Shell River (05MD)
Integrated Watershed Management Plan:
State of the Watershed Report
Groundwater Resources

Groundwater Management Section
February 2008

Manitoba Water Stewardship

Summary

Most of the groundwater used within the Shell River watershed comes from sand and gravel aquifers. Major sand and gravel aquifers are found at depths ranging between 50 and 100 metres in the Roblin area. Throughout most of the rest of watershed these aquifers will consist of smaller lenses and layers of various sizes. Although not uniformly distributed, these aquifers should meet most domestic needs; well yields are highly variable but average 1.6 L^{-s}.

Water quality from the sand and gravel is highly variable. Total dissolved solids range from less than 300 to more than 2000 mgL^{-1}. The water is usually quite hard with noticeable amounts of iron and or manganese. The dissolved solids are mostly made up of calcium, magnesium, bicarbonate and sulphate.

Bedrock aquifers form a less important source of groundwater within the watershed. The aquifer forming Odanah shale is located in the southern-most part of the watershed, mostly in the Inglis – Shellmouth area. Driller's well yields from the Odanah shale vary between 0.2 and 6 Ls^{-1}; averaging 2 Ls^{-1}. Total dissolved solids are quite high, ranging between 1400 and 1700 mg L^{-1}. The water tends to be quite hard with most of the dissolved solids consist of calcium, magnesium, sulphate and bicarbonate. Sodium is somewhat common and only minor amounts of chloride are measured. Isolated pockets of sandstone are present in the central and northern portions of the watershed. There is little information on the well yield and water quality from the sandstone unit.

Overburden thickness is less in the area where shale aquifers are exploited. The greater the thicknesses of the till overburden will restrict the amount of recharge to underlying aquifers but it will also provide a greater amount of protection to the same aquifers.

There are approximately 1200 well logs within the watershed on file with the province. About two-thirds of these were completed as wells. The province conducted drilling investigations starting in 1964; however, there are currently no active provincial monitoring wells operating within the watershed.

Table of Contents

Introduction

Groundwater, like most natural resources, is the jurisdictional responsibility of the provinces. The transfer of responsibility for water from the federal government to the provinces began with *The Natural Resource Transfer Agreement* in 1930, and although groundwater was not specified, it was assumed to be included. In the same year Manitoba passed the *Water Rights Act* which was consequently amended it in 1959 to include groundwater. The 1959 *Water Resources Administration Act* was established to create a comprehensive water management agency. Shortly after, *The Ground Water and Water Well Act* (1963) passed and was meant to address drilling practices and groundwater data collection. Groundwater is regulated under a number of provincial acts including *The Environment Act, The Water Protection Act, The Health Act, The Drinking Water Safety Act, The Water Resources Conservation Act, The Planning Act, The Water Rights Act, The Ground Water and Water Well Act* and subsequent Regulations.

Early regional studies of groundwater and aquifers in Manitoba were carried out by the federal government. These consisted of door to door well surveys, township summaries of water supply and quality, regional maps of surficial geology, well locations and producing zones. Formal studies of groundwater were initiated by the province in the early 1960's and by the mid 60's the Groundwater Management Section began operating a monitoring well network.

The Groundwater Management Section (GMS) of Water Stewardship advises on groundwater management issues including allocation of groundwater and groundwater protection. The GMS operates a monitoring well network, from which data on groundwater conditions such as water levels and water quality is collected, stored and compiled. Studies meant to address specific aquifer or groundwater concerns have been carried out by the section as have regional groundwater resource mapping. Systematic hydrogeologic mapping was conducted from the 1960's through the 1980's consisting of regional stratigraphic drilling, pump testing, well data and quality compilations resulting in 11 regional groundwater availability map series on a scale of 1:250,000. The Section has also prepared reports on hydrogeology and groundwater resources at various scales including towns, drainage basins, municipalities, planning districts and watersheds over the years.

The Ground Water and Water Well Act and Well Drilling Regulation require that water well drillers be licensed by the province and that the driller supply the province with a report of wells drilled. The report should contain information on date, ownership, the well location, a description of the material drilled, and information on well construction and pump testing if completed. This information is stored within a database in the Groundwater Management Section.

