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

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

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

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

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

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

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

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

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 90% of the County where sand and gravel deposits are present, the sand and gravel deposits are less than 30% of the total thickness of the surficial deposits (Page A-21). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas associated with linear bedrock lows.

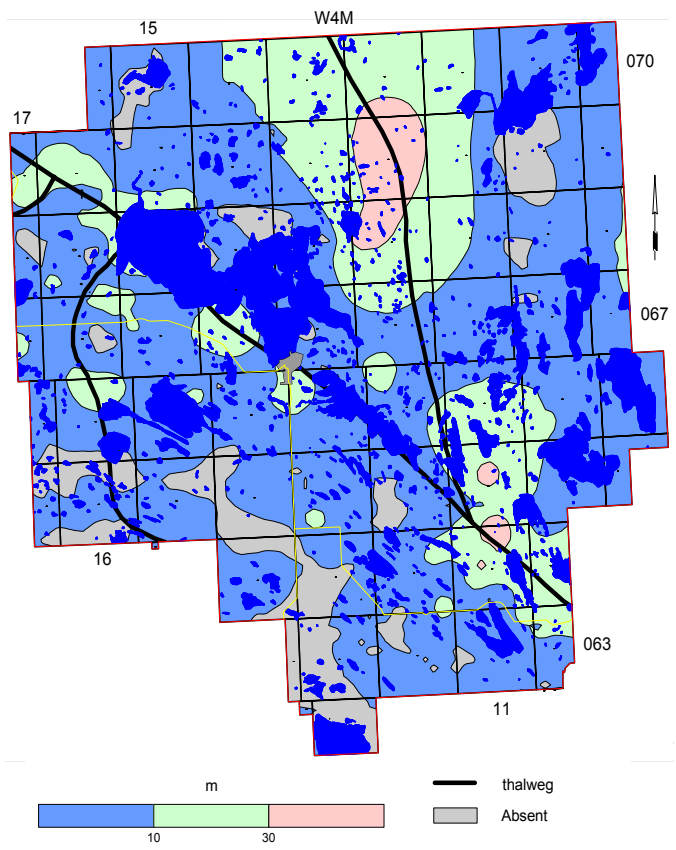

Figure 12. Thickness of Sand and Gravel Deposits

5.3 Surficial Deposits

5.3.1 Quaternary Stratigraphy

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

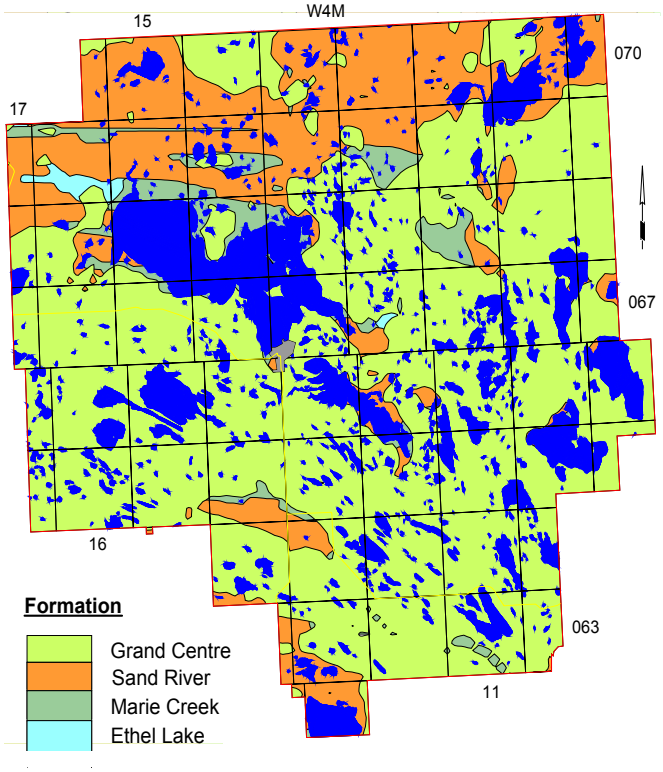

Figure 13. Surficial Geology Map

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

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

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

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

In the County, the Empress Formation – Unit 3 is the lowest stratigraphic unit, all of whose sediments are of glacial origin. The sediments consist primarily of sand and gravel deposits. The determination of the areal extent

