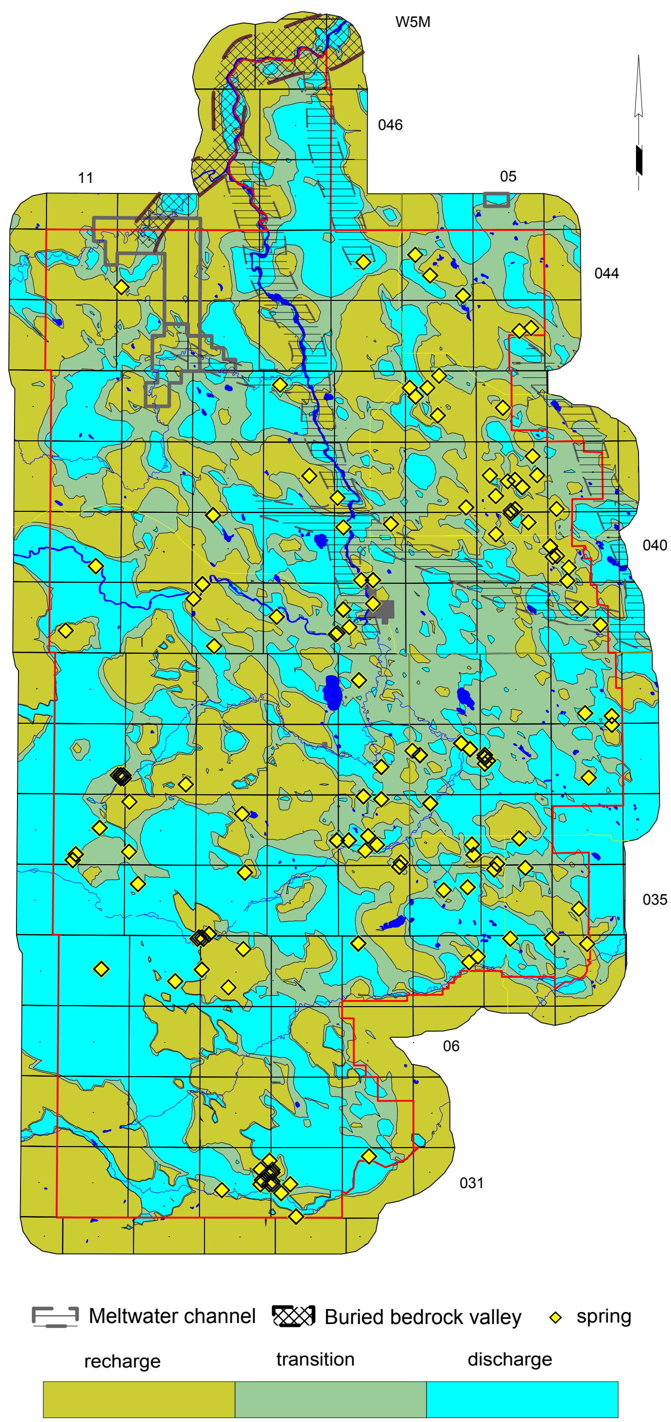
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31


Water-Level Comparison - AENV Obs WW No. 95, Obs WW No. 02-28 & DeMonnin Dom Obs WW - 1999
Highest Weekly Water Level - Obs WW No. 02-28
Daily Water Level - AENV Obs WW No. 95
Highest Daily Water Level - DeMonnin Dom Obs WW
Depth to Water in Metres (Obs WW No. 02-28 and DeMonnin Dom Obs WW)
Depth to Water in Metres (AENV Obs WW No. 95)
-2.0
0.0
2.0
4.0
6.0
8.0
10.0
18
18.5
19
19.5
20
20.5
21
21.5
22
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

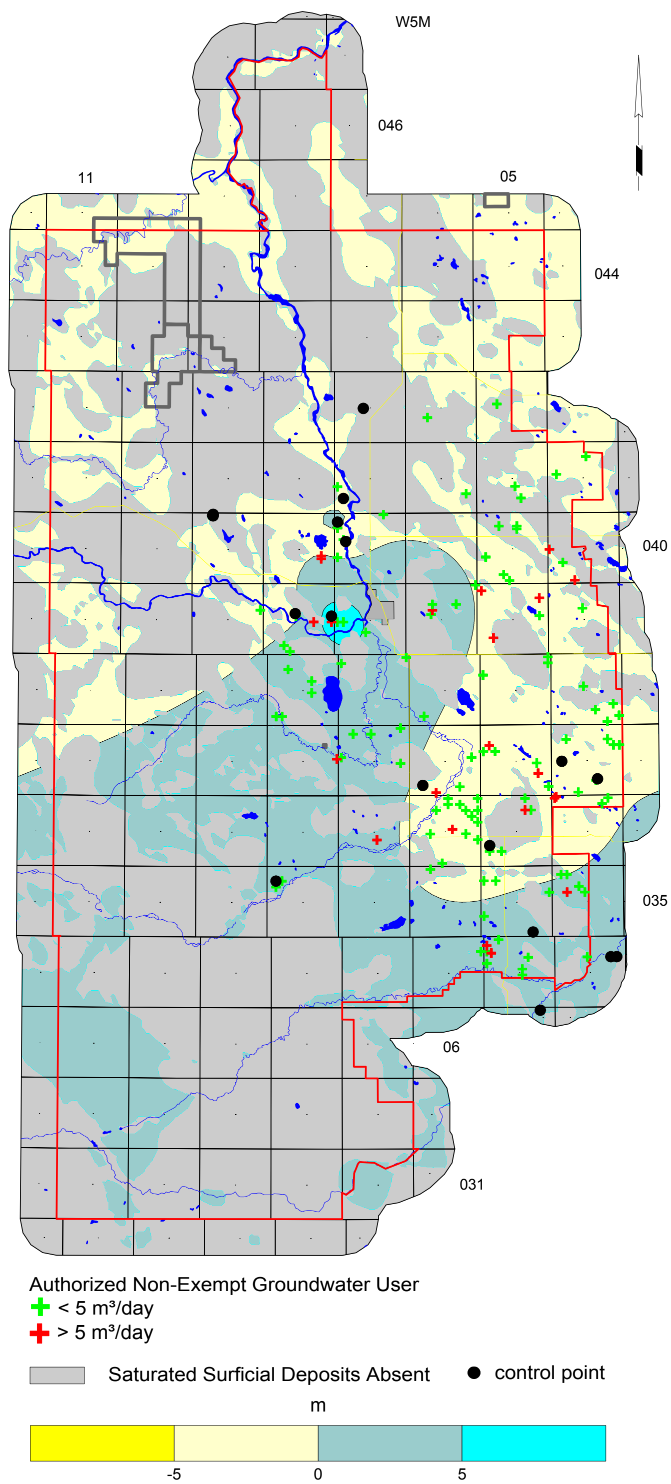
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



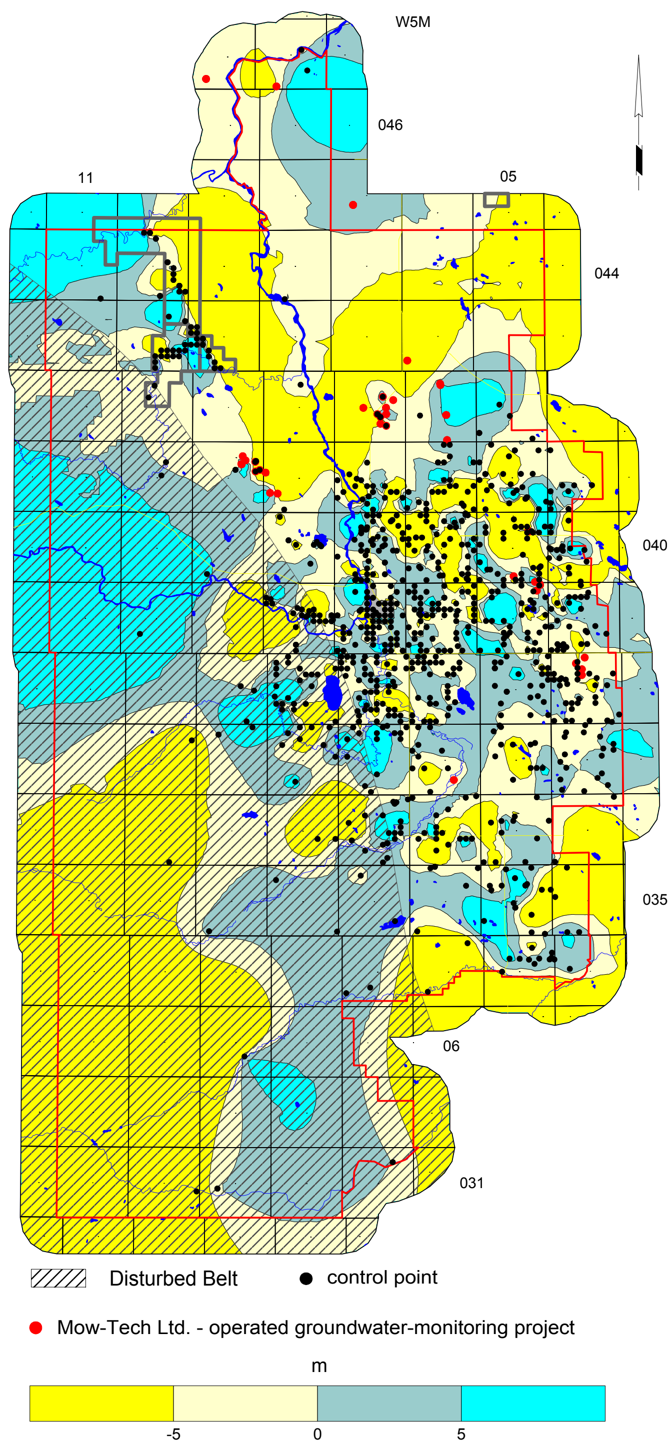
Bedrock Recharge/Discharge Areas



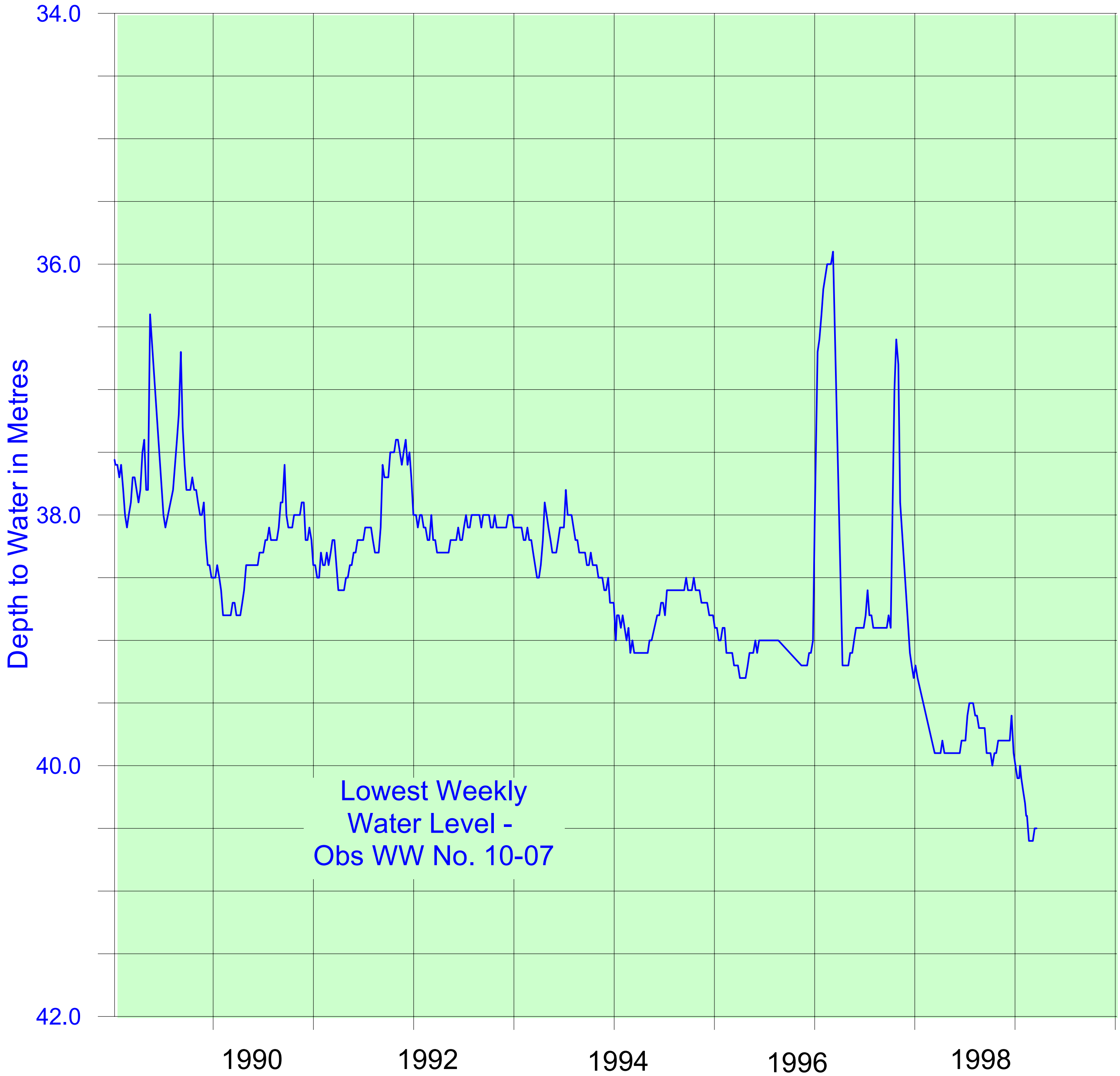
Changes in Water Levels in Surficial Deposits



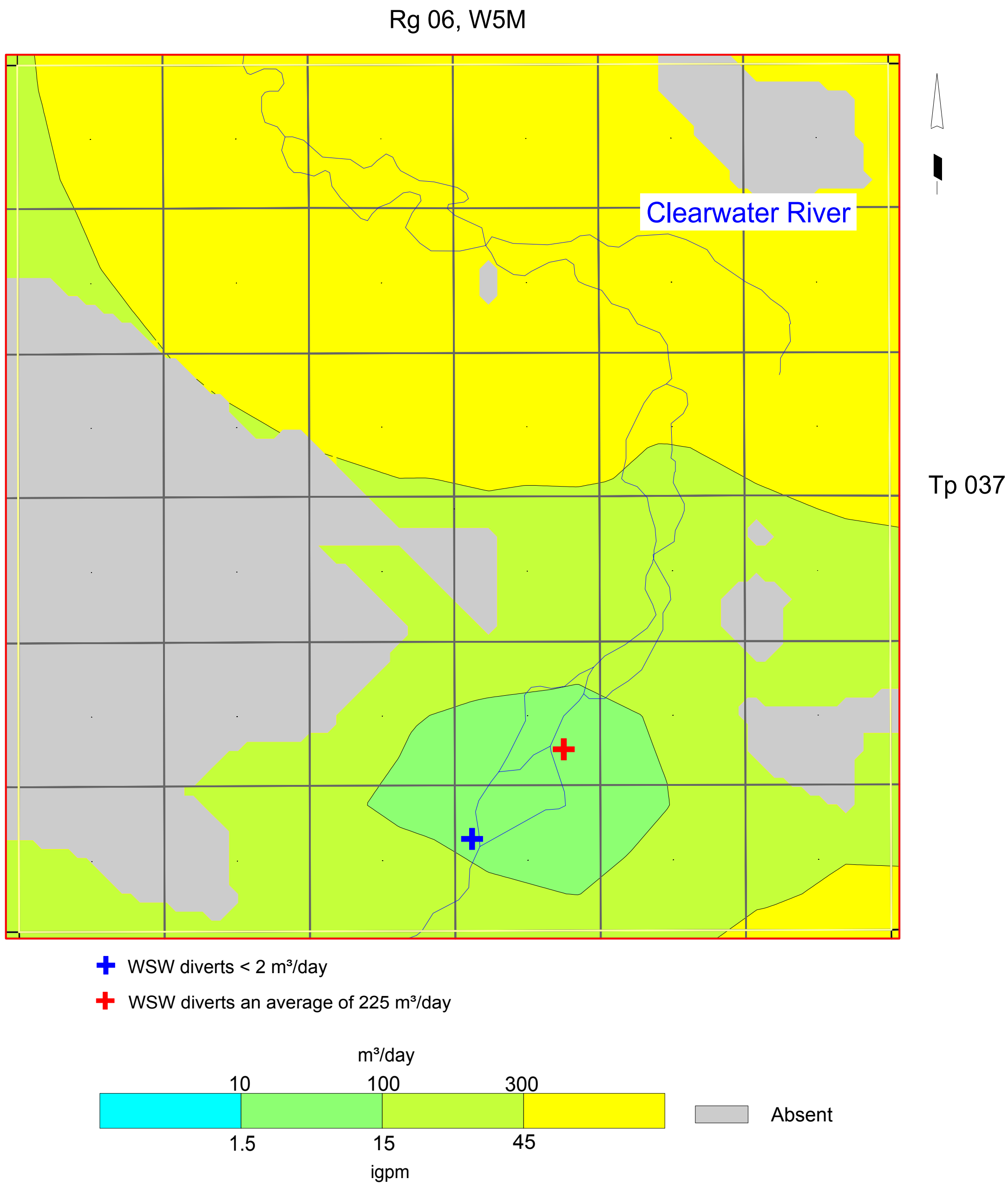
Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)



