



Groundwater Resources of the Lake Saint-Martin Area, Manitoba

Sheet 4 of 6
Hydrogeochemistry

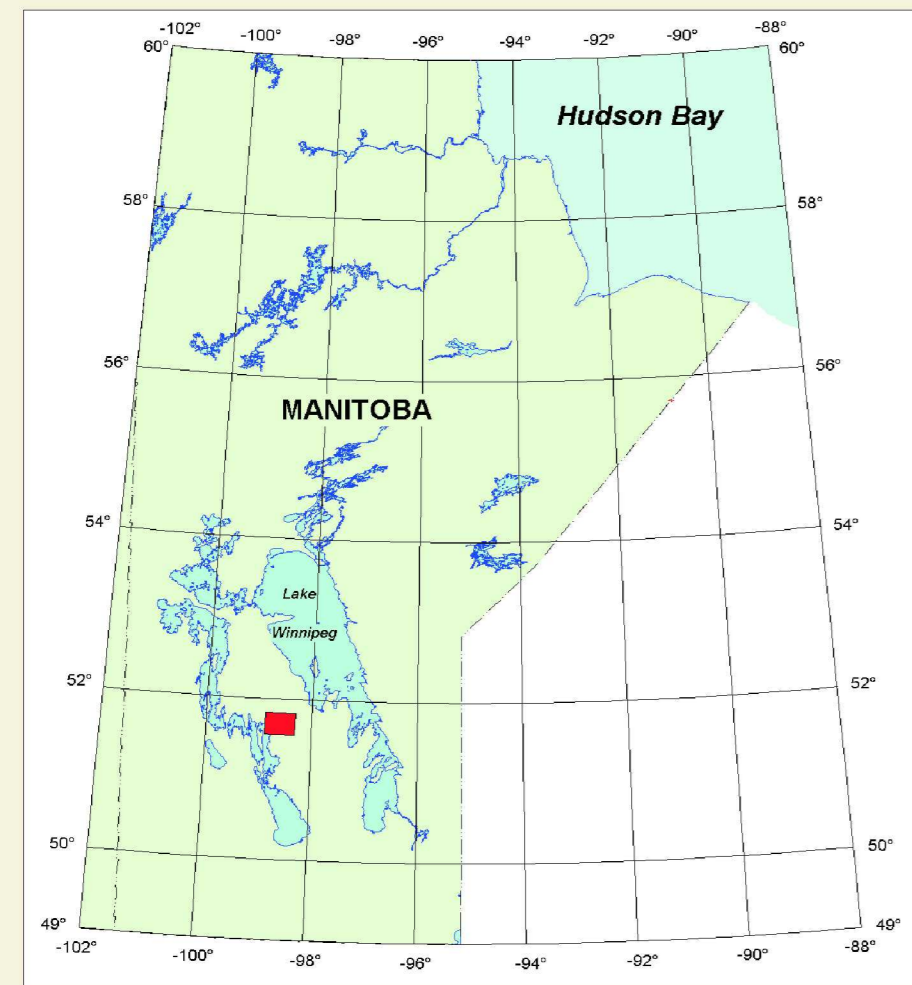
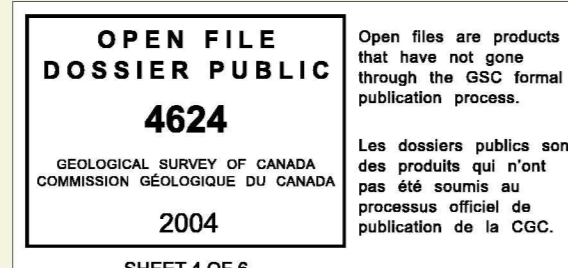