A glossary of select terms used in this report is provided in Appendix A.

Groundwater Backgrounder

Groundwater is water that fills the pores and fractures in the ground. At some point as water recharges the soil and moves down through the profile all of the pore space will be saturated. The surface where this occurs is called the water table. Not only must sediment or rock be saturated to recover groundwater, it must also be permeable enough to allow the water to move at a reasonable rate. Because these properties are largely controlled by the material the water is moving through the geology of the formations are important in understanding water movement. Additionally the natural water quality which the water acquires is highly dependent upon the materials it flows through.

Aquifers and Aquitards

A geologic formation from which economically significant quantities of water flows to a spring or can be pumped for domestic, municipal, agricultural or other uses is called an aquifer. From glacial times on (the Quaternary period of geologic time), aquifers are primarily formed within sand or gravel deposits. Within pre-glacial or bedrock formations, aquifers are formed from sandstone, hard fractured shale/siltstone, permeable limestone, or fractured granitic or metamorphic rocks. . Aquifers can be separated vertically by less permeable layers; layers that do not readily allow water flow or act as barriers to flow. These confining layers are called aquitards and are principally formed from glacial till or clay deposits in Quaternary sediments or by unfractured or soft shale, massive or unfractured limestone, or gypsum in bedrock layers.

During recharge water moves vertically through the soil and shallow geologic horizons until it reaches the water table. The water table can be determined within a shallow dug or drilled hole by allowing the water level to come to a static or resting position. In permeable material the water table forms the top of an unconfined aquifer. In an unconfined aquifer the water table and consequently the amount of water in storage, changes over the seasons or longer climatic periods as water levels fluctuate in response to recharge or discharge from the aquifer.

If an aquifer is situated between aquitards and the water level in a well rises above the base of the upper confining unit the aquifer is called a confined aquifer. In a confined aquifer all of the pore space is filled with water and any addition or reduction of water in storage results in a change of water pressure in the aquifer. When the pressure in the aquifer is above the local ground surface, drilling into this formation will result in a flowing artesian well. Confined aquifers are recharged either at a location of higher elevation where the aquifer is no longer confined or it is recharged slowly, through the layers that confine it.

Groundwater discharge can be dispersed over large areas or focused, such as in springs and commonly discharge areas are topographically controlled. Springs form where the water table intersects the ground surface, commonly in depressions or hillsides, including river banks.

If a higher permeability layer overlies a lower permeability layer on a hillside or river bank the vertical flow of groundwater may be impeded by a low permeability layer causing the water to move laterally to discharge as a spring. Some springs are formed from flowing artesian aquifers where water moves up along fractures or are man-made resulting from unsealed boreholes or blow-outs at the bottom of excavations. Groundwater may also discharge over larger areas resulting in perennially wet areas, bogs or swamps.

Groundwater Flow

Groundwater moves from higher elevation to lower elevation or from higher pressure to lower pressure. The height of the water table or the pressure in an aquifer is called the hydraulic head. The difference in hydraulic head in an aquifer between two locations is used to determine the hydraulic gradient. The groundwater flow direction is from the higher to lower hydraulic pressure along the maximum slope of the hydraulic gradient. Under ambient conditions, groundwater typically moves quite slowly. In a prairie pothole landscape, sloughs will focus recharge into very localized flow systems. In these settings the water table may be high under the sloughs; the amount of recharge coming from sloughs will greatly depend upon the location of the slough in the landscape and the material underlying the slough. The ability for a geologic material to move water is called hydraulic conductivity. The amount of groundwater that moves through a geologic material will depend upon the hydraulic gradient, the hydraulic conductivity and the thickness of the aquifer or aquitard. In unconfined aquifers the water table loosely mimics the surface elevation and in areas of low topographic relief the typical hydraulic gradient is in the range of one metre of water head decline per kilometer distance.