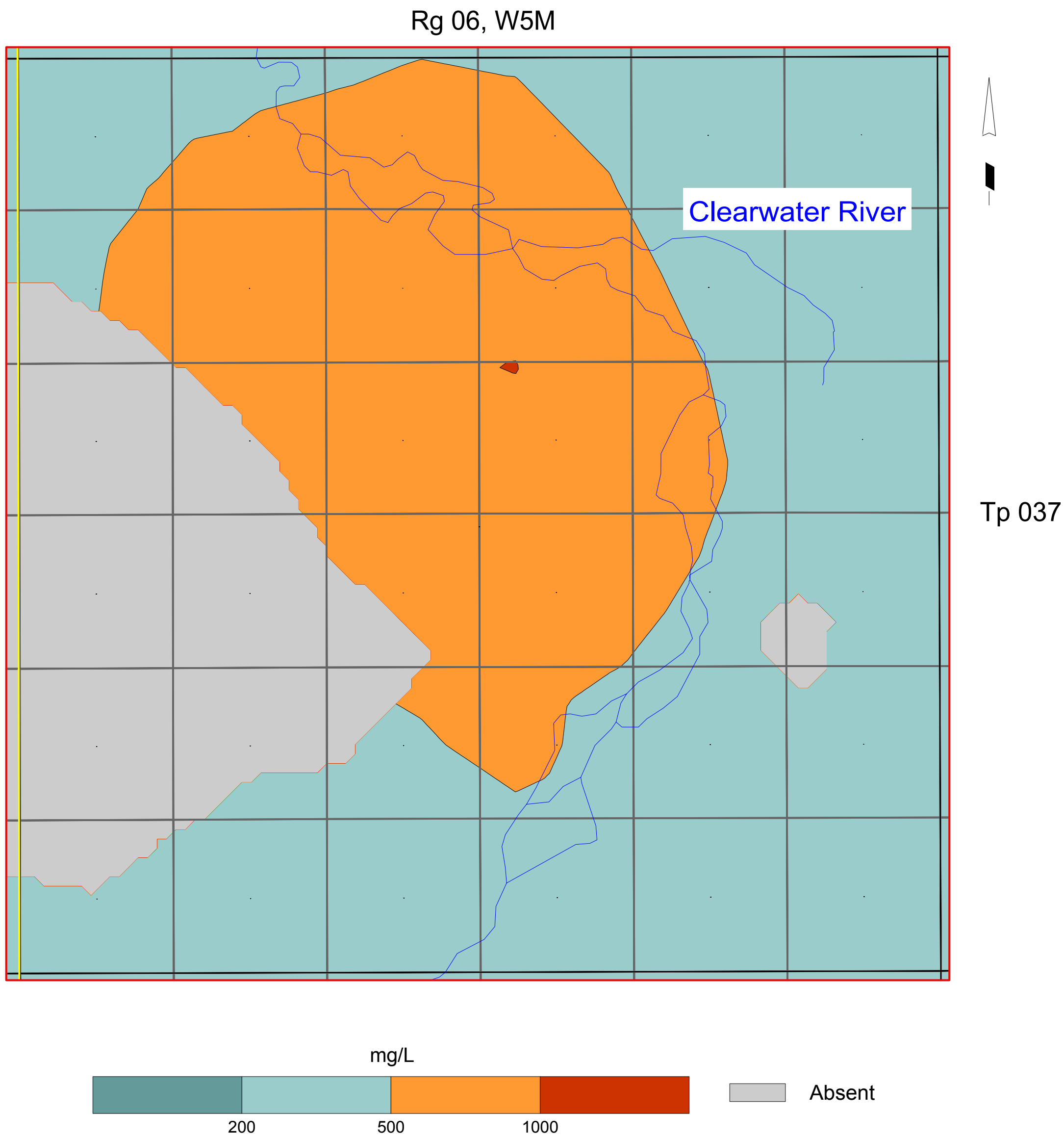
Water Levels in Obs WW No. 10-07



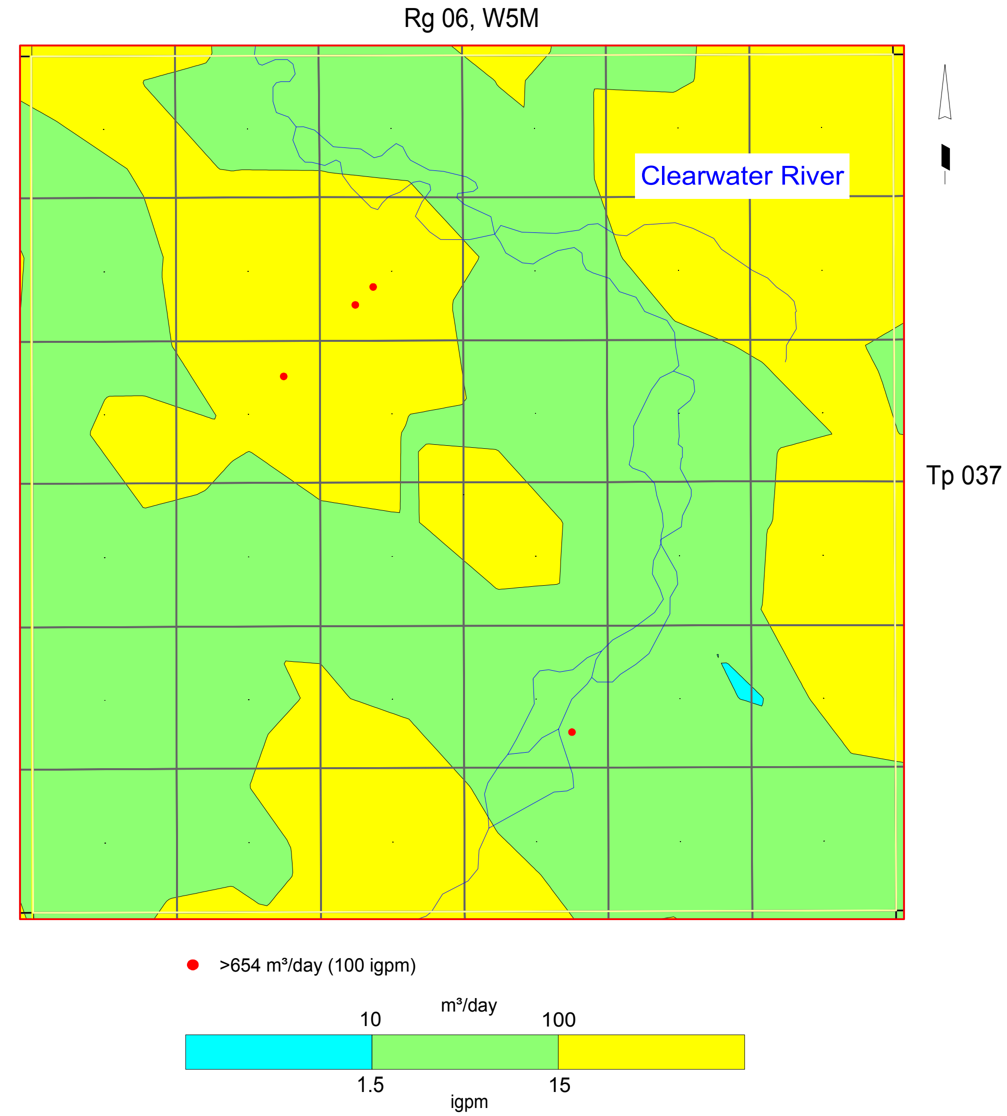
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) – Area 1



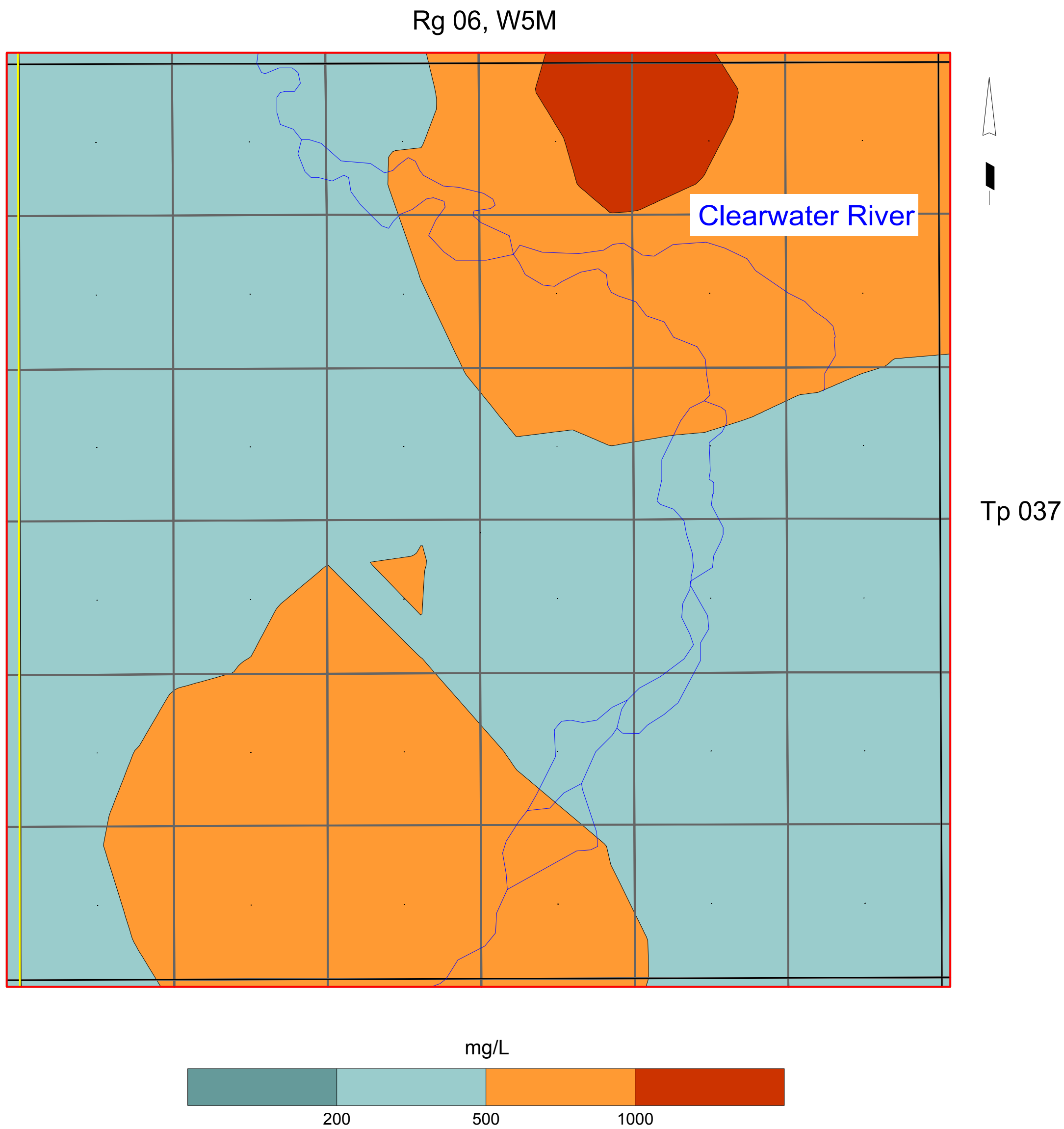
Total Dissolved Solids in Groundwater from Surficial Deposits – Area 1



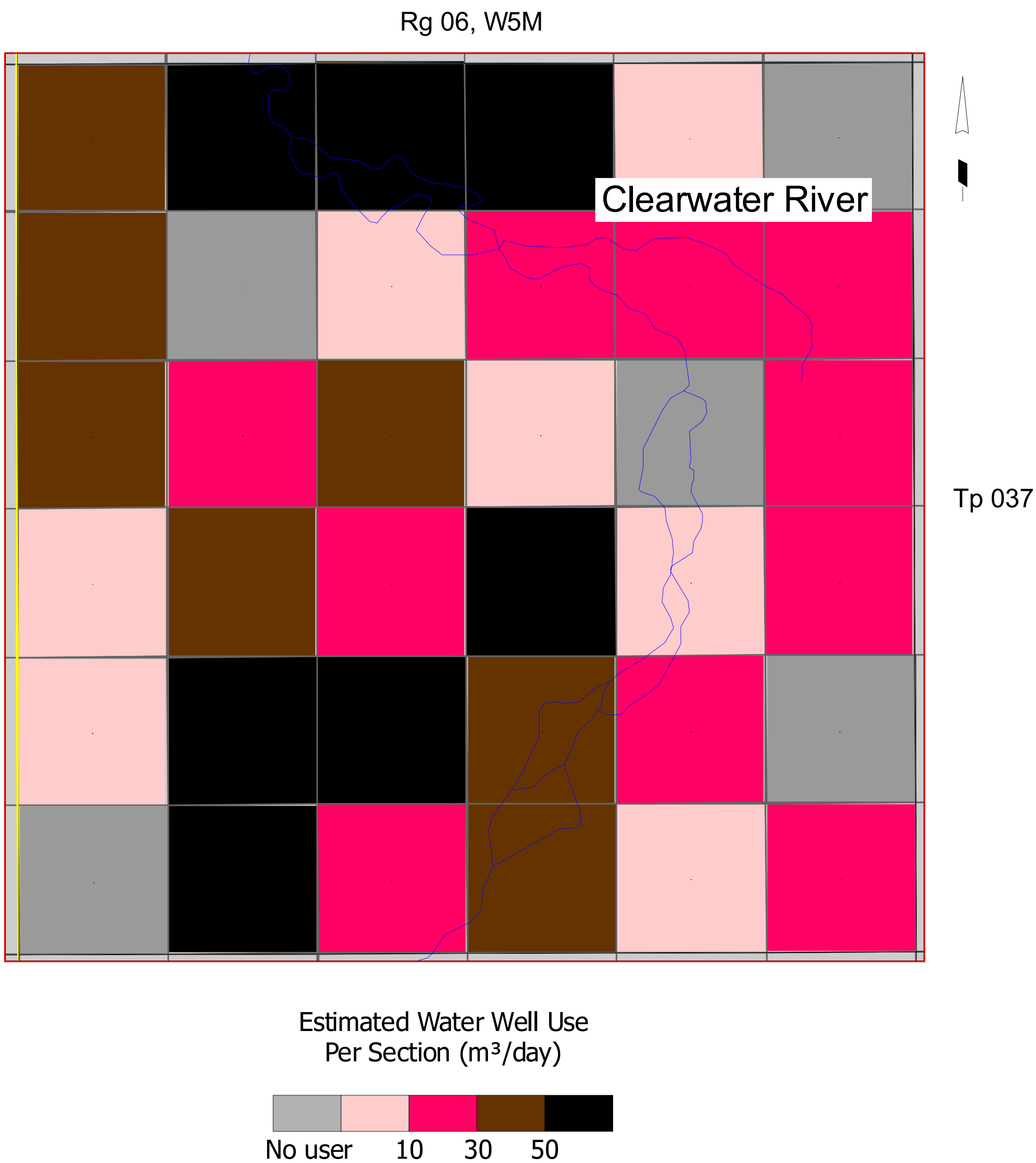
Apparent Yield for Water Wells Completed through Dalehurst Aquifer – Area 1



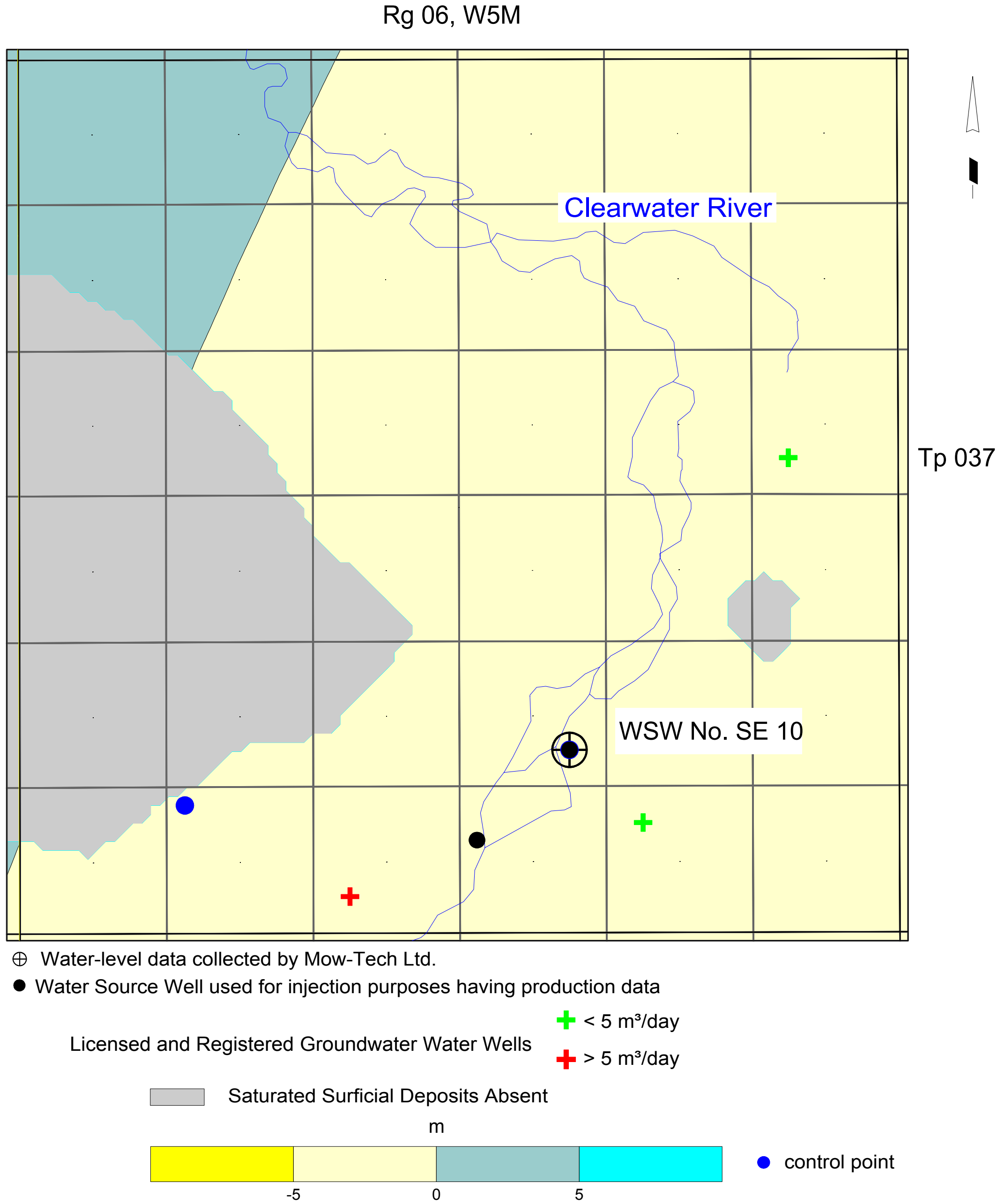
Total Dissolved Solids in Groundwater from Dalehurst Aquifer – Area 1



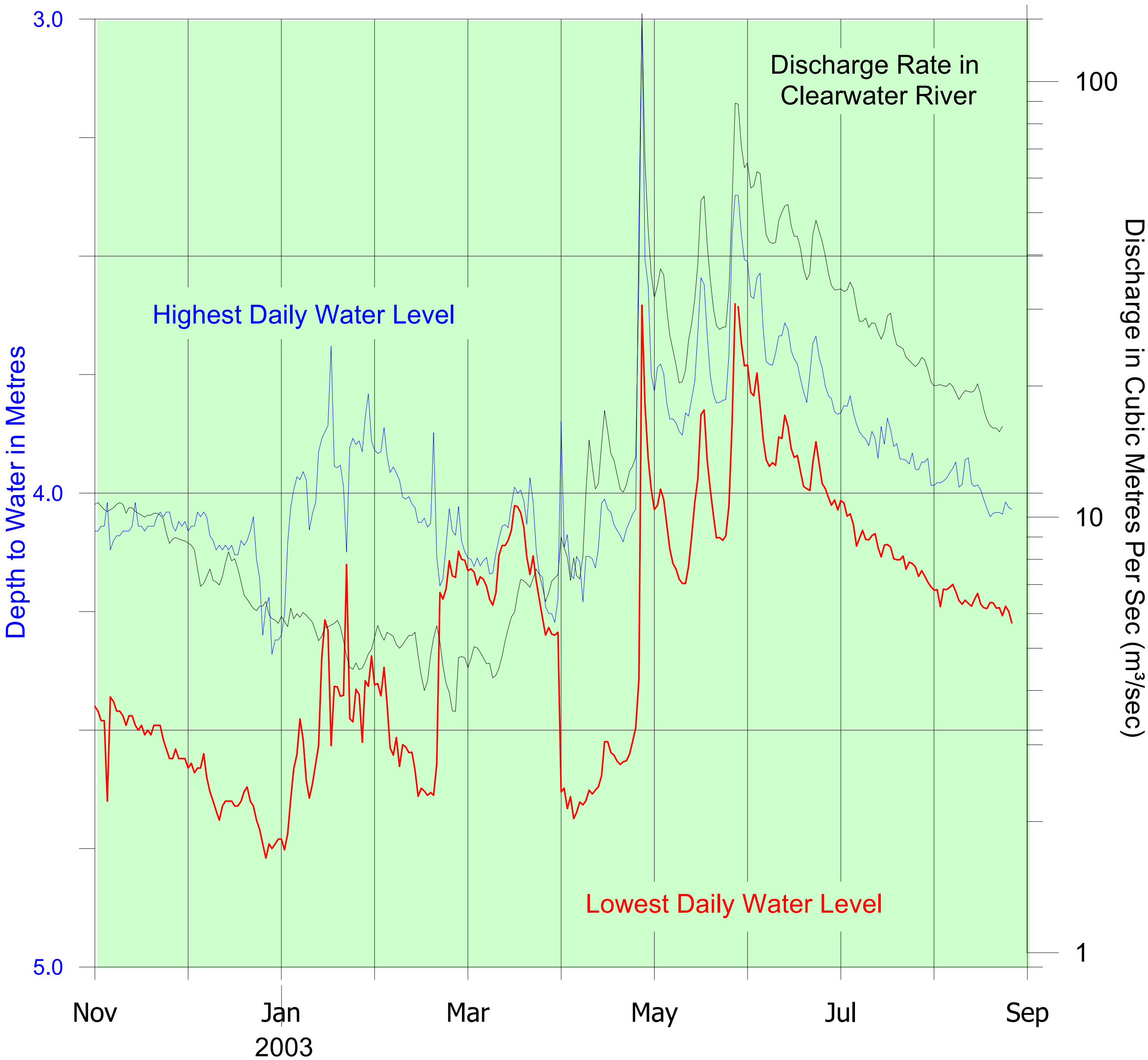
Estimated Water Well Use Per Section - Area 1