Figure 1: Location of study area

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MAJOR DISSOLVED GROUNDWATER CONSTITUENTS

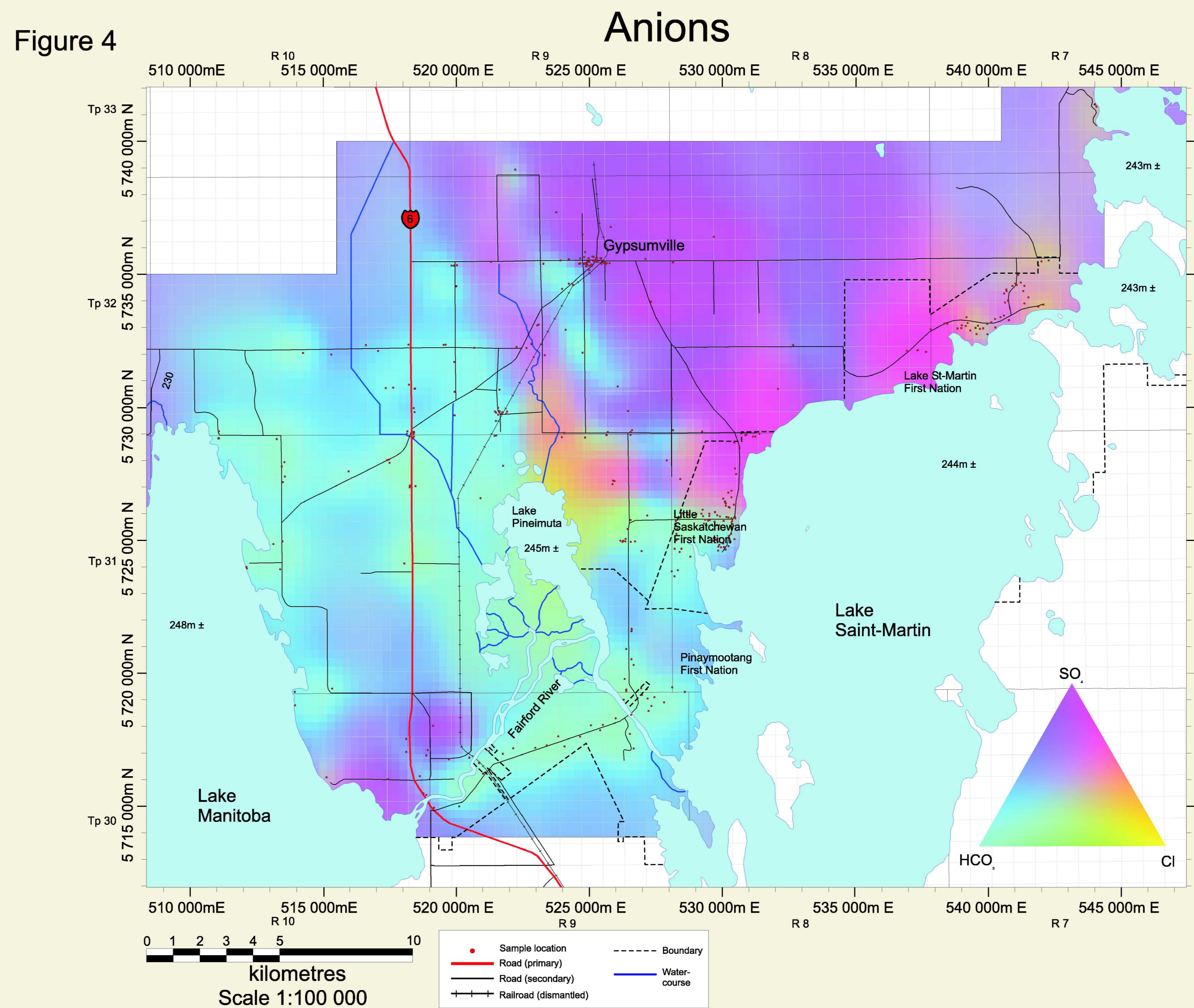
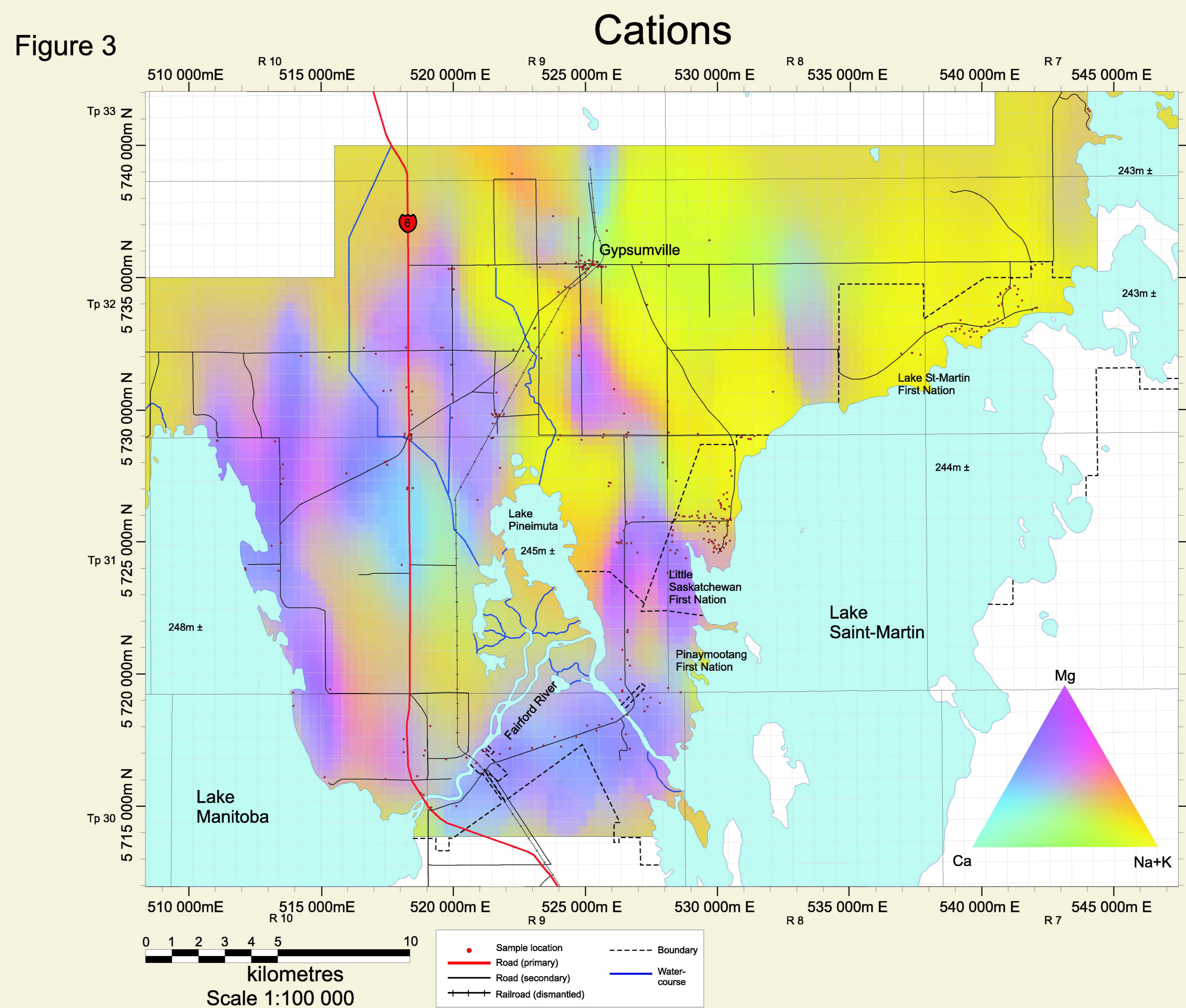