and thickness of the Empress Formation – Unit 3 is the only Formation designation that differs from Andriashek and Fenton. The Empress Formation - Unit 3 directly overlies the bedrock surface in areas of bedrock highs. For this regional study, the determination of the areal extent and thickness of the Empress Formation – Unit 3 is calculated by subtracting the total thickness of the Bonnvyille, Muriel Lake and Bronson Lake formations from the top of the Bonnyville Formation.

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

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

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

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

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

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

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

5.3.2 Aquifers

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

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

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

Table 2. Completion Aquifer

5.3.3 Sand and Gravel Aquifer(s)

The primary sources of groundwater in the County are the aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. In the County, the thickness of the sand and gravel aquifer(s) is generally less than ten metres, but can be more than 30 metres in the Buried Imperial Mills Valley and at the junction of the Buried Helena and Imperial Mills valleys (Page A-22 and on CD-ROM). The non-pumping water-level surface in the sand and gravel aquifer(s) is a subdued replica of the topographic surface (see CD-ROM) and slopes toward Lac La Biche.

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

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

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

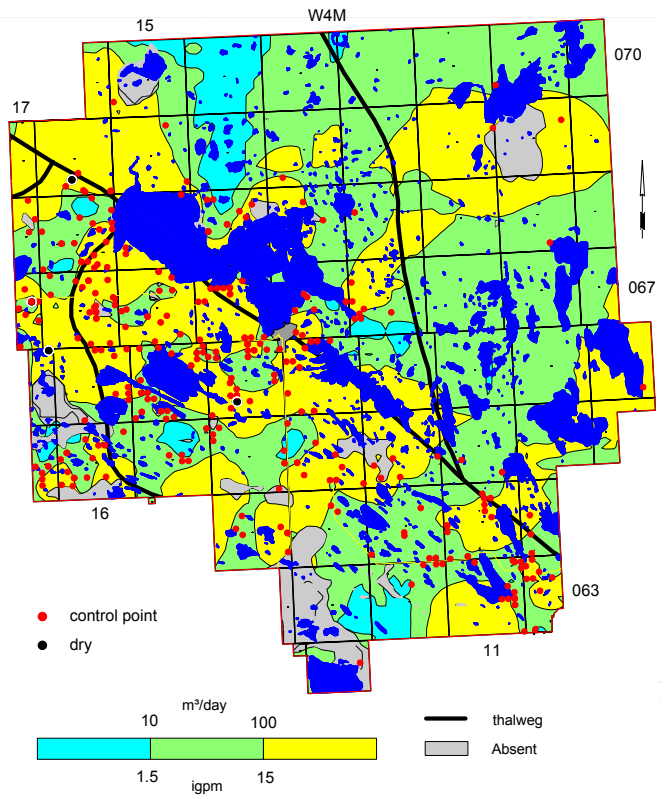

Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

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

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

Chemical Quality of Groundwater from Surficial Deposits

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

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

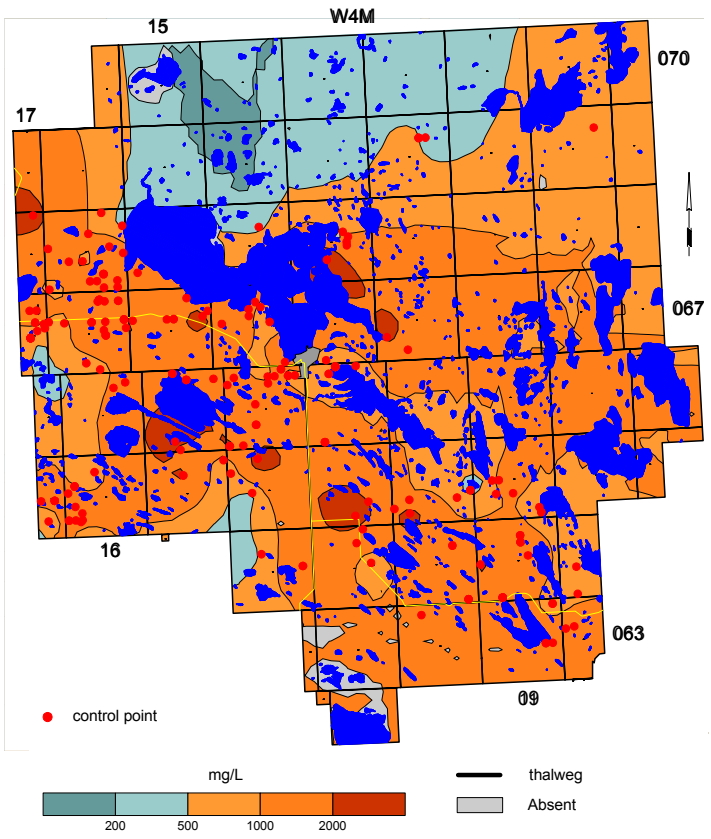

Figure 15. Total Dissolved Solids in Groundwater from Surficial Deposits

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

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

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

Table 4. Concentrations of Constituents in Groundwaters from Surficial Aquifers

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

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

[13] See glossary

5.3.4 Upper Sand and Gravel Aquifer

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

5.3.4.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the surficial deposits; and (2) the depth to the bedrock surface or the depth to the top of the lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel Aquifer is generally less than ten metres, but can be more than 30 metres in the areas associated with linear bedrock lows (see CD-ROM).

5.3.4.2 Apparent Yield

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

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

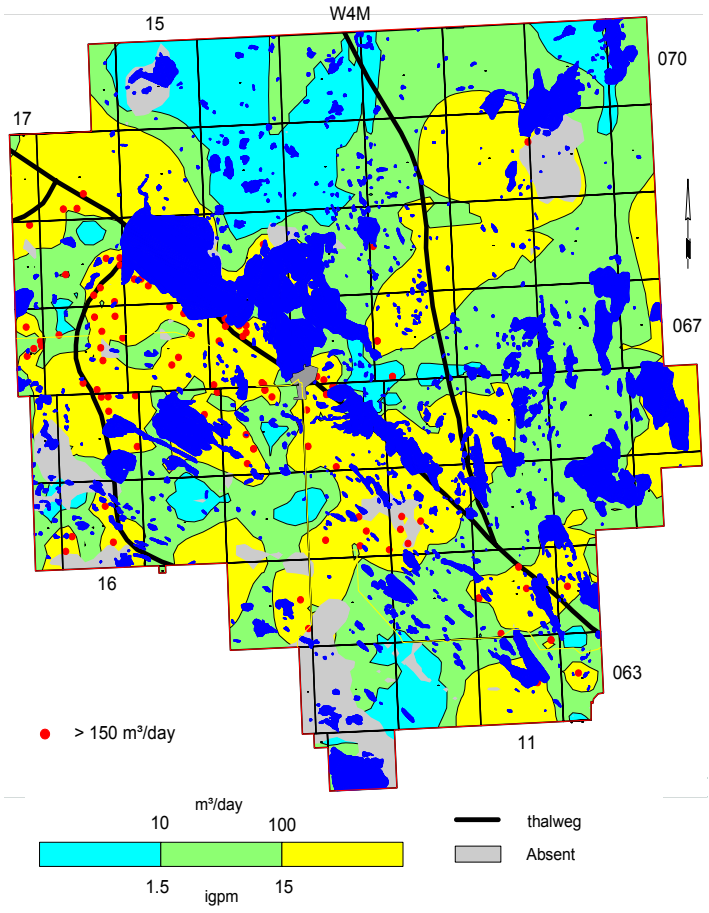

Figure 16. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer