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

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

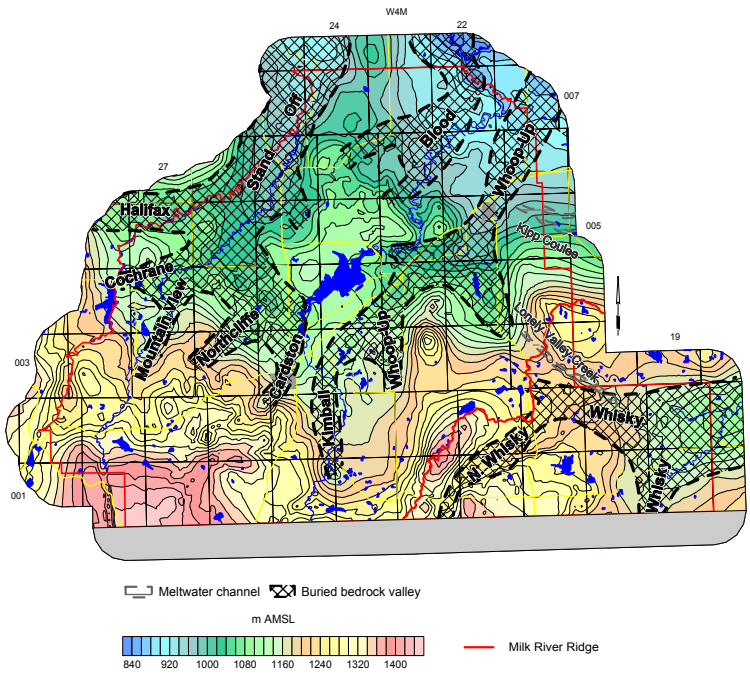

Figure 8. Bedrock Topography

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

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

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

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

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

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

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur mainly east of the Disturbed Belt (see Figure 9). The total thickness of the lower surficial deposits is mainly less than 45 metres, but can be more than 45 metres in the buried bedrock valleys and west of the Milk River Ridge (see CD-ROM). The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the buried bedrock valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous (see CD-ROM).

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

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. The thickness of the upper surficial deposits is mainly less than 50 metres. Upper surficial deposits are present mainly in the southwestern part of the County and are absent from the buried bedrock valleys (see CD-ROM). Because the meltwater channels are mainly an erosional feature, the sand and gravel deposits associated with these features are considered not to be significant aquifers. The upper sand and gravel deposits are usually less than five metres thick (see CD-ROM). Upper sand and gravel deposits are present mainly in the southwestern part of the County and are absent from the buried bedrock valleys (see CD-ROM).