Figure 2

Piper Plot

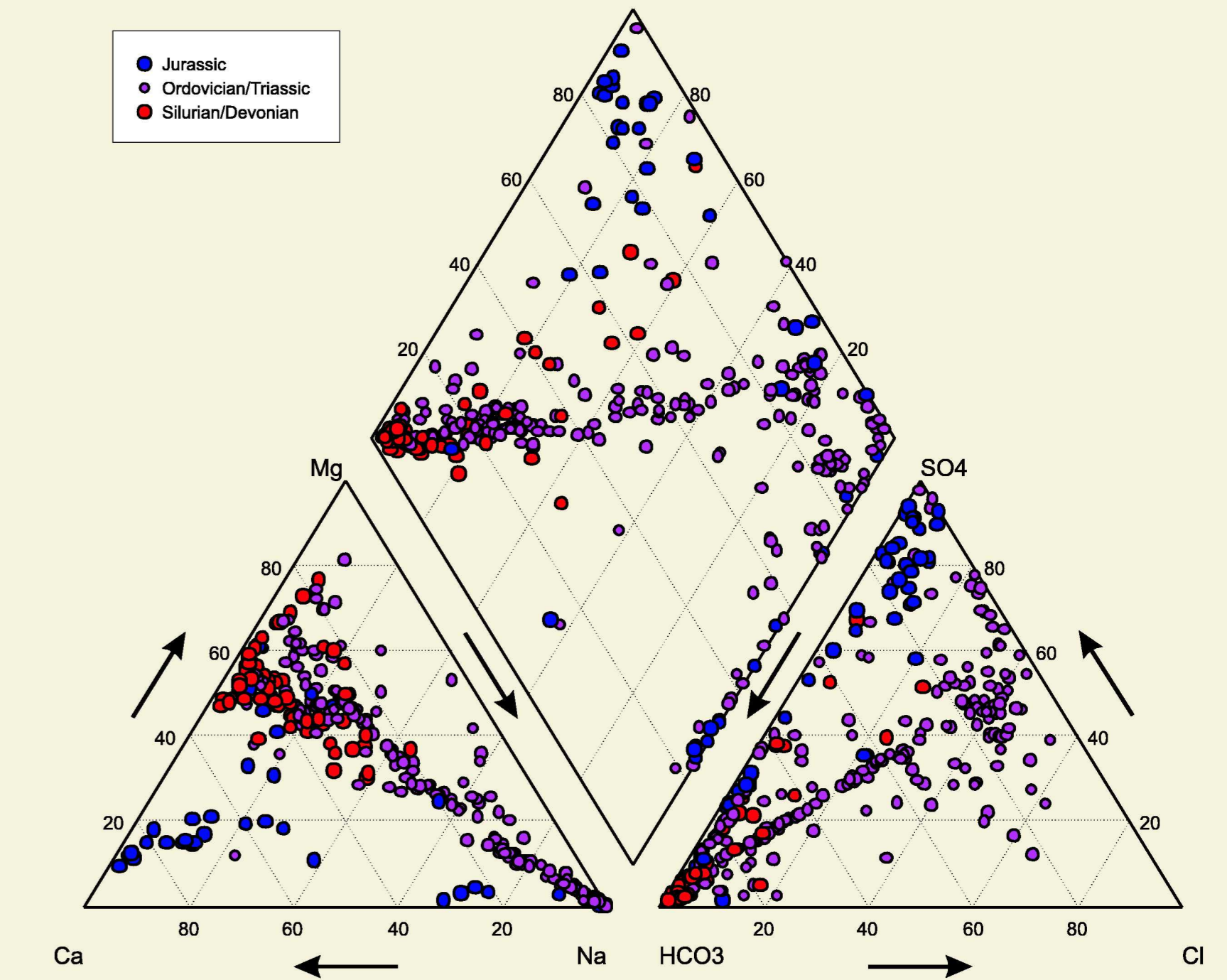