Aquifer Studies and Groundwater Data

The province compiled the groundwater resources on a 1:250,000 map scale for the Duck Mountain (62N) (Sie, 1976) and the Riding Mountain (62) map sheets (Sie, 1978). The Shell River watershed lies largely within the Duck Mountain Groundwater Availability Study area. The provincial also completed the Groundwater Resources in the Roblin Planning District: A Synopsis) (Rutulis, 1986).

The provincial Groundwater Availability Studies include a set of diagrams showing the map sheet location, drift thickness, bedrock topography, surface deposits, a number of cross-sections and a table of selected well water chemistry. The Groundwater Availability series have formed the main regional scale compilation of groundwater data to date. The groundwater synopsis consists of a brief description of groundwater resources and includes maps.

Groundwater Data and Monitoring

The Groundwater Management Section of Water Stewardship maintains a database of well logs for the province. Based on the current data there are 1200 well and test hole records in the Shell River watershed (Figure 1). Almost 850 wells were classified as production wells, and 339 logs are from test holes. The remainder was classified as monitoring wells or other uses. Almost all wells were completed into sand and gravel or as test holes ended in the overburden material. Only 51 logs were reported ending in the bedrock and of these only 24 were reported as developed as production wells.

The Groundwater Management Section drilling investigations began in 1964 and 20 wells were tested (Figure 2). Only one well was completed to monitor water levels, located at NW 36-22-28 W1 in Inglis. Water levels were taken manually during the period of record from 1970 to 1997 (Figure 3).

The province also warehouses groundwater chemistry information from provincial monitoring wells, private wells sampled during various groundwater projects and results that are supplied to the province from drillers or other sources. Only four provincial test wells have chemical analysis. The chemistry from the provincial monitoring wells is available to the public.

Bedrock Aquifers

Bedrock suitable of forming potable aquifers is not present beneath most of the watershed. Only in the southern most portion of watershed, in the Inglis / Shellmouth area, is the aquifer forming Odanah shale present. The Odanah consists of brittle layers of rock separated by layers of softer clay. Fractures can form within the brittle layers which store and transmit water. The soft Millwood shale aquitard underlies most of the remainder of the watershed. There are a few pockets of sandstone reported in townships 26 and 27 ranges 28 and 29. This unit is possibly the same as the formation referenced as the Wynyard Formation in the Duck Mountain Groundwater Availability Study maps and cross-sections.

This sandstone is encountered at depths of 30 to 50 metres depth, below glacial deposits. Well yields from the sandstone reported in driller's logs would be adequate for most domestic needs. Only one field analyses of water quality is on file for the water from the sandstone. The electrical conductivity in that sample was 600 μS/cm.

Driller's well test yields from the Odanah shale vary from less than 0.2 L/s to 6 L/s and average 2 L/s. The total dissolved solids (TDS) of the Odanah ranges between 1,400 and 1,700 mg/L (Figure 4). The dissolved constituents are primarily consist of calcium (Ca), magnesium (Mg), sulphate (SO_4) and bicarbonate (HCO_3) with lesser amounts of sodium (Na) and only minor amounts chloride (Cl). This water is very hard with noticeable amounts of dissolved iron (Fe) and manganese (Mn).

The top of the Millwood shale should adequately define the base of potable groundwater exploration throughout most of the watershed. Most bedrock below this will be increasingly brackish or saline. The exception to this may be near deep valleys where the Millwood may be eroded and underlying bedrock is closer to the surface and forms part of a local flow system of meteoric water recharged in highlands and discharging to valleys.

Valleys cut into the bedrock may contain permeable sediment. Extensive erosion and deposition prior to glaciation formed aquifer systems such as the Hatfield Valley which has been quite well defined on the Saskatchewan side of the border. These valleys may be infilled with Tertiary age sediments and / or Quaternary (glacial) sediments. The extension of the Hatfield Valley in Manitoba lies between Roblin and Russell but has not been well defined. The glacial Assiniboine River has cut into the underlying bedrock during glacial melt; the lower portion has been infilled with alluvial sediments.