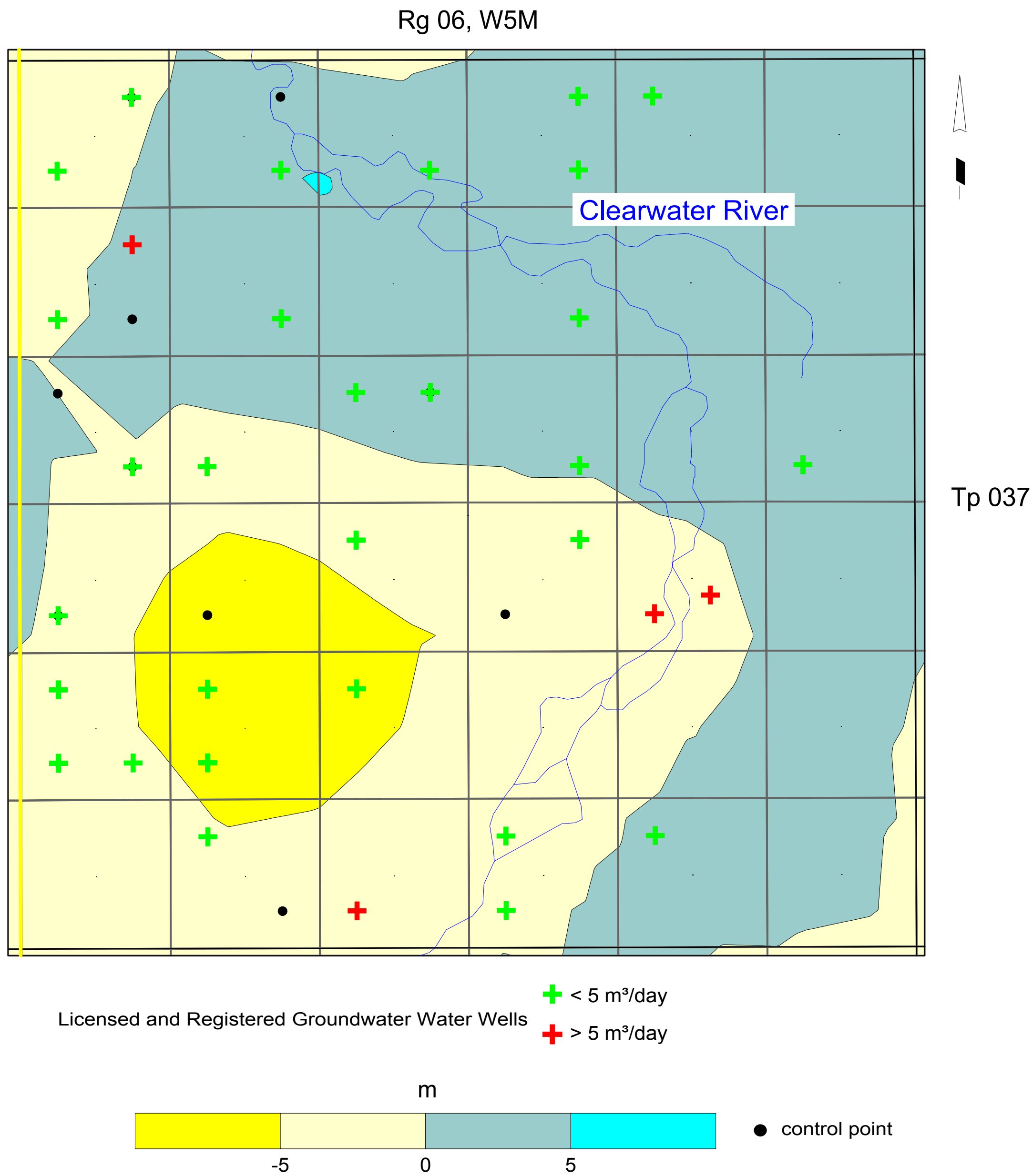
Changes in Water Levels in Surficial Deposits – Area 1



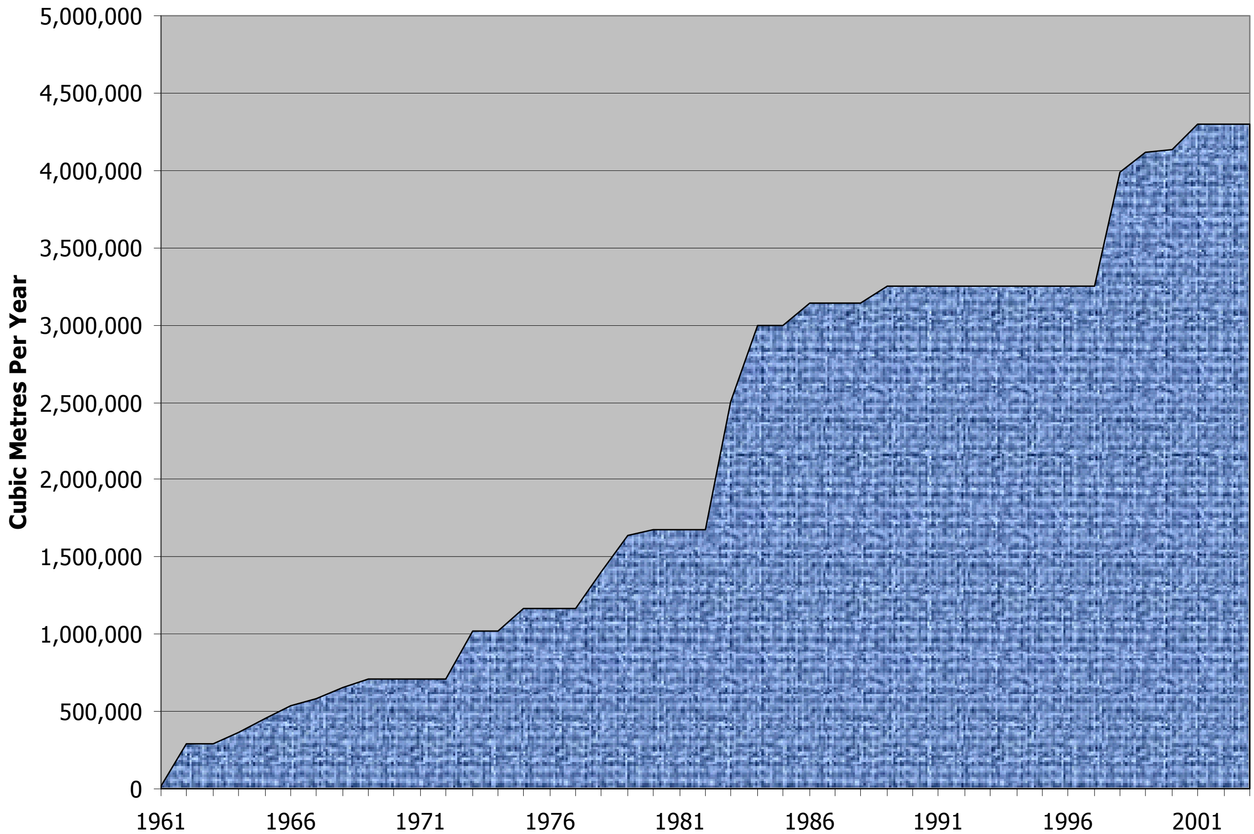
Discharge Rate in Clearwater River and Water-Level Measurements in WSW No. SE 10– Area 1



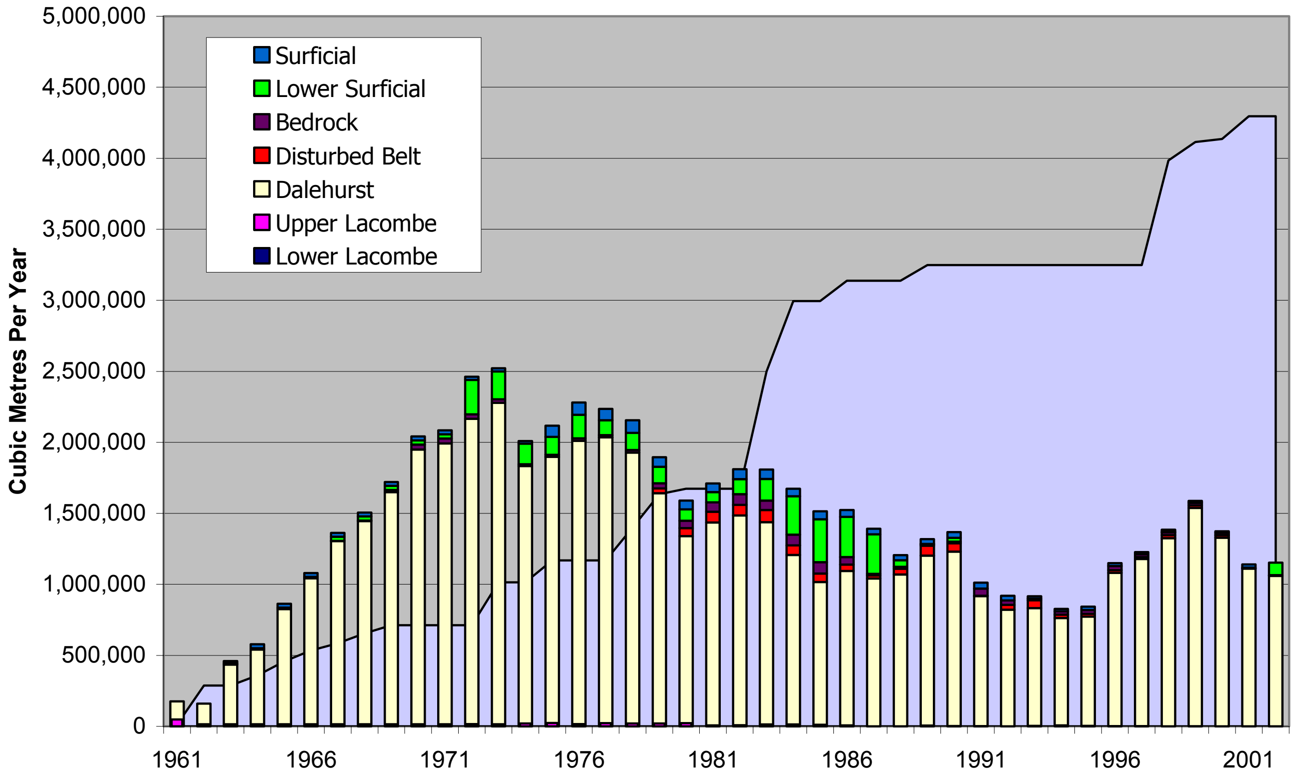
Areas of Potential Groundwater Depletion in Dalehurst Aquifer – Area 1



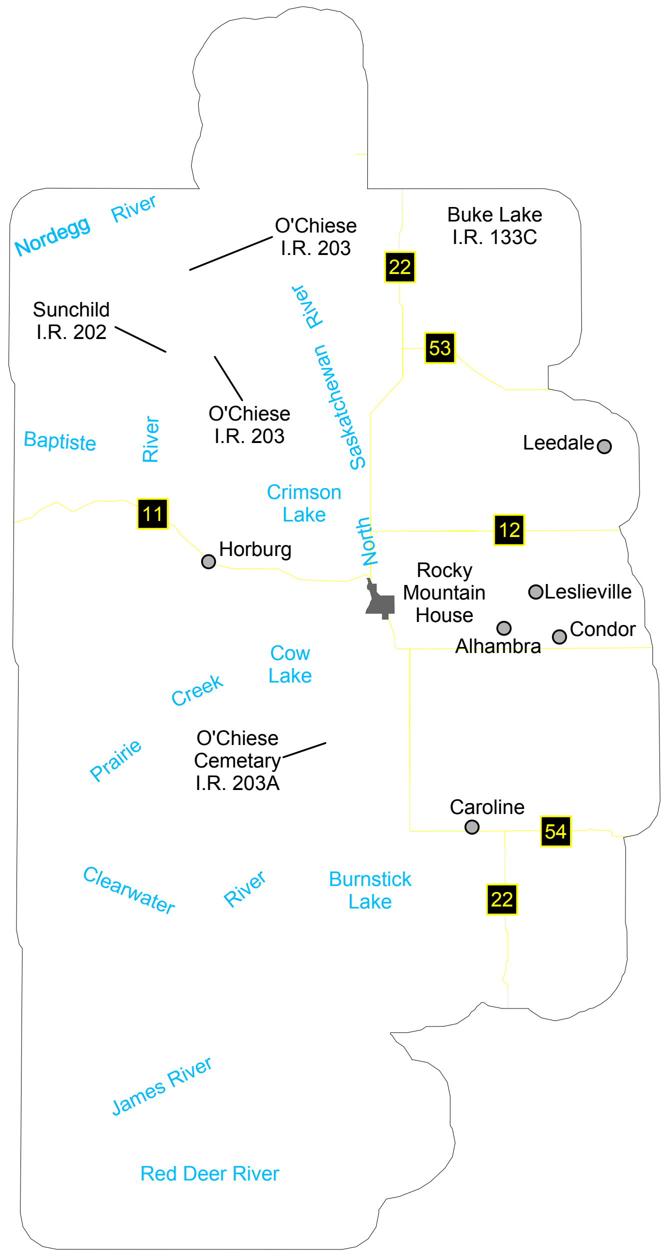
Licensed Groundwater Diversion for Injection Purposes



Licensed Groundwater Versus Reported Diversion



Overlay


Nordegg River
O'Chiese
I.R. 203
Buke Lake
I.R. 133C
22
Sunchild
I.R. 202
River
53
Saskatchewan
O'Chiese
I.R. 203
Baptiste
River
Leedale
Crimson
Lake
11
12
North
Horburg
Rocky
Mountain
House
Leslieville
Alhambra
Condor
Cow
Lake
Creek
O'Chiese
Cemetary
I.R. 203A
Prairie
Caroline
54
Clearwater
River
Burnstick
Lake
22
James River
Red Deer River

CLEARWATER COUNTY

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Licensed Groundwater Diversion for Injection Purposes
Licensed Groundwater Versus Reported Diversion

CLEARWATER COUNTY
Appendix C

General Water Well Information

Domestic Water Well Testing

Purpose and Requirements

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

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

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

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

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

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

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

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

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

Procedure

Site Diagrams

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

Surface Details

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

Groundwater Discharge Point

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

Water-Level Measurements

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

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

Discharge Measurements

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

Water Samples

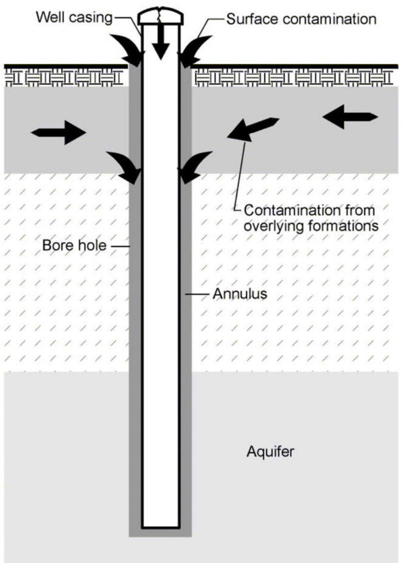
A water sample must be collected between the 4- and 6-minute water-level measurements, whenever there is an observed physical change in the groundwater being pumped, and 10 minutes before the end of the planned pumping interval. Additional water samples must be collected if it is expected that pumping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

Plugging Abandoned Wells

Adapted from Water Wells that Last Generations (PFRA 2000)

For more information refer to the Water Wells That Last video series Part II — Managing and Maintaining.

Figure 1 Well Contamination



Wells that are no longer being used should be plugged. They are a serious public safety and environmental hazard.

Plugging Abandoned Wells

When a well is no longer being used or maintained for future use, it is considered abandoned. Abandoned wells pose a serious threat to the preservation of groundwater quality. They are also a serious safety hazard for children and animals.

There are approximately 59,000 farmsteads in Alberta and most of these have at least one well. In addition there are a great number of non-farming rural residents that rely on water wells. The exact number of abandoned wells in Alberta is unknown but is estimated to be in the tens of thousands. Plugging an abandoned well prevents:

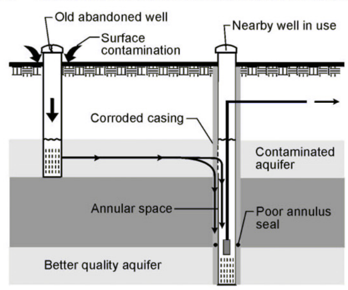
- Downward movement of water in the well or well annulus
- Surface contamination from reaching aquifers
- Intermixing of water between aquifers of different water quality
- Serious accidents from happening.

Unfortunately, groundwater contamination and its effects are usually not recognized until groundwater quality is seriously affected and nearby wells have been contaminated. Surface contaminants can enter a well several ways:

- Directly through the surface opening if the cap is loose, cracked or missing
- Through unsealed spaces along the outside of the casing (see Figure 1, Well Contamination).

When the steel casing of an abandoned well starts to corrode, holes will develop. When this takes place, surface contaminants or poor quality water from shallow aquifers may migrate into the deeper aquifers of nearby operating wells (see Figure 2, Contamination From an Abandoned Well).

Figure 2 Contamination From an Abandoned Well



Who is Responsible?

In Alberta, responsibility for plugging a water well is defined by legislation. The well owner is responsible for plugging the well when:

- The well is no longer being used as a water supply
- The well is in a poor state of repair and the pumping equipment has been removed or cannot be repaired or replaced
- The well produces water that is unsuitable for drinking.

The drilling contractor is legally responsible for immediately plugging a well when it is not completed due to construction problems or inadequate yield. Before you sign a contract with a driller, ask questions about what materials are going to be used to plug the well and associated costs.