Figure 5

TDS

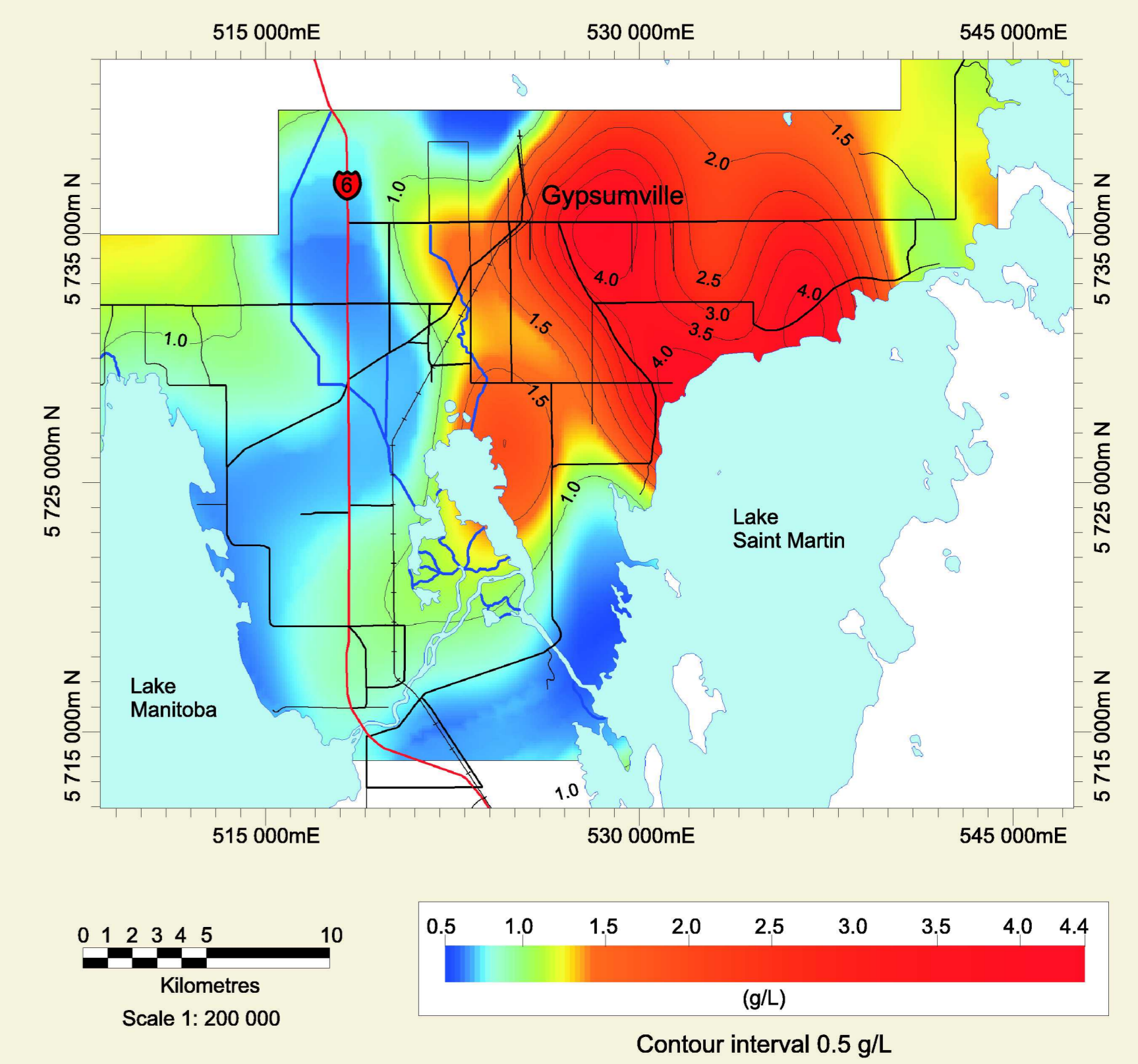