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

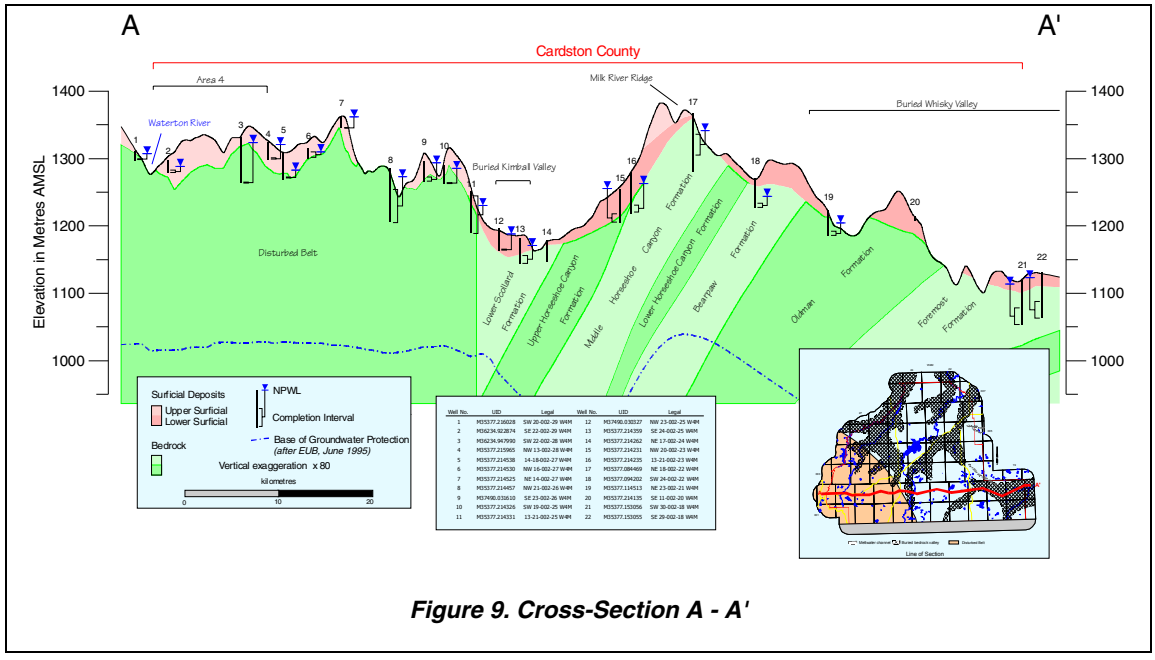

Figure 9. Cross-Section A - A'

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

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

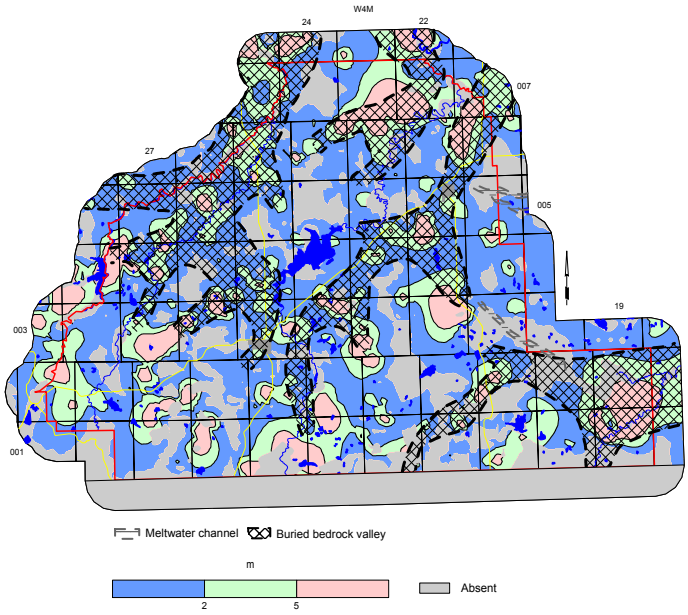

Figure 10. Thickness of Sand and Gravel Deposits

5.2.2 Sand and Gravel Aquifer(s)

The main source of groundwater in the County is aquifers in the surficial deposits. The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the non-pumping water level in water wells that are less than 20 metres deep. The base of the surficial deposits is the bedrock surface.

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

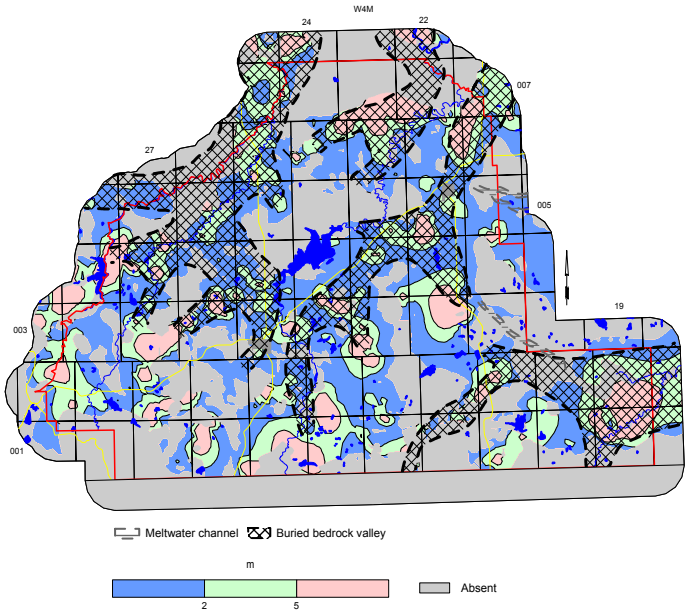

Figure 11. Thickness of Sand and Gravel Aquifer(s)

Of the 2,671 water wells in the database, 427 were defined as being completed in surficial aquifers, based on lithologic information and water well completion details. From the present hydrogeological analysis, 1,107 water wells are completed in aquifers in the surficial deposits. Of the 1,107 water wells, 135 are completed in aquifers in the upper surficial deposits, 418 are completed in aquifers in the lower surficial deposits, and 553 water wells are completed in multiple surficial aquifers. This number of water wells (1,107) is 2.6 times the number (427) determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the elevation of the bedrock surface determined from the gridded bedrock topographic surface at the same location, then the water well is considered to be completed in an aquifer in the surficial deposits.