It is generally best to hire a drilling contractor to complete the plugging of your well. This person has the expertise and equipment to do a proper job. Unless you use the right plugging materials and have them properly placed in the well, you will end up with a poorly sealed well that will continue to allow contaminants to enter into the groundwater. When a replacement well is drilled, your old well should be immediately plugged.

Process of Plugging a Well

There are several steps to take before actually plugging the well. Some steps you will be able to do yourself and others you may want to consult with, or hire, a drilling contractor to complete.

Preparation

For information on how to take a non-pumping water level measurement, see Module 5 "Monitoring Your Water Well."

To know exactly how much plugging material is needed, measure the total depth and diameter of the well, plus the non-pumping water level (the depth to the standing water in the well). If possible, compare these measurements to the information on the drilling report from when the well was originally constructed. The only time you should even consider plugging a well yourself is when the well is open to its original depth.

Ideally the casing should be removed from the well before the plugging process begins. Often only the liner casing is removed and the surface casing is left intact because it is more difficult to remove and it could separate down hole. The older the well, the more difficult it will be to successfully remove the casing. If the casing is left in place, it should be perforated, particularly if there is evidence of water movement in the annulus of the well. Any casing left in place must be cut off 0.5 m (20 in.) below ground surface after the well is plugged.

Materials

Materials that are used to plug a well must be uncontaminated and impervious. They must prevent any movement of water. See the chart below for acceptable and unacceptable materials.

Cement grout and concrete may shrink after setting so may not create as good a seal as bentonite.

Sand and gravel are not acceptable materials. They are not impervious materials because water can easily move through them.

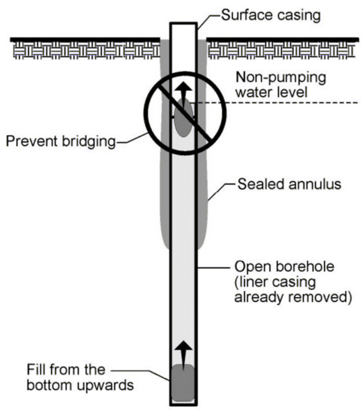
Acceptable Materials	Unacceptable Materials
• grout - neat cement (cement mixed with water) - sand cement (cement, sand and water)	sand
• concrete (cement, sand and aggregate mixed with water)	gravel
• manufactured high yield bentonite products	drilling mud or fluid
• clean, uncontaminated clay (for large diameter wells)	

High yield bentonite is a special type of clay that swells when wet to provide a very effective impervious seal. It comes in a powder that when mixed with water produces a slurry that can be pumped into the well. It is also manufactured in pellet or granular form that is designed to pour into the well. This type of bentonite when mixed with water will actually swell to about eight times its original size and will form a water-tight plug.

It is important to understand that bentonite cannot be used as a plugging material in some situations. When the chloride level in the well water is greater than 4000 mg/L, or the calcium level is greater than 700 mg/L, bentonite will not swell properly, so then it is best to use a cement grout.

Large diameter or bored wells pose special problems because of their size and volume of material required to fill them. A lower cost alternative for the plugging material is clean, uncontaminated clay that can be shovelled into the well until it is filled. This must be done carefully, however, to ensure the clay reaches the bottom of the well and seals off all empty space. The cribbing must be cut off below ground surface and the well topped up with high yield bentonite to make a water-tight seal.

Figure 3 Bridging



Method

Aside from choosing the appropriate plugging material, the method of placing material into the well is most critical. Regulation requires that the plugging material must be introduced from the bottom of the well and placed progressively upward to ground surface.

If the plugging material is cement grout, concrete or bentonite slurry, special equipment is needed. The material must be placed into the well through a tremie pipe that is usually about 3 in. in diameter. At all times this pipe must be kept below the surface of the plugging material to prevent it from diluting or separating. It is recommended that you hire a drilling contractor when a slurry is chosen as the plugging material because the drilling contractor will have the proper equipment and experience to do the job correctly.

When bentonite pellets are chosen for the plugging material, they can be poured into the well from the ground surface. These pellets have a weight material added to help them sink to the bottom of the hole. They are also coated to prevent immediate swelling on contact with water. When poured slowly, they should reach the bottom of the well before swelling. If you are not careful, however, these pellets will bridge off down hole and the well will be only partially plugged (see Figure 3, Bridging).

Before you pour in the pellets, you can determine how many feet of well casing can be filled with the size of pellets you have chosen. As the well is being filled, measure the depth to the top of the plugging material quite frequently. Then you will know if the plug is rising faster than expected indicating a bridge has formed. If this happens, be sure to break it up before adding more material to the well.

Steps to Plugging a Well

By regulation, a well must be filled full length with impervious material. That material must be introduced into the well at the bottom and be placed progressively upward to ground surface.

Step 1 Remove all pumping equipment from the well. Thoroughly flush out the well using a bailer or air compressor.

Step 2 Measure the total depth of the well, the diameter and the non-pumping water level. If possible, compare these figures with the information on the original drilling report. Confirm whether the well is open to its original depth.

Step 3 Use these figures to decide which plugging material is appropriate and how much you will need. A drilling contractor can help you decide. Whether or not the casing can be successfully pulled out will also determine which material to use and what method is appropriate for placing it into the well. If the casing cannot be removed, choose a slurry that can be pumped under pressure into the well so that any space around the outside of the casing will also get filled in.

Step 4 Disinfect the well. Add enough chlorine to bring the water standing in the well to a chlorine concentration of 200 mg/L. For every 450 L (100 gal.) of water in the well, add 2 L (.4 gal.) of household bleach (5.25% chlorine). See Module 6 "Shock Chlorination—Well Maintenance" to calculate how much water is in your well. Leave this chlorine in your well.

Step 5 If possible, remove the well casing.

Step 6 Place the plugging material into the well. It must be introduced at the bottom of the well and placed progressively upwards to ground surface. The only exception to this rule is when the plugging material being used is a bentonite pellet that has been designed and manufactured for pouring into the well from the ground surface.

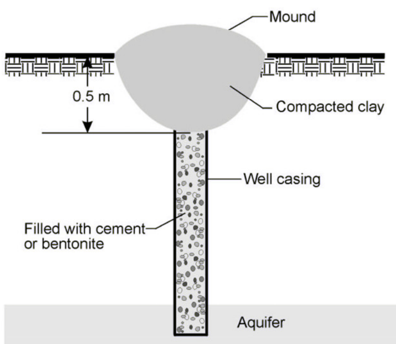
Step 7 If the casing was not already removed, dig around it and cut it off a minimum of 0.5 m (20 in.) below the ground surface (see Figure 4, Cutting Off the Casing and Mounding the Clay).

Step 8 Backfill and mound this portion of the hole with material appropriate for intended use of the land (i.e., clay) (see Figure 4, Cutting Off the Casing and Mounding the Clay).

Step 9 Use the worksheet at the end of this module to record the details of your well plugging. Include the well owner name, location, total depth, casing diameter, type and amount of plugging material used, date and method of placing material into the well. Send a copy of this record to:

Alberta Environment
Groundwater Information Centre
10th Floor, Oxbridge Place
Edmonton, Alberta T5K 2J6

Figure 4 Cutting Off the Casing and Mounding the Clay



Special Problems

Flowing wells present special problems for plugging. It is highly recommended that you use the services of a drilling contractor. Before a flowing well can be plugged, the flow must be controlled. Several methods can be used.

- Reduce the flow by pouring high specific gravity fluids such as drilling mud or cement into the well.
- If there is a nearby well that is tapped into the same aquifer as the flowing well being plugged, pump it to create a drawdown in the well being plugged.
- Where practical, extend the well casing high enough above the ground surface to stop the flow.

Worksheet

For future reference, use the "Record of Well Plugging" worksheet to record the date of plugging, materials and procedures used. Also mark or map the location of this plugged well for future reference. A sample copy is included at the back of this module. Working copies are included in the pocket on the back cover. Keep the worksheet in the back pocket.

Worksheet

Record of Well Plugging

Alberta ENVIRONMENT

Original landowner's name:_______________ Date of plugging:_______________

Legal land location of well: Qtr ______ Sec ______ Twp ______ Rge ______ W of ___ Meridian
Lot ______ Blk ______ Plan ______

Location reference points on the farm (i.e., distance from buildings):_______________

Current well depth: ______ Original well depth: ______ Well diameter: ______

Was well casing removed before plugging? _______________

Water characteristics: (attach any analysis done)

Reason for plugging the well: _______________

Type and quantity of plugging material used: _______________

How was material placed into the well? _______________

Who completed the procedure? _______________

Mail a copy of this worksheet to Alberta Environment, Groundwater Information Centre. Include a copy of the original drilling report if possible.

Alberta Environment
Groundwater Information Centre
10th Floor, Oxbridge Place
Edmonton, Alberta T5K 2J6

* **Working copies are included in the pocket on the back cover.**

Water Act - Water (Ministerial) Regulation

PROVINCE OF ALBERTA

WATER ACT

WATER (MINISTERIAL) REGULATION

Alberta Regulation 205/98

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

Table of Contents

Chemical Analysis of Farm Water Supplies

Adapted from Agdex 716 (D04) Published April 1991

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

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

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

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

Water Quality Criteria

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

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

Sodium

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

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

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

Potassium

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

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

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

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

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

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

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

The concentration in livestock water should not exceed 10 ppm.

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

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

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

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

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

Conductivity

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

pH

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

Hardness

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

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

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

Alkalinity

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

Water Treatment

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

Helpful Conversions

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

References

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

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

Additional Information

VIDEOS

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

BOOKLET

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

ALBERTA ENVIRONMENT

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

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

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

WATER WELL LICENSING
Alan Hingston (Edmonton: 780-427-6429) - http://www3.gov.ab.ca/env/regions/central/

GEOPHYSICAL INSPECTION SERVICE
Edmonton: 780-427-3932

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

GENERAL LICENSING INQUIRIES
Lethbridge: 403-381-5392

UNIVERSITY OF ALBERTA – Department of Earth and Atmospheric Sciences - Hydrogeology
Carl Mendoza (Edmonton: 780-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology
Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE
Dean Lien (Edmonton: 780-427-2433)

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

Glen Brandt (Red Deer: 403-340-4248) - brandtg@agr.gc.ca
Terry Dash (Calgary: 403-292-5719) - dasht@agr.gc.ca