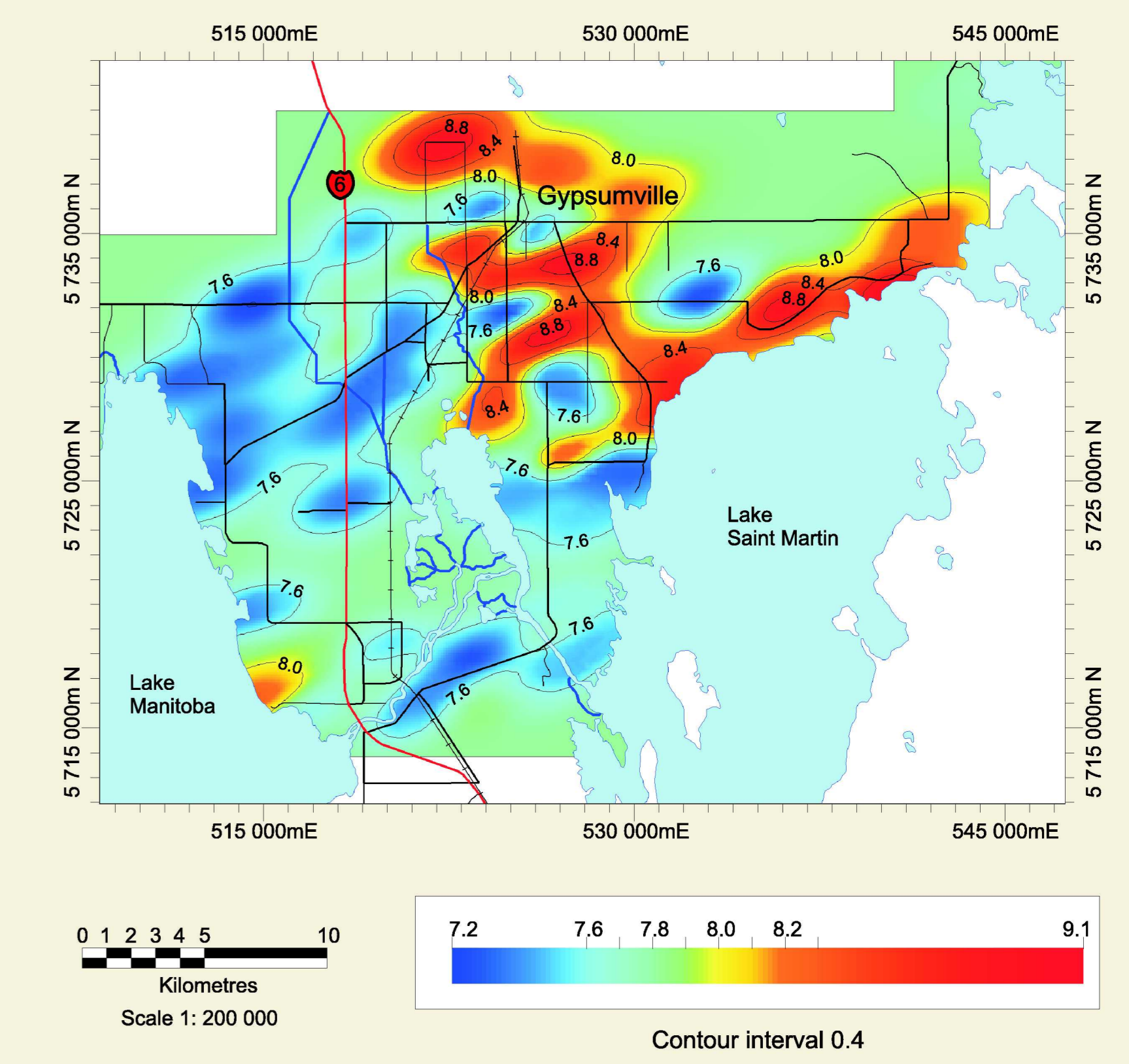