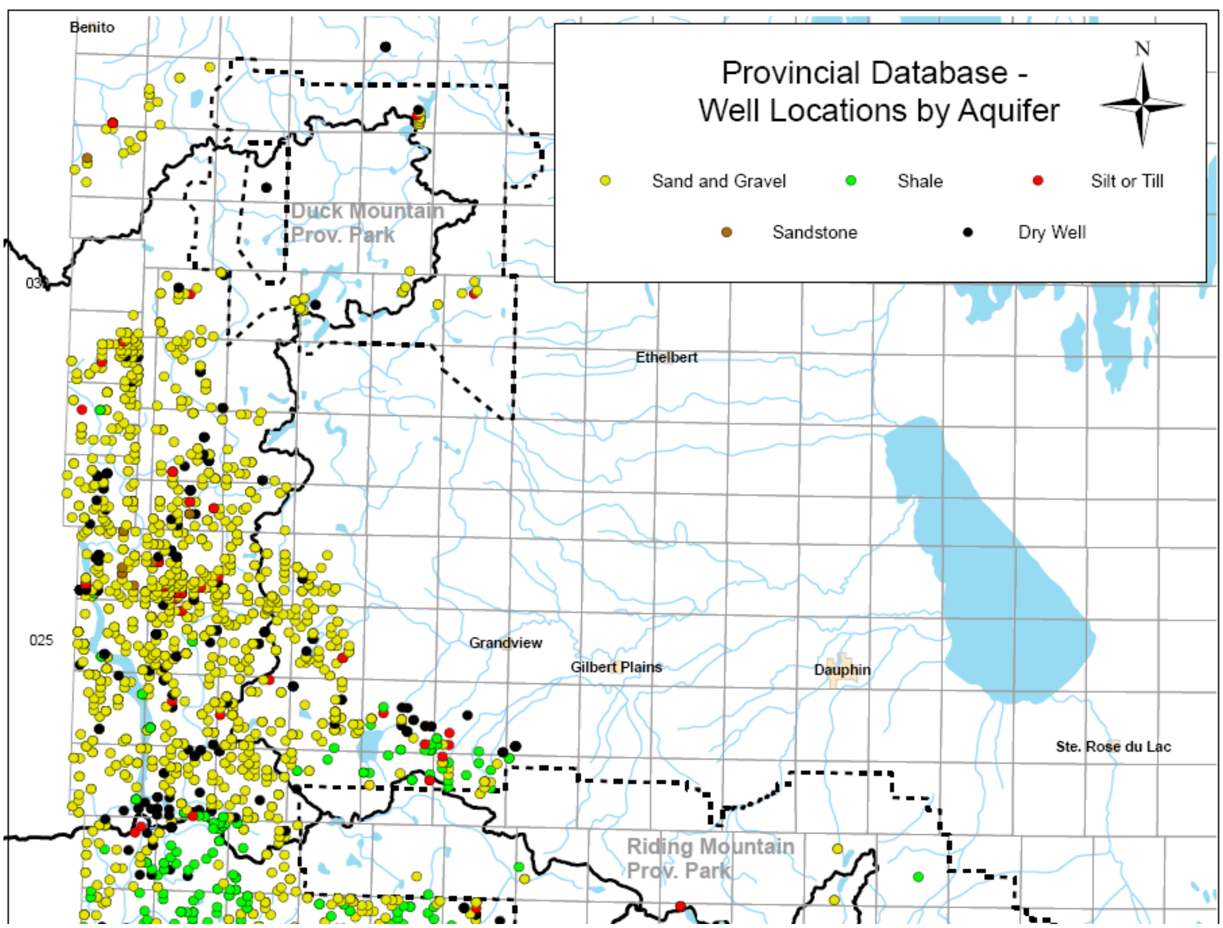

Figure 1. Well log locations from the provincial well database coded by aquifer material in which the borehole ended or was completed into. Wells are displayed in the centre of the quarter-section in which they are drilled unless more accurate information is available. Multiple wells may be stacked at any one location.