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

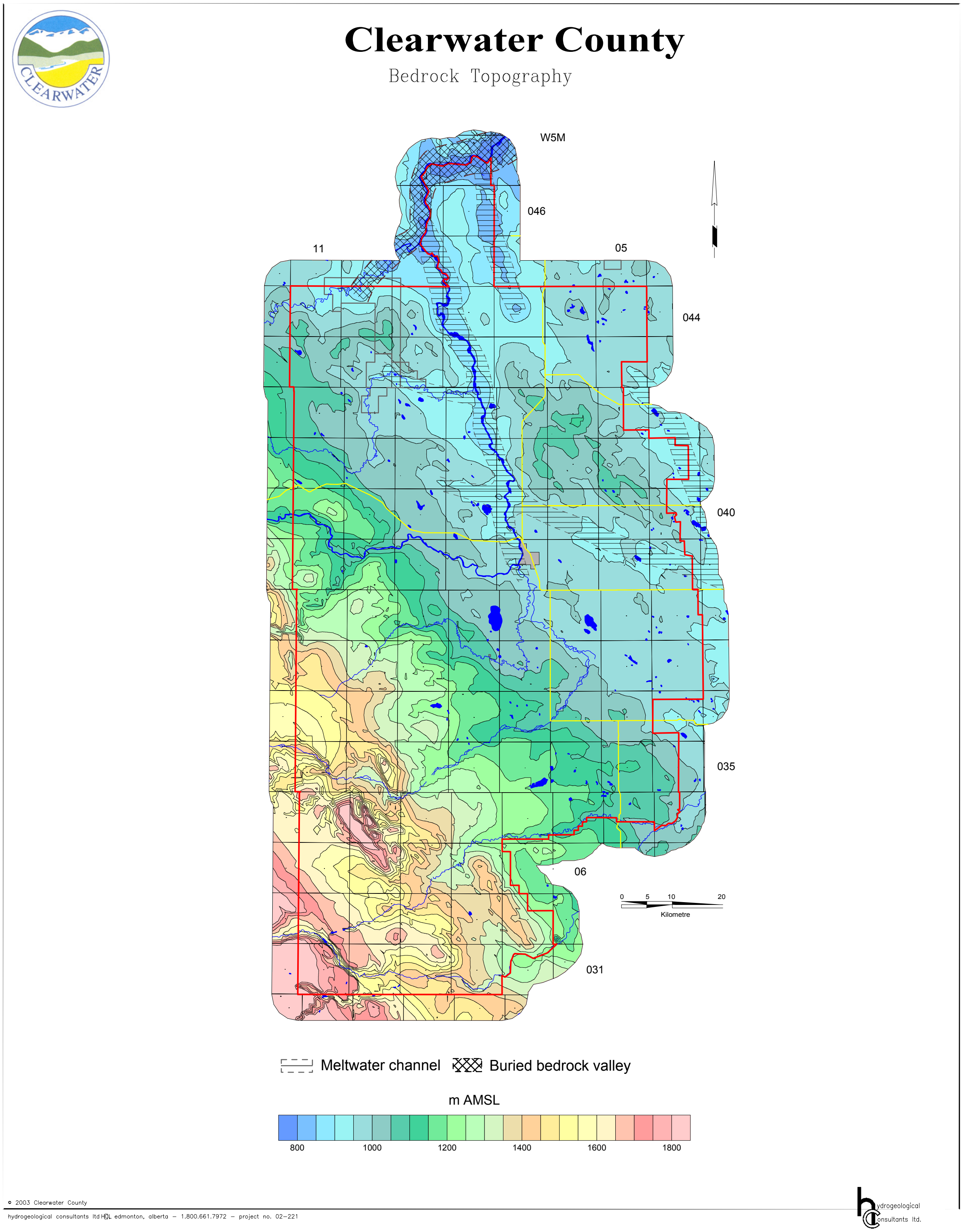
LOCAL HEALTH DEPARTMENTS

CLEARWATER COUNTY

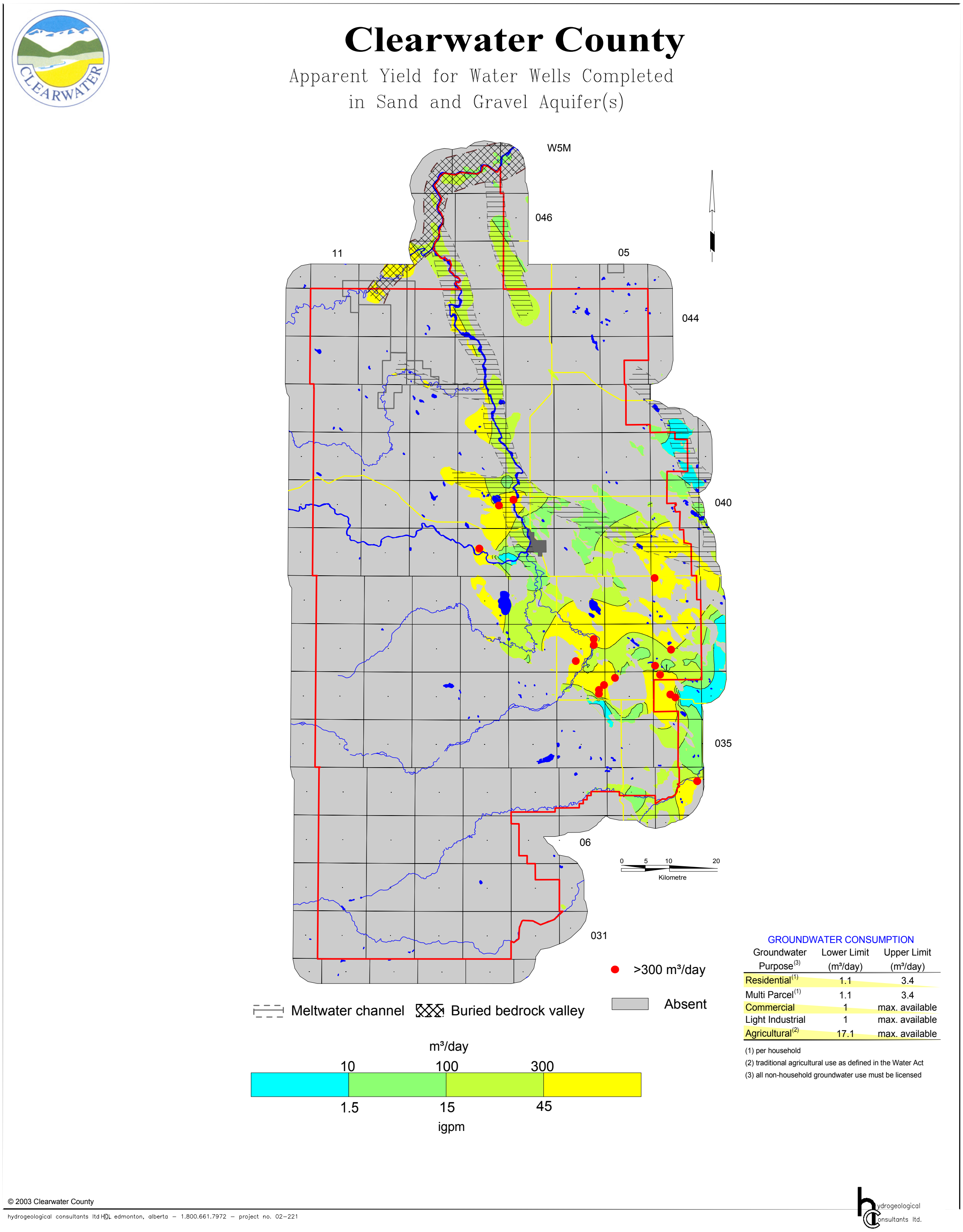
Appendix D

Maps and Figures Included as Large Plots

Bedrock Topography



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

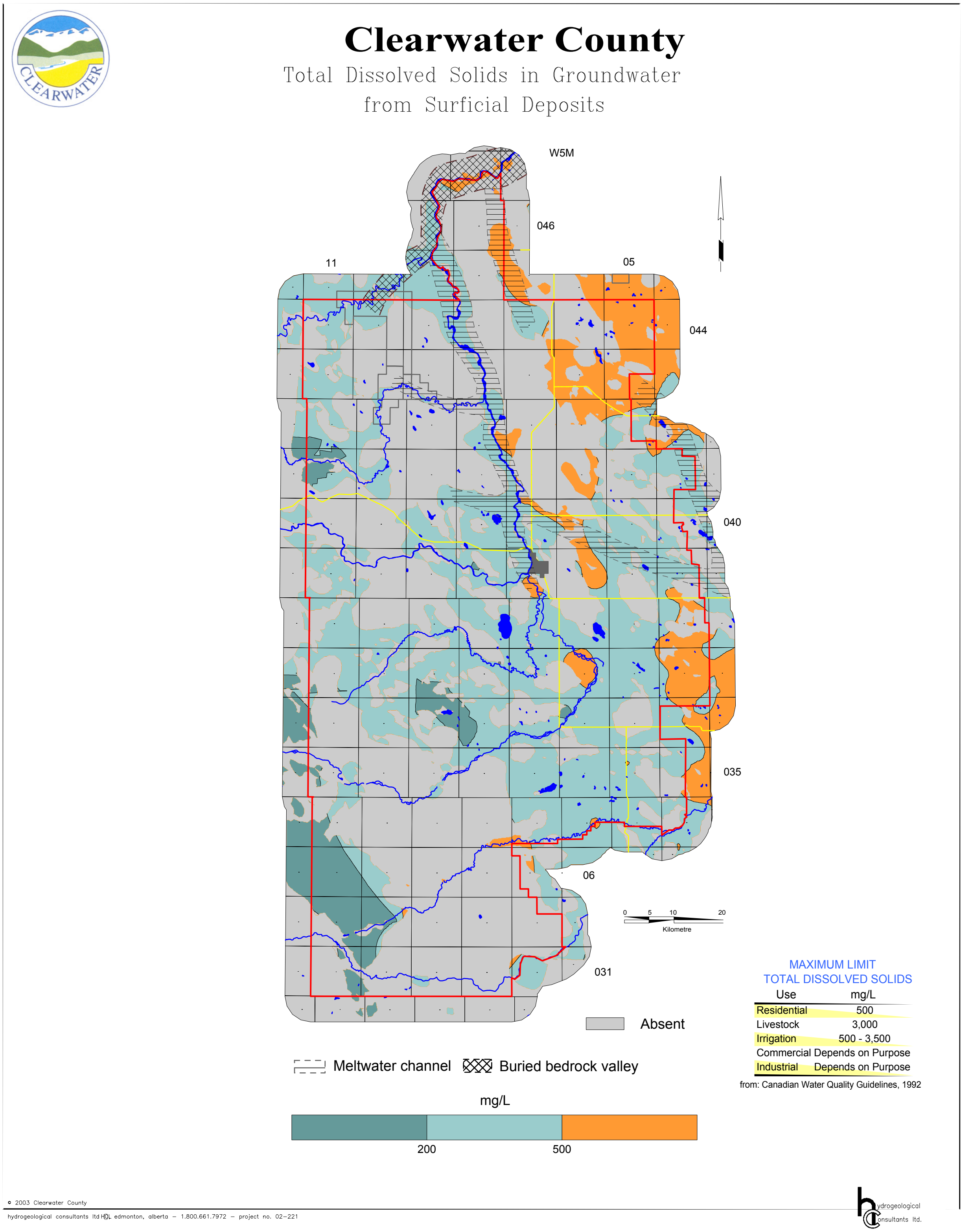


GROUNDWATER CONSUMPTION

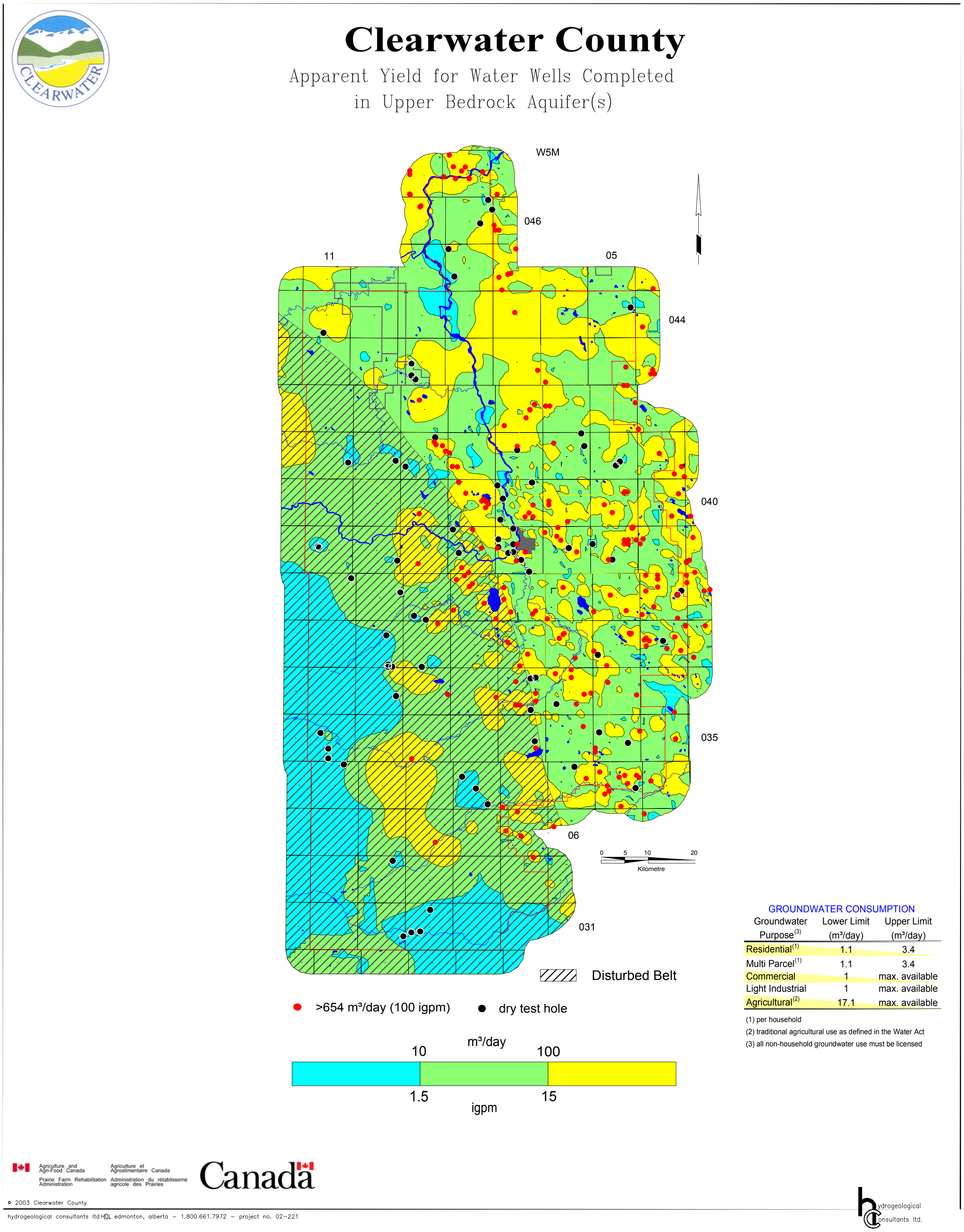
Groundwater Purpose(3)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential(1)	1.1	3.4
Multi Parcel(1)	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural(2)	17.1	max. available

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

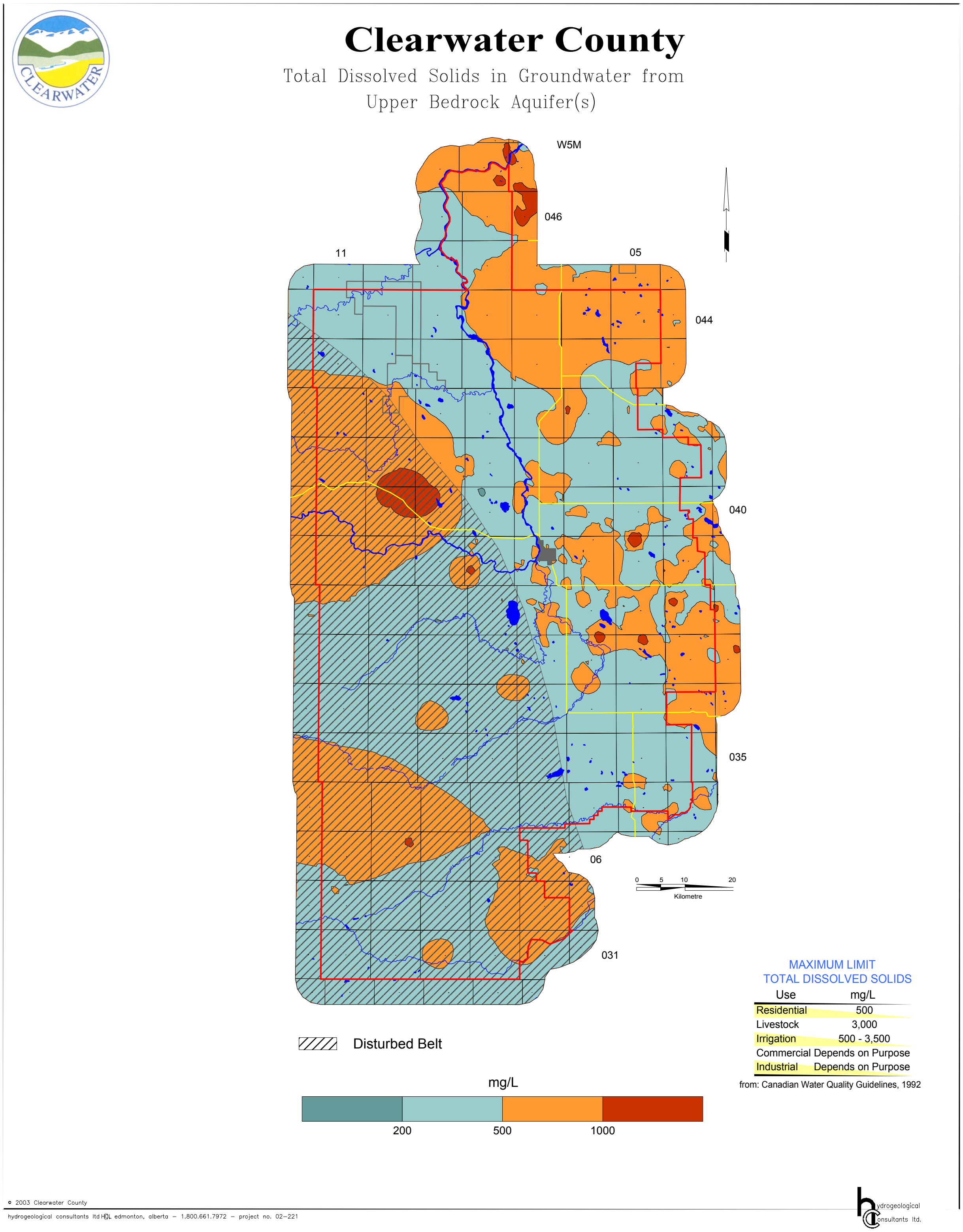
Total Dissolved Solids in Groundwater from Surficial Deposits



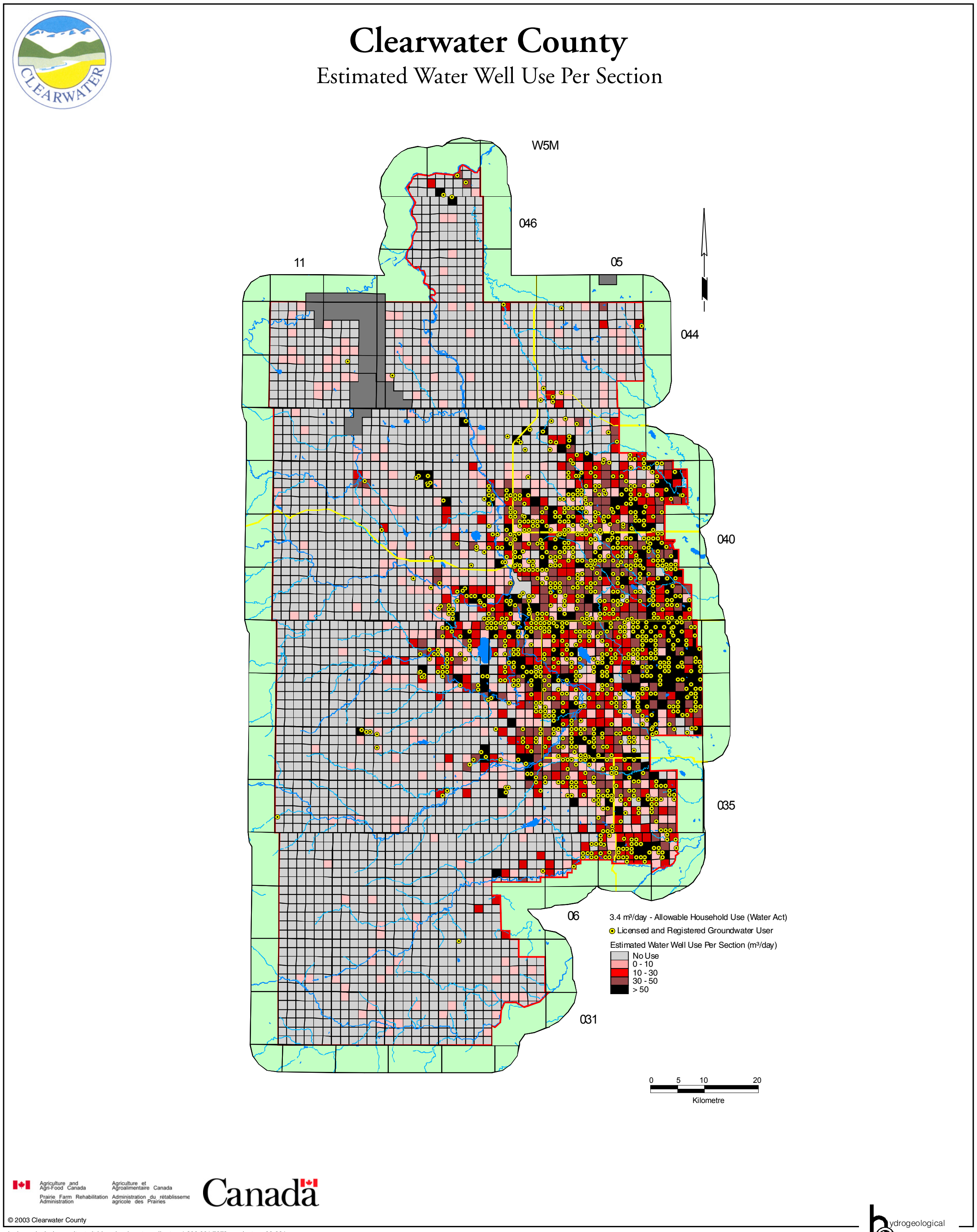
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



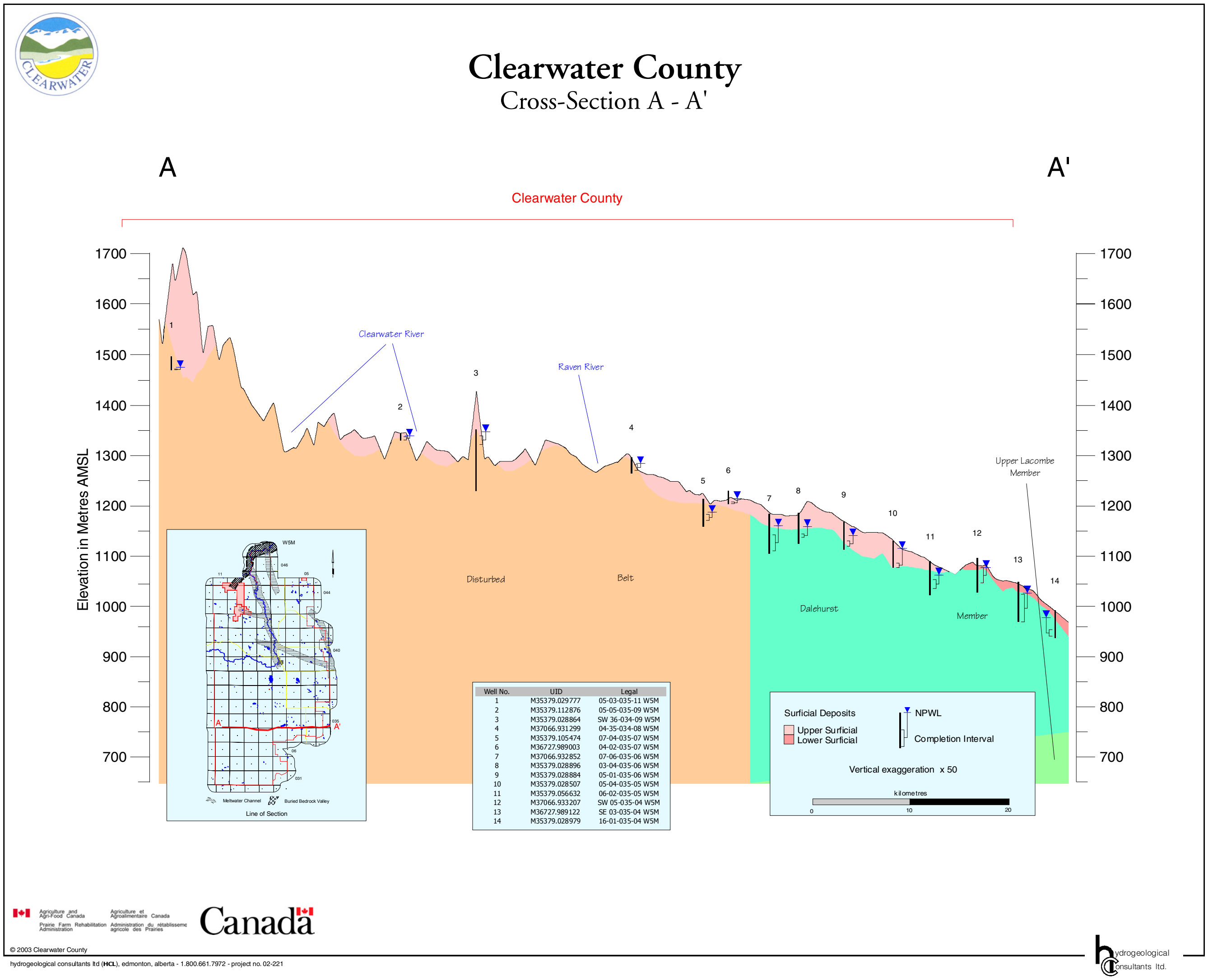
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



Estimated Water Well Use Per Section



Cross-Section A - A'



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6	M36727.989003	04-02-035-07 W5M
7	M37066.932852	07-06-035-06 W5M
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9	M35379.028884	05-01-035-06 W5M
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12	M37066.933207	SW 05-035-04 W5M
13	M36727.989122	SE 03-035-04 W5M
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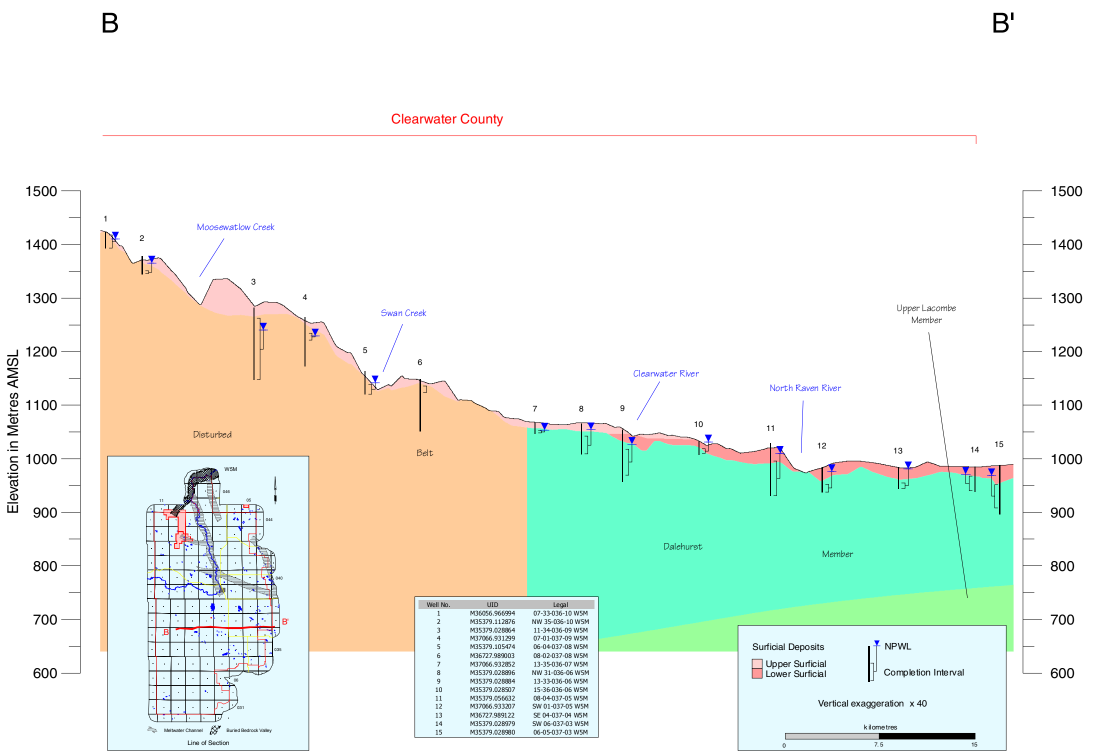
Cross-Section B - B'

Clearwater County
Cross-Section B - B'



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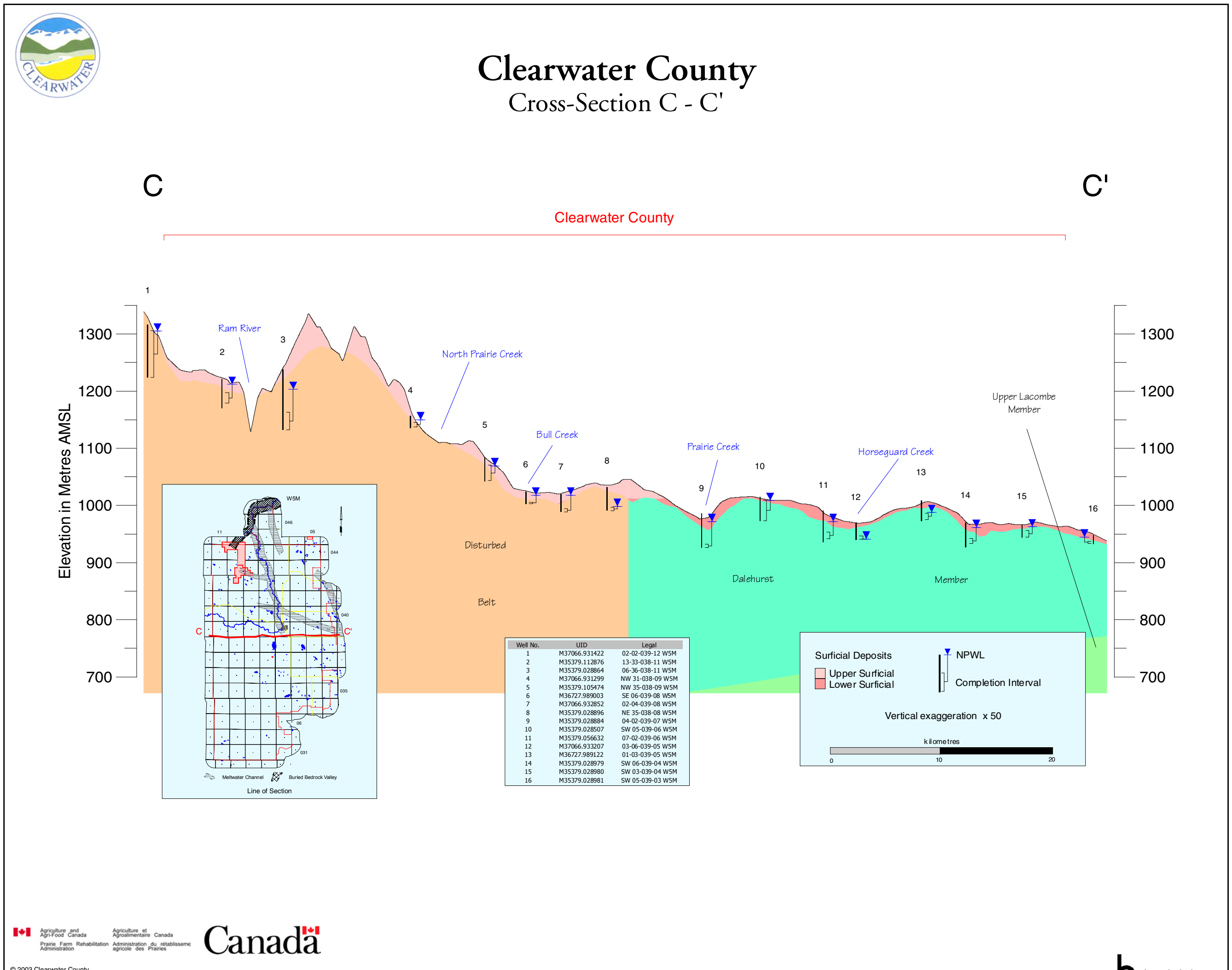
Agriculture and Agri-Food Canada — Prairie Farm Rehabilitation Administration
Agriculture et Agroalimentaire Canada — Administration du rétablissement agricole des Prairies
Canada

hydrogeological consultants ltd (**HCL**), edmonton, alberta - 1.800.661.7972 - project no. 02-221

Cross-Section C - C’



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7	M37066.932852	02-04-039-08 W5M
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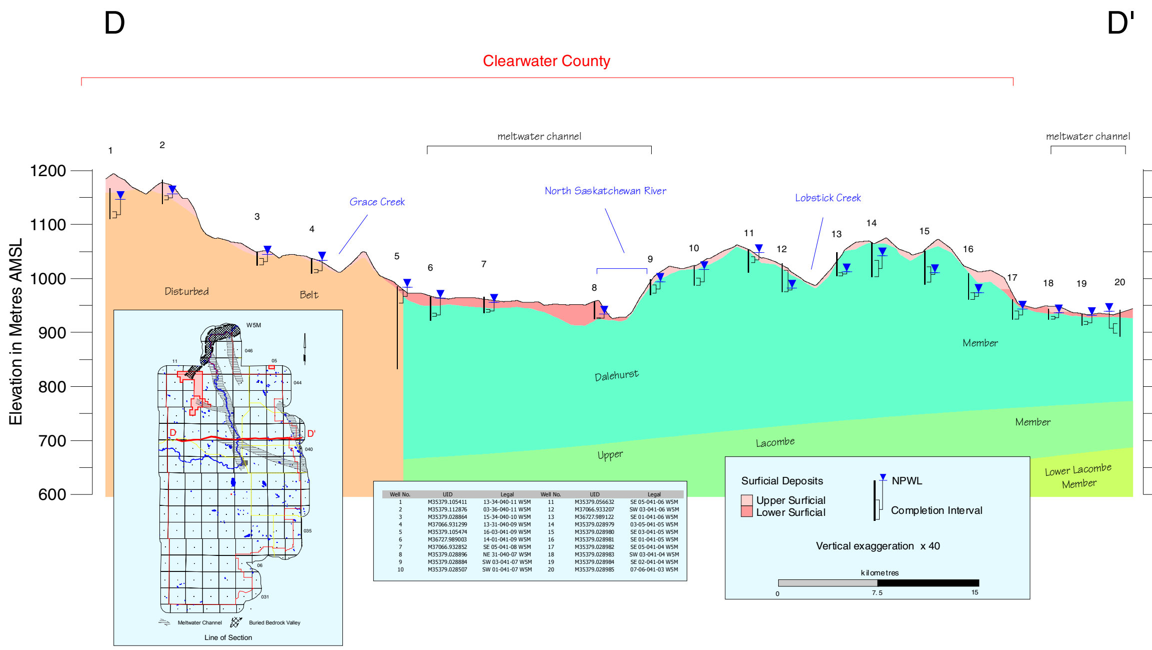
Cross-Section D - D'

Clearwater County
Cross-Section D - D'



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5	M35379.105474	16-03-041-09 W5M	15	M35379.028980	SE 03-041-05 W5M
6	M36727.989003	14-01-041-09 W5M	16	M35379.028981	SE 01-041-05 W5M
7	M37066.932852	SE 05-041-08 W5M	17	M35379.028982	SE 05-041-04 W5M
8	M35379.028896	NE 31-040-07 W5M	18	M35379.028983	SW 03-041-04 W5M
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Prairie Farm Rehabilitation Administration / Administration du rétablissement agricole des Prairies
Canada

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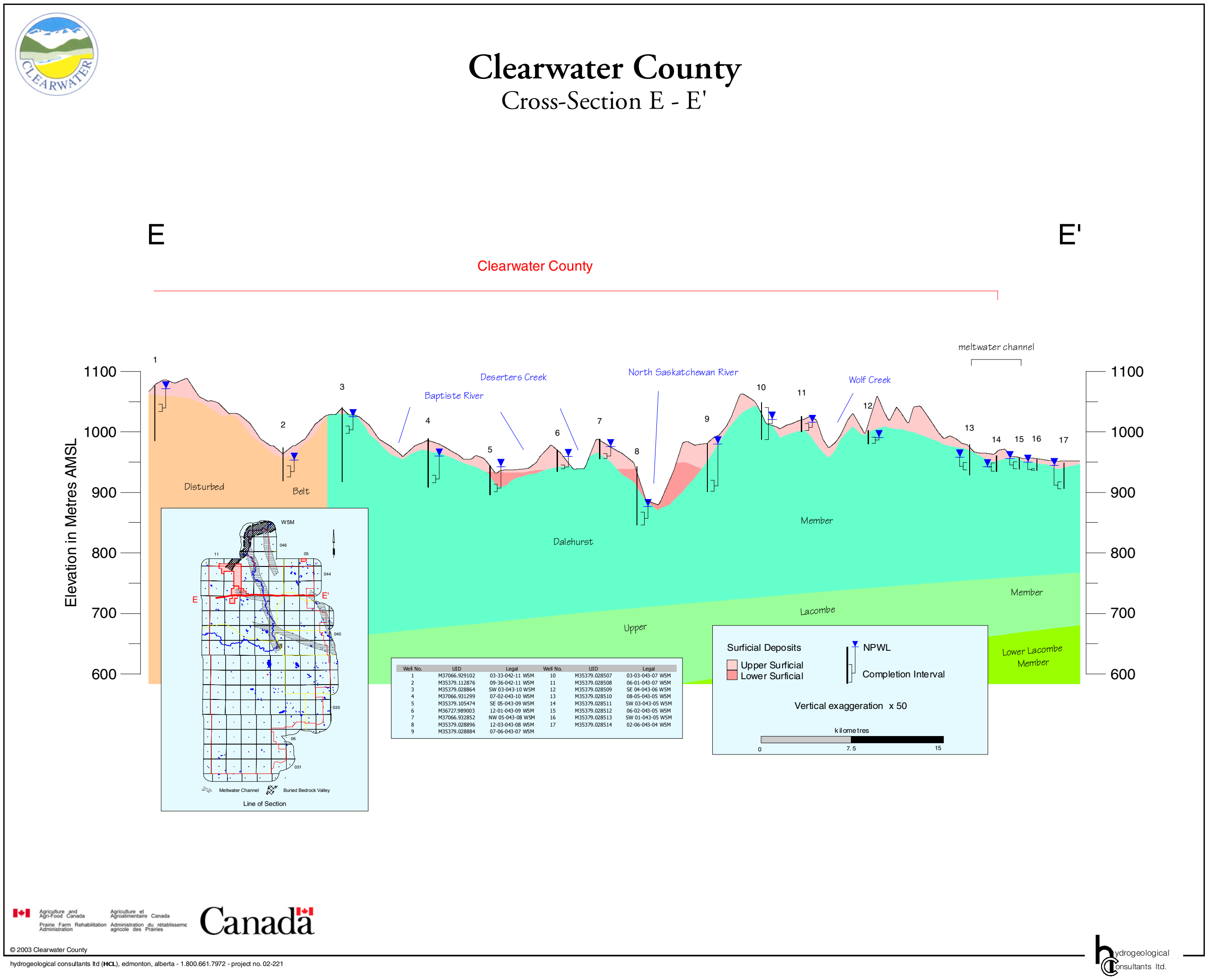
Cross-Section E - E'



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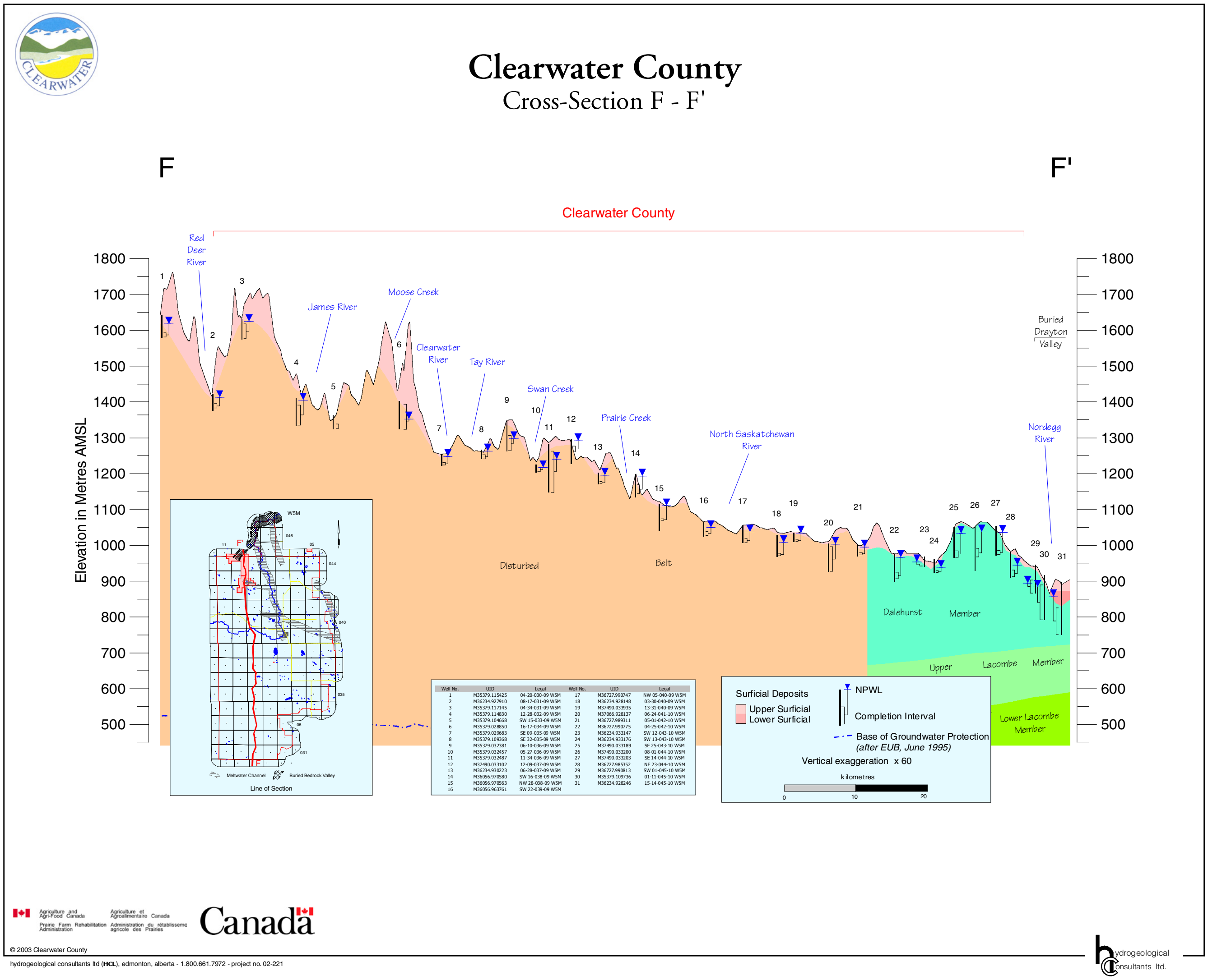

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9	M35379.032381	06-10-036-09 W5M	25	M37490.033189	SE 25-043-10 W5M
10	M35379.032457	05-27-036-09 W5M	26	M37490.033200	08-01-044-10 W5M
11	M35379.032487	11-34-036-09 W5M	27	M37490.033203	SE 14-044-10 W5M
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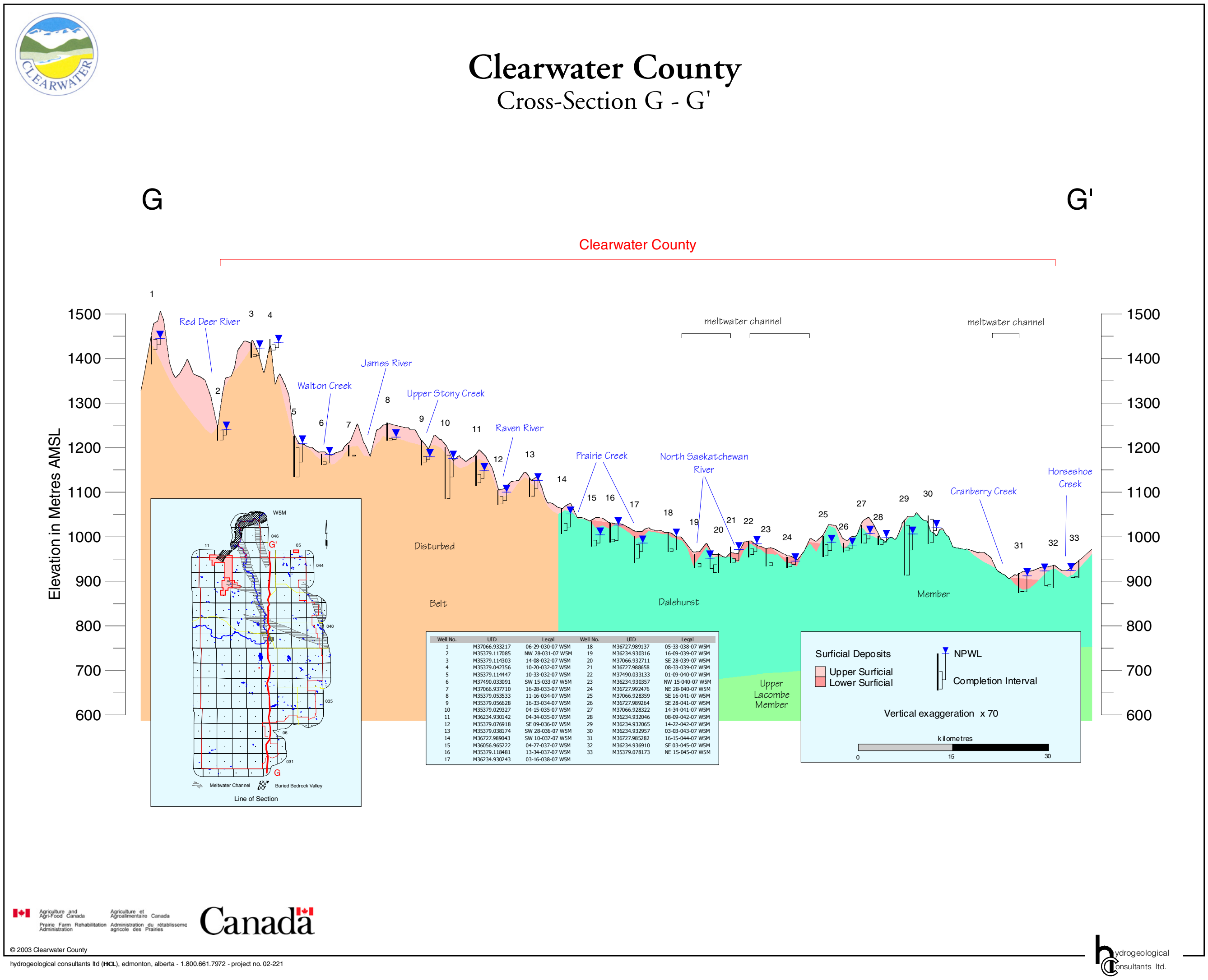
Cross-Section G - G’