Figure 6

pH



Map Notes

Introduction

The geochemistry of groundwaters in bedrock aquifers of the Lake Saint-Martin area (Figure 1) was mapped previously by Betscher (1987) at a scale of 1:250 000. As part of its detailed groundwater investigations in the area, the Geological Survey of Canada has conducted an extensive sampling of well water chemistry. A summary of survey results for major dissolved constituents and physico-chemical parameters is presented here.

Hydrogeological Setting

The geology and hydrostratigraphy of bedrock aquifers in the study area are described on sheets #1 and #3 of this series. Groundwater flow directions in the aquifers are determined from the map of piezometric levels shown in Figure 2 of Sheet #3. Several shallow, local-scale, flow systems can be identified. Outside the impact structure, groundwater flows from recharge areas on low bedrock ridges in the northwest of the study area and between lakes Manitoba and Pineimuta, toward discharge areas in adjacent lakes and wetlands. Inside the impact structure, groundwater flows south, from karstic uplands north and east of Gypsumville, toward Lake Saint-Martin and Lake Pineimuta. Elevated heads in a deeper regional groundwater flow system may be driving the strong artesian conditions observed in the basin extending north from Lake Pineimuta although the discharging waters themselves are probably derived locally. There may also be some mixing of shallow groundwater with deeper, more saline groundwater in the zone of uplifted and faulted rocks on the margin of the impact structure. Additional insight into the origin, movement and fate of groundwaters in the study area can be gained by the analysis of groundwater chemistry described below.

Hydrogeochemical Facies

All groundwater naturally contains a wide assortment of dissolved constituents in varying concentrations depending on such factors as aquifer geology and travel time in the subsurface. However, only a small number of constituents usually make up the bulk of the total dissolved solids within a groundwater sample. The major cations, or dissolved species with a positive electrical charge, are calcium (Ca²⁺), magnesium (Mg²⁺) and sodium (Na⁺). Potassium (K⁺) is sometimes important also. The major anions, or dissolved species with a negative charge, are bicarbonate (HCO₃⁻), sulfate (SO₄²⁻) and chloride (Cl⁻). Because water is electrically neutral, the total concentrations of major cations and anions must be approximately equal when their concentrations are expressed in units (milliequivalents/L) that take into account their relative electrical charge or valence. The concentrations of individual cations and anions can then be normalized by their total concentration in order to express their relative concentration or fraction. Since there are three major cations and three major anions, these fractions can be displayed using triangular or ternary plots such as those in Figure 2. In this type of figure, known as a Piper plot, a groundwater sample is represented by a point in each of the three fields. The cation composition of the sample is characterized by its position in the left-hand ternary plot whereas the sample's anion composition is characterized by its position in the right-hand plot. The central diamond-shaped plot characterizes the sample's unique association of cations and anions. Typical associations of cations and anions are known as hydrogeochemical facies and they are indicative of the aquifer host rocks and the geochemical processes that take place along the flow path.

The Piper plot in Figure 2 shows the major cation and anion composition of samples from the regional groundwater survey. Samples are assigned a symbol based on three main aquifer types: dolomites of the Silurian Interlake Group and Devonian Ashern Formation; Red beds and evaporites of the Jurassic crater fill deposits; rocks of the crater margins including uplifted Ordovician dolomites and Triassic impact-related breccias. Samples from the first group typically belong to the magnesium-calcium-bicarbonate facies although some mixing with sulfate waters may be indicated. Samples from the second group belong to the calcium-sulfate and sodium-sulfate facies although a small number of samples from Gypsumville belong to the sodium-bicarbonate facies. Samples from the third group are more scattered as a result of mixing with shallow groundwaters of the other two groups. However, they do tend to cluster in the sodium-sulfate-chloride facies.