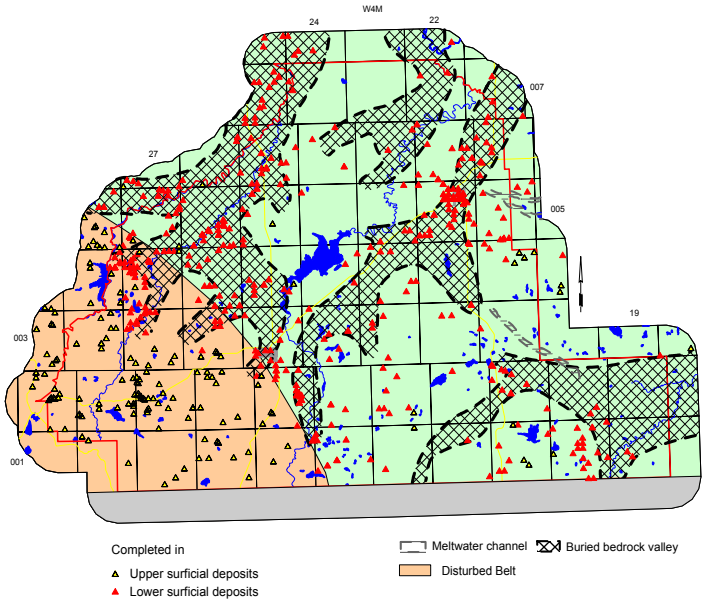

Figure 12. Water Wells Completed in Upper and Lower Surficial Deposits

Water wells completed in the upper surficial deposits occur mainly within the Disturbed Belt; water wells completed in the lower surficial deposits occur mainly in buried bedrock valleys (Figure 12). Even though only about 41% of water wells in the County are completed in surficial aquifers, 13 of the 20 highest yielding water wells in the County are completed in surficial deposits (and 55 of the 100 highest yielding water wells).

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

In the County, there are 219 records for surficial water wells with apparent yield data, which is 20% of the 1,107 surficial water wells. Of the 219 water well records with apparent yield values, 92 have been assigned to aquifers associated with specific geologic units. Thirteen percent (28) of the 219 water wells completed in the sand and gravel aquifer(s) have apparent yields that are less than ten m³/day, 49% (108) have apparent yield values that range from 10 to 100 m³/day, and 38% (83) have apparent yields that are greater than 100 m³/day, as shown in Table 3. In addition to the 219 records for surficial water wells, there are six records that indicate that the water well is dry[17], or abandoned with "insufficient water". In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to each of the six dry holes prior to gridding. The majority of the dry holes are in multiple surficial completions.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Upper Surficial	25	6	12	7
Lower Surficial	67	7	37	23
Multiple Completions	127	15	59	53
Totals	219	28	108	83