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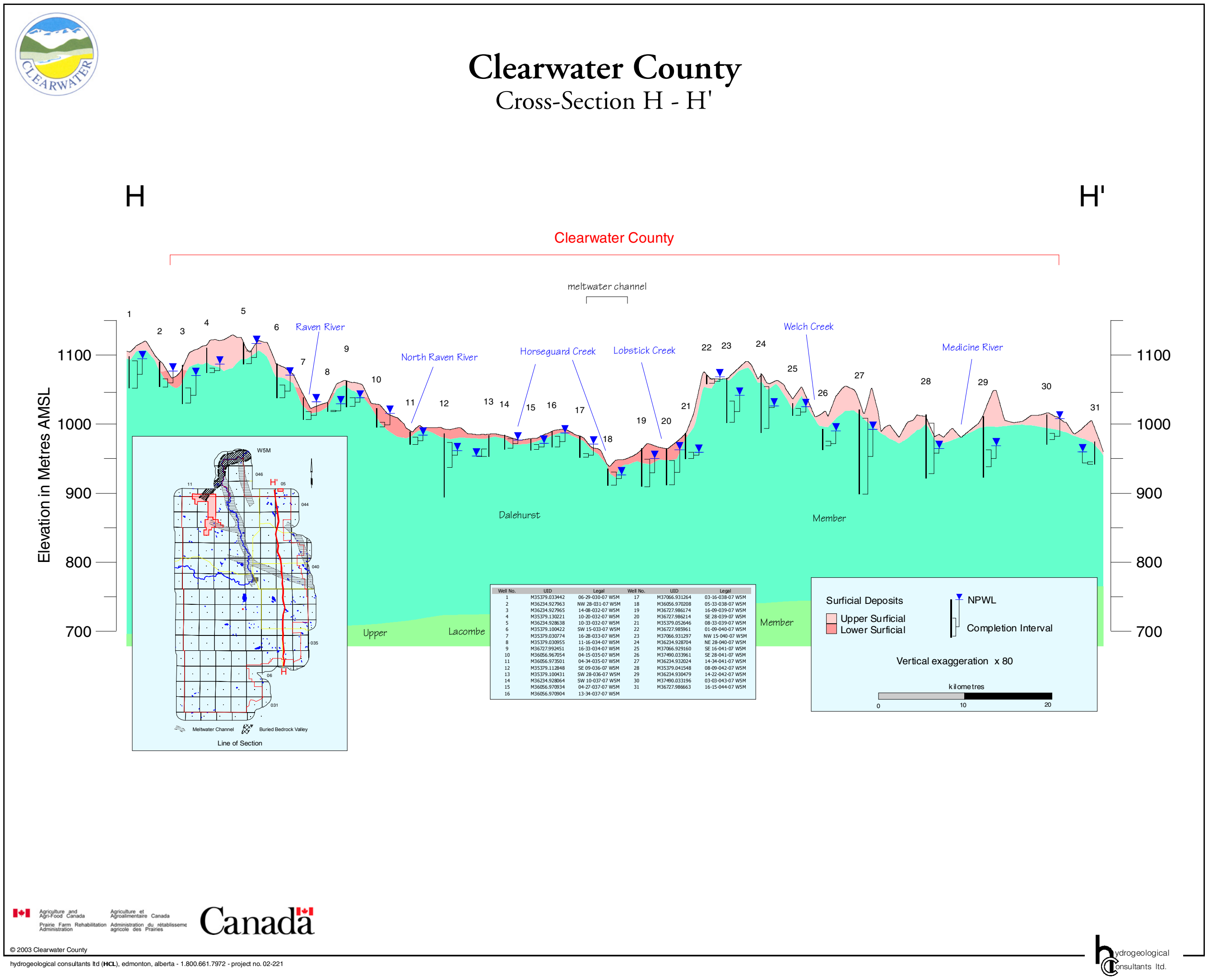
1	M37066.933217	06-29-030-07 W5M	18	M36727.989137	05-33-038-07 W5M
2	M35379.117085	NW 28-031-07 W5M	19	M36234.930316	16-09-039-07 W5M
3	M35379.114303	14-08-032-07 W5M	20	M37066.932711	SE 28-039-07 W5M
4	M35379.042356	10-20-032-07 W5M	21	M36727.988658	08-33-039-07 W5M
5	M35379.114447	10-33-032-07 W5M	22	M37490.033133	01-09-040-07 W5M
6	M37490.033091	SW 15-033-07 W5M	23	M36234.930357	NW 15-040-07 W5M
7	M37066.937710	16-28-033-07 W5M	24	M36727.992476	NE 28-040-07 W5M
8	M35379.053533	11-16-034-07 W5M	25	M37066.928359	SE 16-041-07 W5M
9	M35379.056628	16-33-034-07 W5M	26	M36727.989264	SE 28-041-07 W5M
10	M35379.029327	04-15-035-07 W5M	27	M37066.928322	14-34-041-07 W5M
11	M36234.930142	04-34-035-07 W5M	28	M36234.932046	08-09-042-07 W5M
12	M35379.076918	SE 09-036-07 W5M	29	M36234.932065	14-22-042-07 W5M
13	M35379.038174	SW 28-036-07 W5M	30	M36234.932957	03-03-043-07 W5M
14	M36727.989043	SW 10-037-07 W5M	31	M36727.985282	16-15-044-07 W5M
15	M36056.965222	04-27-037-07 W5M	32	M36234.936910	SE 03-045-07 W5M
16	M35379.118481	13-34-037-07 W5M	33	M35379.078173	NE 15-045-07 W5M
17	M36234.930243	03-16-038-07 W5M			

Cross-Section H - H'



Well No.	UID	Legal	Well No.	UID	Legal
1	M35379.033442	06-29-030-07 W5M	17	M37066.931264	03-16-038-07 W5M
2	M36234.927963	NW 28-031-07 W5M	18	M36056.970208	05-33-038-07 W5M
3	M36234.927965	14-08-032-07 W5M	19	M36727.986174	16-09-039-07 W5M
4	M35379.130221	10-20-032-07 W5M	20	M36727.986214	SE 28-039-07 W5M
5	M36234.928638	10-33-032-07 W5M	21	M35379.052646	08-33-039-07 W5M
6	M35379.100422	SW 15-033-07 W5M	22	M36727.985961	01-09-040-07 W5M
7	M35379.030774	16-28-033-07 W5M	23	M37066.931297	NW 15-040-07 W5M
8	M35379.030955	11-16-034-07 W5M	24	M36234.928704	NE 28-040-07 W5M
9	M36727.992451	16-33-034-07 W5M	25	M37066.929160	SE 16-041-07 W5M
10	M36056.967054	04-15-035-07 W5M	26	M37490.033961	SE 28-041-07 W5M
11	M36056.973501	04-34-035-07 W5M	27	M36234.932024	14-34-041-07 W5M
12	M35379.112848	SE 09-036-07 W5M	28	M35379.041548	08-09-042-07 W5M
13	M35379.100431	SW 28-036-07 W5M	29	M36234.930479	14-22-042-07 W5M
14	M36234.928064	SW 10-037-07 W5M	30	M37490.033196	03-03-043-07 W5M
15	M36056.970934	04-27-037-07 W5M	31	M36727.986663	16-15-044-07 W5M
16	M36056.970904	13-34-037-07 W5M			

CLEARWATER COUNTY

Appendix E

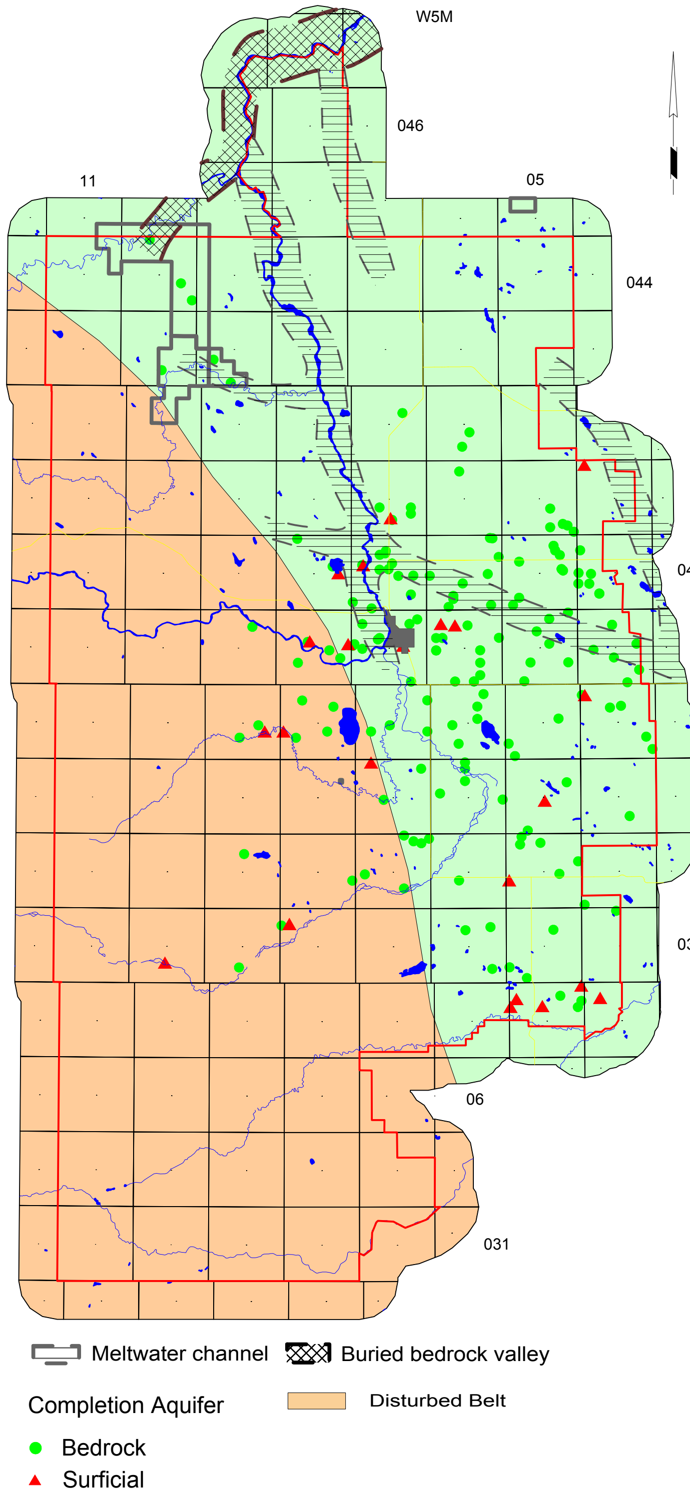
Water Wells Recommended for Field Verification

and

County-Operated Water Wells

Water Wells Recommended for Field Verification

(details on following pages)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Adams, Lyle L.	04-32-036-05 W5M	Dalehurst Member	07-Nov-83	32.3	106.0	5.49	18.0	M36056.967068
Alberta Baptist Church Camp Ltd.	EH 26-035-06 W5M	Dalehurst Member	25-Jun-73	40.2	132.0	2.44	8.0	M35379.029062
Alberta Energy & Resources	SE 11-040-07 W5M	Dalehurst Member	07-Oct-77	18.3	60.0	2.4	8.0	M37066.928877
Alberta Forest Service	SE 09-035-09 W5M	Disturbed Belt	19-May-86	30.5	100.0	6.0	19.7	M35379.029683
Amerada Minerals	13-23-042-07 W5M	Dalehurst Member	18-May-96	39.0	128.0	14.6	48.0	M36170.882610
Amoco Canada Petroleum Compar	12-30-035-08 W5M	Disturbed Belt	22-Oct-82	22.3	73.0	4.3	14.0	M35379.029616
Anderson, Gale	SW 26-038-08 W5M	Disturbed Belt	21-Mar-84	38.1	125.0	25.9	85.0	M36056.970672
Anderson, Norman	01-16-039-04 W5M	Dalehurst Member	01-Jan-59	39.6	130.0	18.3	60.0	M35379.037532
Augart, Elmer	NE 33-035-04 W5M	Dalehurst Member	05-Jun-74	24.4	80.0	4.6	15.0	M37066.937908
BAILEY, LAWRENCE	NW 11-039-06 W5M	Dalehurst Member	11-Dec-80	35.1	115.0	5.5	18.0	M36056.969998
BAKER, R.S.	NW 12-039-05 W5M	Dalehurst Member	09-Sep-77	13.7	45.0	4.9	16.0	M36056.970262
Bersch, L J	NE 36-034-05 W5M	Surficial	01-May-63	18.3	60.0	5.5	18.0	M35379.130293
Bert, D	SE 13-038-07 W5M	Dalehurst Member	12-Oct-76	24.4	80.0	11.0	36.0	M36056.965581
Bird, Ken	07-05-035-05 W5M	Dalehurst Member	07-Sep-77	59.4	195.0	14.9	49.0	M35379.028516
Bkennan, Fred	13-29-039-06 W5M	Lower Surficial	31-May-82	27.4	90.0	13.7	45.0	M36056.963627
Bohme, Cal	NE 32-040-08 W5M	Dalehurst Member	11-Apr-75	18.3	60.0	6.1	20.0	M36076.565793
Bosch, R.	SE 05-040-06 W5M	Dalehurst Member	06-Nov-76	21.3	70.0	3.7	12.0	M36727.986037
BOUVETTE, DON	NE 24-036-05 W5M	Dalehurst Member	14-Mar-81	34.1	112.0	6.1	20.0	M36056.967119
Brettell, Edward	13-04-040-06 W5M	Dalehurst Member	03-Mar-81	28.4	93.0	0.0	0.0	M36727.986033
Bridge, Gordon	SE 01-041-05 W5M	Dalehurst Member	23-Oct-81	22.3	73.0	5.8	18.9	M37066.929498
Brown, Patricia; White, M.	SE 27-035-05 W5M	Dalehurst Member	05-Jun-85	32.0	105.0	22.9	75.0	M35379.028971
Bunch, Walter	NW 30-040-04 W5M	Dalehurst Member	16-Oct-80	45.7	150.0	33.5	110.0	M35379.039024
Campbell, Ernest	04-23-039-07 W5M	Lower Surficial	01-Sep-69	19.8	65.0	4.0	13.0	M36727.988521
Camps, John	04-09-040-06 W5M	Dalehurst Member	21-Aug-81	17.7	58.0	6.1	20.0	M36727.986074
Chevallier, Don	SW 36-039-07 W5M	Dalehurst Member	05-May-80	22.3	73.0	4.6	15.0	M36727.988677
Clause, Peter	16-02-041-05 W5M	Dalehurst Member	02-May-77	12.2	40.0	6.7	22.1	M37066.929501
Cochran, J.	07-26-040-05 W5M	Dalehurst Member	30-May-79	30.5	100.0	16.8	55.0	M36727.985928
Collicutt, Bill	NW 14-039-06 W5M	Dalehurst Member	27-Aug-83	22.9	75.0	3.1	10.0	M36234.933248
Corbeil, S	NW 26-034-05 W5M	Dalehurst Member	18-Aug-80	27.4	90.0	20.4	67.0	M35379.130033
Cossuta, Olives	02-05-040-07 W5M	Dalehurst Member	03-Sep-81	61.0	200.0	16.8	55.0	M36727.988746
Crookedlegs, Joe	SE 04-043-09 W5M	Dalehurst Member	27-Nov-71	31.4	103.0	15.2	50.0	M36234.932992*
Dean, Reg	SE 13-036-08 W5M	Disturbed Belt	23-Sep-85	18.0	59.0	3.7	12.0	M35379.032275
Dearle, Don	09-19-040-07 W5M	Lower Surficial	14-Jun-95	11.6	38.0	2.5	8.1	M35379.118486
Department of Land & Forests	12-26-039-09 W5M	Disturbed Belt	19-Mar-70	15.2	50.0	5.2	17.0	M36056.963756
Department of Lands & Forests	12-06-040-07 W5M	Dalehurst Member	18-Sep-71	38.1	125.0	36.9	121.0	M37066.928943
Dept Lands & Forests	09-09-035-10 W5M	Surficial	23-Aug-67	22.3	73.0	3.4	11.0	M35379.029750
Desjardins, R.D.	01-09-042-06 W5M	Dalehurst Member	04-Jul-80	25.6	84.0	5.5	18.0	M36234.931994
Dobson, Brian	SE 35-036-07 W5M	Dalehurst Member	18-Oct-95	21.9	72.0	4.3	14.0	M35379.062527
Dome Petroleum Ltd.	01-11-035-06 W5M	Dalehurst Member	13-Mar-81	83.8	275.0	44.5	146.0	M35379.028910
Duncan, Peter	SE 23-039-04 W5M	Dalehurst Member	17-Sep-73	35.1	115.0	9.1	30.0	M35379.042852
Dzeik, A	SW 30-034-05 W5M	Surficial	04-Sep-80	43.3	142.0	18.6	61.0	M35379.130113
Farnell, Reg	09-19-040-07 W5M	Dalehurst Member	28-Aug-82	57.9	190.0	10.7	35.0	M37066.929387
Feddama, E J	NE 25-034-05 W5M	Dalehurst Member	20-Oct-81	25.9	85.0	4.6	15.0	M35379.129921
Feldkamp, R	SE 28-034-05 W5M	Surficial	09-Oct-86	13.4	44.0	5.5	18.0	M35379.130050
Feys, Alios	NE 14-040-07 W5M	Dalehurst Member	12-Mar-90	30.5	100.0	21.3	70.0	M35379.052483
Fisher, E. K.	SE 14-041-07 W5M	Dalehurst Member		17.4	57.0	9.5	31.0	M37066.928310
Fisher, Jim	08-21-039-08 W5M	Disturbed Belt	20-Nov-82	15.9	52.0	4.6	15.0	M36056.973096
Fisher, Jim	SE 21-039-08 W5M	Lower Surficial	30-Jun-75	12.2	40.0	1.5	5.0	M36056.973098
Gerber, F. H.	NW 12-038-04 W5M	Dalehurst Member	27-May-83	40.5	133.0	3.7	12.0	M36056.965930
Gervais, W.	NW 36-040-06 W5M	Dalehurst Member	06-Oct-82	22.3	73.0	8.2	27.0	M36727.986876
Glover, David	NW 18-040-06 W5M	Dalehurst Member	21-Jul-77	33.5	110.0	18.0	59.0	M36727.986142