Figure 3 shows a map of the cation facies, where the inset ternary colour scale expresses the fractions of calcium, magnesium and sodium (lumped with potassium) in each groundwater sample. Figure 4 shows a map of the anion facies, where the ternary colour scale expresses the fractions of bicarbonate, sulfate and chloride in a sample. Groundwaters outside the impact structure typically exhibit low sodium fractions and magnesium/calcium ratios close to 1. The dominant anion is bicarbonate. This association reflects the dolomitic bedrock, the proximity of recharge areas and the generally short flow paths. Within the impact structure, sodium is the dominant cation and sulfate is the dominant anion. However, locally, calcium is an important cation in the outcrop area north of Gypsumville, reflecting the dissolution of gypsum. The elevated sodium fractions may be explained by cation exchange as groundwaters flow through argillaceous red bed deposits and, possibly, by the presence of sodium salts such as glauberite in the evaporite sequence (McCabe and Bannatyne, 1970). On the margins of the impact structure, groundwaters are mainly of the sodium-sulfate type and they exhibit a fairly sharp contact with the magnesium-calcium-bicarbonate waters outside the impact structure. However, Figure 4 shows that there are areas of elevated chloride in the belt of uplifted Ordovician rocks, between Lake Pineimuta and Lake Saint-Martin, and in the impact breccias of the Narrows area north of Lake Saint-Martin. Indeed, samples from these areas belong to the third group identified on the Piper plot in Figure 2, suggesting that more saline water from deeper formations may be mixing with shallow groundwater in the fractured and uplifted rocks on the crater rim.

Total Dissolved Solids

Figure 5 shows that the Canadian Drinking Water Quality aesthetic objective for total dissolved solids (TDS) of 0.5 g/L (Health Canada, 2002) is exceeded throughout the study area. However, TDS concentrations greater than 1 g/L are generally found within the impact structure. Highest levels are found along the flow path extending south-south-east from Gypsumville toward Lake Saint-Martin. A maximum TDS concentration of 7.8 g/L was observed at the southern end of this flow path, in a well on the reserve of the Little Saskatchewan First Nation. Elevated levels of TDS are also found in a lobed region straddling the southern rim of the impact structure and extending toward Lake Pineimuta. This region coincides with a bedrock depression (see sheet 2 of this series) and the chloride-enriched waters apparent in Figure 4.

pH

Figure 6 shows that the pattern of pH variations within the study area is more complex than that of TDS variations. Near-neutral values of pH, averaging 7.5, are found in groundwaters outside the impact structure and in isolated pockets within. However, within the impact structure, pH levels generally approach or exceed 8.5, the upper limit of Canadian Drinking Water Quality aesthetic objectives (Health Canada, 2002). The highest pH value observed in the field (10.83) was obtained from a well located approximately 2.5 km southeast of Gypsumville. Similar values were observed in wells at the north end of the Little Saskatchewan First Nation reserve.

Groundwater alkalinity within the study areas exhibits spatial patterns very similar to those of pH although values are reversed: areas of high alkalinity usually correspond to areas of lower pH and vice versa. The highest observed value of 0.73 g/L was obtained from a well located between Lake Pineimuta and Lake Saint-Martin, to the west of the Little Saskatchewan First Nation reserve.

Map Production Notes

During the month of August in 1998, 384 water samples were collected from wells and streams within the study area. Water well sample locations are marked on the figures. All samples were analyzed for major cations and anions, as well as trace and ultra-trace metal contents. Waters at 42 sites were sampled for stable isotope analyses. Parameters measured in the field include pH, Eh, conductivity, dissolved oxygen and temperature. All survey results are publicly available from the authors at the GSC or from Water Branch of Manitoba Conservation.

Mapping of geochemical parameters was performed using the geostatistical spatial interpolation method known as Indicator Kriging, with the median indicator approximation (Deutsch and Journé, 1992). However, because of the high density of sample locations in more populated areas, a preliminary cell declustering was carried out prior to kriging. This involved pooling all samples falling within the same quarter section (64.64 ha) cell. Interpolation by kriging was then performed on a regular 300m by 300m grid using a single global search neighborhood encompassing all pooled data locations.

It is important to recognize that kriged estimates of geochemical parameters, like those obtained by other spatial interpolation methods, are smoothed compared to actual values. In other words, the maps of geochemical parameters shown here represent general trends in values and not their true spatial variability. Thus, individual well analyses should not be expected to agree exactly with mapped values at the same location. The uncertainty in parameter estimates is lower in the central portion of the study area, where well control is better. However, this uncertainty increases toward peripheral areas. Portions of the study area where uncertainty is unacceptably large are left blank.

References

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