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

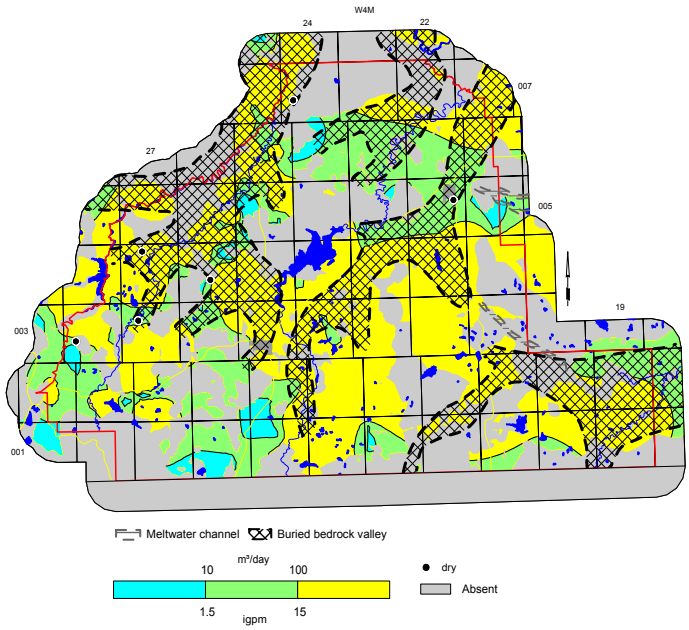

Figure 13. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

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

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

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

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

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

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

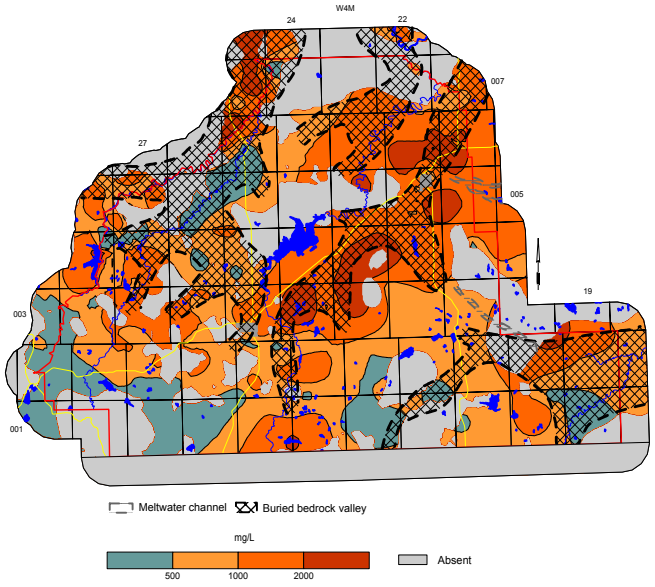

Figure 14. Total Dissolved Solids in Groundwater from Surficial Deposits

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

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

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

Table 4. Concentrations of Constituents in Groundwaters from Surficial Deposits

In the County, the nitrate + nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of ten mg/L in 32 of the 267 groundwater samples analyzed (up to about 1986).

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

[18] See glossary

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers are present within the surficial deposits at no particular depth. Saturated sand and gravel deposits in the upper surficial deposits are not usually continuous over large areas but are expected over approximately 15% of the County.

5.2.3.1 Aquifer Thickness

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

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of high yields for water wells; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the long-term yields of the water wells are expected to be less than the apparent yields. The long-term yields for water wells completed through this Aquifer are expected to be mainly less than those shown on the adjacent figure.

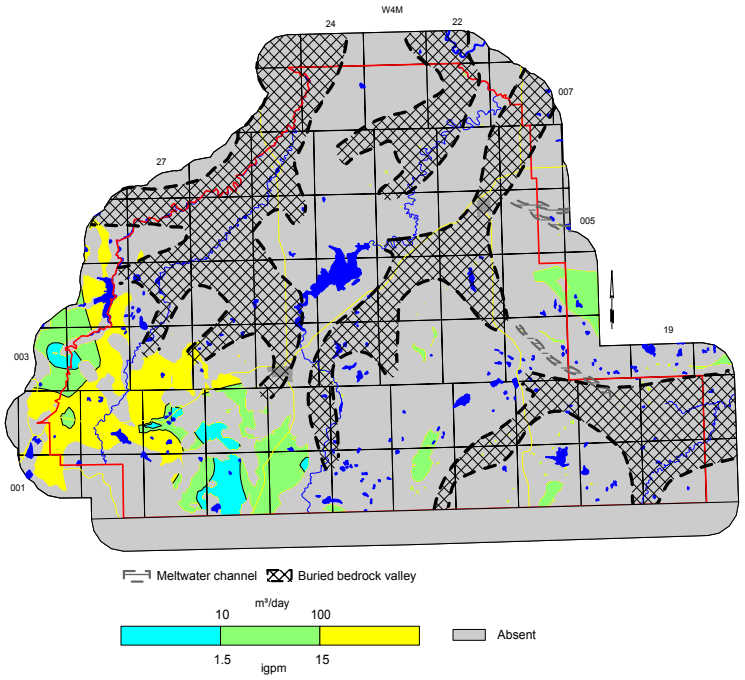

Figure 15. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

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

In the County, there are twenty-one authorized non-exempt water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 43 m^3/day (Table 1, page 6). Twenty of the twenty-one non-exempt authorizations are for registrations for traditional agriculture use under the *Water Act*. Six of the twenty-one authorized non-exempt water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.