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Feet	NPWL Metres	Feet	UID
Gold, Hugh	14-20-040-05 W5M	Dalehurst Member	08-Jul-81	34.8	114.0	25.6	84.0	M36727.986273
Gopher, George	NW 33-044-10 W5M	Dalehurst Member	01-Jul-72	44.2	145.0	24.38	80.0	M36727.985357*
GRAHAM, EARL	NW 32-036-05 W5M	Dalehurst Member	16-Sep-85	27.4	90.0	6.1	20.0	M36056.967064
GREENE, WAYNE	NE 29-038-08 W5M	Disturbed Belt	18-Jun-81	22.6	74.0	0.91	3.0	M36056.970647
Greenwood, E.	08-06-040-05 W5M	Dalehurst Member		23.0	75.5	2.01	6.6	M37213.583890
Greenwood, Irvin	05-01-040-06 W5M	Dalehurst Member	30-Nov-66	14.0	46.0	4.57	15.0	M36727.985994
Gulf Canada Ltd	05-27-036-09 W5M	Disturbed Belt	14-Jun-83	18.3	60.0	7.7	25.3	M35379.032457
Hall, Clifford	SW 16-041-07 W5M	Dalehurst Member	16-Apr-73	32.3	106.0	11.29	37.0	M37066.928358
Hansinger, Bill	16-14-040-06 W5M	Dalehurst Member	09-Sep-69	30.5	100.0	15.24	50.0	M36727.986118
Hanson, Jim	SW 18-038-08 W5M	Surficial	12-Jun-72	19.2	63.0	12.19	40.0	M36234.933230
HANSON, PAULETTE	SW 23-038-05 W5M	Dalehurst Member	07-Oct-81	15.2	50.0	4.57	15.0	M36056.970978
HARRIS, R.A.	NW 09-039-05 W5M	Dalehurst Member	27-Sep-69	21.9	72.0	6.4	21.0	M36056.970303
Heikkinen, Alfred	NW 26-040-05 W5M	Dalehurst Member	24-Aug-74	21.6	71.0	10.97	36.0	M36727.985940
HENOULT, MARCEL	NW 32-037-07 W5M	Lower Surficial	01-Jun-73	30.5	100.0	8.23	27.0	M36056.971251
Heringer, Alfred	NE 28-039-04 W5M	Dalehurst Member	21-Nov-78	38.1	125.0	22.86	75.0	M35379.042877
Hill, Randy	SE 23-040-08 W5M	Dalehurst Member	10-Jul-91	27.4	90.0	1.52	5.0	M35379.061387
HOBBS, KEN	SW 36-037-07 W5M	Dalehurst Member	13-Jun-84	30.8	101.0	3.05	10.0	M36056.971228
HOPP, EDWIN	NE 17-038-06 W5M	Dalehurst Member	26-Aug-82	16.2	53.0	3.66	12.0	M36056.970791
HUBLE, R	NE 01-038-04 W5M	Dalehurst Member	01-Jan-61	41.2	135.0	1.83	6.0	M36056.966046
HULBERG, I.C.	SW 04-039-06 W5M	Dalehurst Member	10-Sep-73	24.4	80.0	3.96	13.0	M36056.970036
Humphrey, Hubert	04-35-040-05 W5M	Dalehurst Member	03-May-68	15.2	50.0	10.06	33.0	M36727.985986
Imberry, Ralph	SW 21-040-07 W5M	Dalehurst Member	12-Jan-77	32.0	105.0	5.48	18.0	M37066.929371
Jameson, Harold	NE 18-036-07 W5M	Disturbed Belt	07-Nov-84	48.8	160.0	20.73	68.0	M35379.038071
Jameson, Terry	NE 30-035-08 W5M	Upper Surficial	10-Jun-75	8.8	29.0	3.35	11.0	M35379.029618
Johnston, D.	SE 15-038-08 W5M	Disturbed Belt	11-May-84	23.2	76.0	8.53	28.0	M36234.933215
JONES, ED	SE 33-036-05 W5M	Dalehurst Member	19-Nov-69	29.9	98.0	6.1	20.0	M36056.967052
Kautz, Carl	NE 24-039-06 W5M	Dalehurst Member	15-May-80	57.6	189.0	10.36	34.0	M36234.933347
Keingersky, Lewis	SE 03-039-06 W5M	Dalehurst Member	03-May-85	30.5	100.0	4.27	14.0	M36056.970047
Keingersky, Lewis	SE 03-039-06 W5M	Dalehurst Member	10-Jun-82	26.5	87.0	3.66	12.0	M36056.970048
Kinder, Eldon	01-03-039-04 W5M	Dalehurst Member		12.8	42.0	9.75	32.0	M35379.037390
Kissick, Jim	SW 18-036-05 W5M	Lower Surficial	30-Apr-76	22.9	75.0	-0.91	-3.0	M36056.967140
Knudson, John	NW 01-041-05 W5M	Dalehurst Member	30-Nov-80	41.2	135.0	25.3	83.0	M37066.929475
Kohtala, Lena	01-16-040-06 W5M	Dalehurst Member	13-Jul-81	30.5	100.0	6.71	22.0	M36727.986126
Kraft, Carol	04-13-039-08 W5M	Dalehurst Member	27-Aug-81	18.3	60.0	3.05	10.0	M36056.973157
Kreutzer, R.	16-18-039-07 W5M	Dalehurst Member	21-Jun-74	18.3	60.0	2.44	8.0	M36727.988405
Kubik, Rick	NW 29-034-04 W5M	Lower Surficial	03-Aug-79	8.5	28.0	3.66	12.0	M35379.130112
Kult, Emil	01-11-039-04 W5M	Dalehurst Member	15-Mar-75	32.0	105.0	18.29	60.0	M35379.037496
Lacount, Don	NW 08-038-08 W5M	Disturbed Belt	20-Sep-74	15.2	50.0	0.91	3.0	M36234.926117
Lagrelle, Simeon	SW 10-043-10 W5M	Dalehurst Member	03-Dec-71	18.6	61.0	4.57	15.0	M36234.933105*
LEE, GEORGE	12-15-037-05 W5M	Lower Surficial	16-Jun-69	11.3	37.0	3.05	10.0	M36056.973476
LESLIE, GORDON	SE 28-039-05 W5M	Dalehurst Member	01-Apr-83	22.9	75.0	12.19	40.0	M36056.970131
LETWIN, H.	SE 22-039-05 W5M	Dalehurst Member	14-May-84	49.1	161.0	38.1	125.0	M36056.970206
LEVETT, MIKE	NE 13-037-06 W5M	Dalehurst Member	30-Jun-77	17.7	58.0	8.53	28.0	M36056.973281
Loeppky, Sid	SW 16-036-06 W5M	Dalehurst Member	19-Oct-78	49.4	162.0	42.67	140.0	M35379.039469
Lumb, George	16-21-040-07 W5M	Dalehurst Member	08-Aug-97	16.8	55.0	9.14	30.0	M36234.930359
Lumb, George	SW 28-040-07 W5M	Dalehurst Member	14-Sep-88	29.0	95.0	11.28	37.0	M36869.841124
Madson, Jerry	04-19-039-07 W5M	Dalehurst Member	20-Oct-80	42.7	140.0	19.51	64.0	M36727.988414
MANNERFELDT, KEITH	NE 33-037-06 W5M	Dalehurst Member	04-Apr-86	24.4	80.0	10.06	33.0	M36056.973211
Mason, C.H.	SE 25-040-06 W5M	Dalehurst Member	07-Nov-60	19.8	65.0	6.1	20.0	M36727.986793
MAY, LEE	10-31-041-04 W5M	Lower Surficial	18-May-81	11.3	37.0	4.88	16.0	M36056.963849
MCCARRON	NE 18-039-06 W5M	Dalehurst Member	23-Apr-81	33.5	110.0	10.67	35.0	M36234.933283
MCDONALD, MARGARET	SE 19-037-06 W5M	Dalehurst Member	01-Jun-79	22.9	75.0	4.57	15.0	M36056.973292
MCEACHERN, J	NE 16-038-07 W5M	Dalehurst Member	15-Nov-82	19.8	65.0	10.67	35.0	M36056.965555
MCLELLAN, DON	SW 35-038-06 W5M	Dalehurst Member	28-Sep-84	38.1	125.0	7.62	25.0	M36056.970690
Menult, Bill	15-26-039-07 W5M	Dalehurst Member	26-Sep-81	25.0	82.0	7.01	23.0	M36727.988573
Merklin, Fred	NW 17-040-04 W5M	Dalehurst Member	29-Aug-84	41.2	135.0	31.36	102.9	M35379.038004

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Miller, Bruce	SW 10-041-07 W5M	Dalehurst Member	17-May-82	40.5	133.0	16.8	55.0	M37066.928223
Miller, Bruce	05-10-041-07 W5M	Lower Surficial	13-Mar-80	41.2	135.0	10.7	35.0	M37066.928224
MOLNER, PHYLIS	SE 33-037-06 W5M	Dalehurst Member	11-Apr-86	32.0	105.0	16.2	53.0	M36056.973214
MORRISH, ALFERD R.	NW 14-039-08 W5M	Disturbed Belt	30-May-83	36.9	121.0	14.3	47.0	M36056.973121
MOUNTAIN WEST COAST	SW 19-039-07 W5M	Dalehurst Member	11-Jun-81	19.2	63.0	3.7	12.0	M36727.988416
Noirot, Calvin	09-36-036-07 W5M	Dalehurst Member	28-Jul-81	21.3	70.0	3.1	10.0	M35379.038367
OSBORNE, WAYNE	NE 09-038-09 W5M	Disturbed Belt	01-Oct-82	17.1	56.0	5.5	18.0	M36056.970602
Oshust, Nick	NW 27-039-06 W5M	Dalehurst Member	23-Apr-70	41.5	136.0	13.6	44.7	M36727.988312
OST, ROGER	SE 22-038-06 W5M	Dalehurst Member	26-Sep-77	22.9	75.0	4.9	16.0	M36056.970776
OUDERKIRK, GLEN	SE 06-038-05 W5M	Dalehurst Member	16-Sep-75	12.2	40.0	3.4	11.0	M36056.971042
Overgaurd, Bob	NE 28-040-07 W5M	Dalehurst Member	02-Jun-95	29.0	95.0	13.7	45.0	M35379.081770
Parodi, John	16-34-036-07 W5M	Dalehurst Member	30-Aug-79	16.5	54.0	3.1	10.0	M35379.038259
Parr, F.	01-23-040-05 W5M	Dalehurst Member	12-Aug-67	33.5	110.0	18.6	61.0	M36727.985905
Parr, Russel	SE 23-040-05 W5M	Dalehurst Member	28016	30.5	100.0	21.3	70.0	M36727.985906
Paul, Wayne	NW 20-039-06 W5M	Dalehurst Member	17-Jul-81	25.0	82.0	1.8	6.0	M36234.933309
Pengelly, Rosanna	SE 28-035-06 W5M	Dalehurst Member	30-Jan-70	58.5	192.0	15.5	51.0	M35379.029135
Perkins, Bob	NW 36-040-06 W5M	Dalehurst Member	06-Oct-82	22.3	73.0	8.2	27.0	M36722.035151
Phillips, MURRAY	SW 07-038-05 W5M	Dalehurst Member	06-Nov-70	20.4	67.0	3.4	11.0	M36056.971039
PINE HILLS GULF CLUB	16-30-039-07 W5M	Dalehurst Member	22-Jul-84	53.3	175.0	24.4	80.0	M36727.988650
Pollitt, Robert J.	SW 18-040-04 W5M	Dalehurst Member	15-Oct-93	39.6	130.0	24.2	79.5	M35379.073813
PULAY, CHRIS & JOHN	NE 08-039-08 W5M	Disturbed Belt	25-Aug-75	24.4	80.0	16.8	55.0	M36056.973165
Qually, A.	NE 11-041-07 W5M	Dalehurst Member	13-May-81	21.9	72.0	11.0	36.0	M37066.928255
RAVIO, M.	SE 24-039-08 W5M	Lower Surficial	16-Jan-64	13.1	43.0	8.2	27.0	M36056.963814
Redford, Reg.	NW 21-039-07 W5M	Dalehurst Member	17-Jun-85	19.8	65.0	6.4	21.0	M36727.988444
REED, KEN	NW 16-037-07 W5M	Disturbed Belt	20-Aug-66	33.5	110.0	14.6	48.0	M36056.971314
REW, CHUCK	SE 02-039-07 W5M	Dalehurst Member	29-May-72	30.5	100.0	18.3	60.0	M36056.963545
Rodermond, James	SE 34-039-05 W5M	Dalehurst Member	16-Dec-80	24.4	80.0	10.7	35.0	M36056.970081
Rollier, Jim	NE 15-040-07 W5M	Dalehurst Member	28-Mar-71	21.0	69.0	5.5	18.0	M36870.563751
Rooke, Richard	NW 28-039-06 W5M	Lower Surficial	20-Jul-74	26.8	88.0	0.0	0.0	M36727.988326
Rudd, Ken	SE 18-040-04 W5M	Dalehurst Member	19-Mar-86	47.2	155.0	25.9	85.0	M35379.038016
Salomons, J & A	NE 25-038-07 W5M	Dalehurst Member	05-Apr-73	15.2	50.0	4.3	14.0	M36234.926139
Schiemann, H	NE 30-034-05 W5M	Upper Surficial	01-Oct-71	11.9	39.0	1.3	4.2	M35379.130155
SHIPPELT, RUDOLPH	01-26-037-05 W5M	Dalehurst Member	07-Oct-83	25.9	85.0	3.1	10.0	M36056.973431
Simmelink, Ben	NW 22-040-07 W5M	Dalehurst Member	20-Aug-60	21.3	70.0	9.2	30.0	M37066.929373
Skrocki, Walter	NW 02-039-06 W5M	Dalehurst Member	01-Nov-72	33.5	110.0	13.7	45.0	M36056.970054
Smart, Calvin	09-10-036-07 W5M	Disturbed Belt	27-Jul-83	21.3	70.0	3.1	10.0	M35379.037639
Smid, Tom	SE 27-038-06 W5M	Dalehurst Member	13-Sep-78	21.3	70.0	3.7	12.0	M36056.970749
Smith, Les	NW 36-039-05 W5M	Dalehurst Member	03-Jun-82	32.0	105.0	11.0	36.0	M36056.970065
Smith, Mel	NW 14-036-05 W5M	Dalehurst Member	13-Jun-83	42.7	140.0	27.4	90.0	M36056.967161
Solland, Melvin	08-10-037-04 W5M	Dalehurst Member	12-Dec-64	16.2	53.0	2.7	9.0	M36056.966920
Steeves, Jesse	NE 28-040-07 W5M	Dalehurst Member	07-Jun-72	28.0	92.0	9.2	30.0	M37066.929325
Strachan Camp Ground Well 1	SE 14-038-09 W5M	Surficial	15-Aug-67	12.5	41.0	2.8	9.2	M36056.970593
Strawberry, George	15-01-044-10 W5M	Dalehurst Member	26-May-75	27.4	90.0	6.1	20.0	M36727.985331*
Strawberry, Sam	SE 14-044-10 W5M	Dalehurst Member	29-Jul-70	65.2	214.0	55.5	182.0	M36727.985348*
Sztym, Mike	01-15-041-05 W5M	Dalehurst Member	24-Dec-82	32.3	106.0	6.1	20.0	M37066.929449
Tarnasky, W A	NE 16-038-07 W5M	Dalehurst Member	01-Dec-81	33.5	110.0	7.6	25.0	M36056.965556
Taskila, W.	03-28-038-04 W5M	Dalehurst Member	01-Jan-69	15.2	50.0	7.0	23.0	M36056.965775
Taylor, Merv	SW 07-035-05 W5M	Dalehurst Member	16-Jul-82	73.2	240.0	21.3	70.0	M35379.028597
Taylor, Stan	NW 18-040-04 W5M	Dalehurst Member	30-Oct-80	21.3	70.0	10.7	35.0	M35379.055623
Teskey, Bob & Ringness, Betty	NE 14-040-08 W5M	Lower Surficial	04-Jun-90	21.9	72.0	1.5	5.0	M35379.053368
Tessmer, Murial	12-21-039-07 W5M	Dalehurst Member	21-Sep-81	47.9	157.0	8.2	27.0	M36727.988445
Thompson, Tom	SW 36-036-07 W5M	Dalehurst Member	06-Jun-85	24.4	80.0	16.8	55.0	M35379.038364
Tose, John W.	SE 05-037-05 W5M	Dalehurst Member	22-Oct-60	21.9	72.0	3.1	10.0	M36056.973534
Tougas, Ubalo	SW 09-038-06 W5M	Dalehurst Member	25-Oct-77	37.2	122.0	5.2	17.0	M36056.970824
Turner, A.	SW 27-038-04 W5M	Dalehurst Member	01-Oct-73	27.4	90.0	7.3	24.0	M36056.965788
Umsheid, Mark	SE 28-037-06 W5M	Dalehurst Member	25-Jul-75	22.3	73.0	3.1	10.0	M36056.973245
Urbinsky, Paul	NW 17-039-04 W5M	Dalehurst Member	08-Mar-77	23.8	78.0	18.3	60.0	M37066.939427

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Valeri, O	SW 25-034-05 W5M	Dalehurst Member	01-Jun-72	26.2	86.0	2.9	9.4	M35379.129912
Van Dirstein, David	SE 08-040-04 W5M	Dalehurst Member	31-Aug-84	79.2	260.0	64.0	210.0	M37066.937384
Van Dirstein, David	SE 08-040-04 W5M	Dalehurst Member	19-May-77	61.0	200.0	50.3	165.0	M37066.937385
Verhaeghe, Walter	02-33-041-06 W5M	Dalehurst Member	28-Jun-82	18.3	60.0	2.8	9.1	M37066.928276
Vos, Tony	04-31-038-04 W5M	Dalehurst Member	30-Apr-76	22.9	75.0	12.2	40.0	M36056.965734
Vos, Tony	03-31-038-04 W5M	Lower Surficial	11-Jun-80	22.6	74.0	12.8	42.0	M36056.965735
Waddell, Marie	09-03-041-05 W5M	Dalehurst Member	25-Nov-76	43.0	141.0	28.9	95.0	M37066.929486
Walders, Dave	NW 14-038-09 W5M	Disturbed Belt	15-Oct-79	19.8	65.0	6.1	20.0	M36056.970589
Wascana Energy Inc	06-15-042-06 W5M	Dalehurst Member	06-Mar-98	68.6	225.0	53.3	175.0	M36189.596588
Williams, Harold	SE 05-039-05 W5M	Dalehurst Member	27-Sep-78	39.3	129.0	3.7	12.0	M36056.970353
Windchester, Jim	NE 18-039-06 W5M	Dalehurst Member	29-Apr-81	37.2	122.0	3.7	12.0	M36234.933284
Witford	03-17-043-09 W5M	Dalehurst Member	11-Jun-75	61.0	200.0	43.0	141.0	M36234.933022*
Woods, D	SW 17-038-07 W5M	Dalehurst Member	21-Aug-72	21.3	70.0	5.2	17.0	M36056.965543
Wozniczka, John	NE 19-039-06 W5M	Dalehurst Member	18-Oct-78	25.9	85.0	2.4	8.0	M36234.933298
Wyatt, W.	SW 06-036-04 W5M	Dalehurst Member	28-Jun-73	15.2	50.0	4.3	14.0	M35379.029952
Zeggelaar, Andy	NW 05-040-05 W5M	Dalehurst Member	14-Jun-88	20.7	68.0	6.1	20.0	M36727.986183

* Water wells located on First Nations lands

CLEARWATER COUNTY-OPERATED WATER WELLS

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Md Clearwater #99	NE 11-036-06 W5M	Dalehurst Member	9/17/1991	33.53	110.0	7.62	25.0	M35379.061443