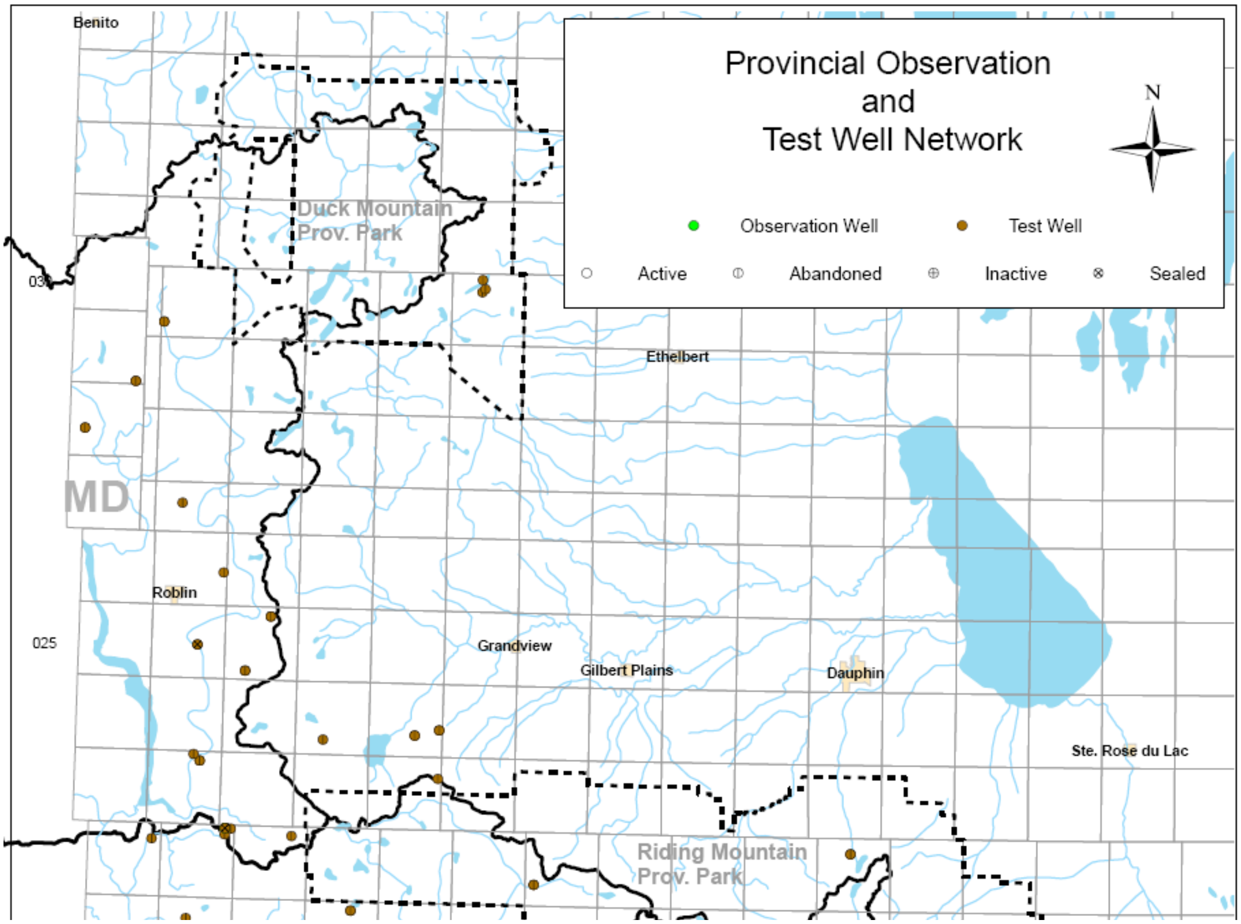

Figure 2. Location of Groundwater Management's drilling activity including status for the watershed and surrounding area. There are currently no active stations in the watershed; inactive stations have collected observations during some period in the past; sealed wells are wells that have recently been sealed with an available well sealing log; method of abandonment is not available for abandoned holes but common practices at the time of abandonment most likely would have been used.

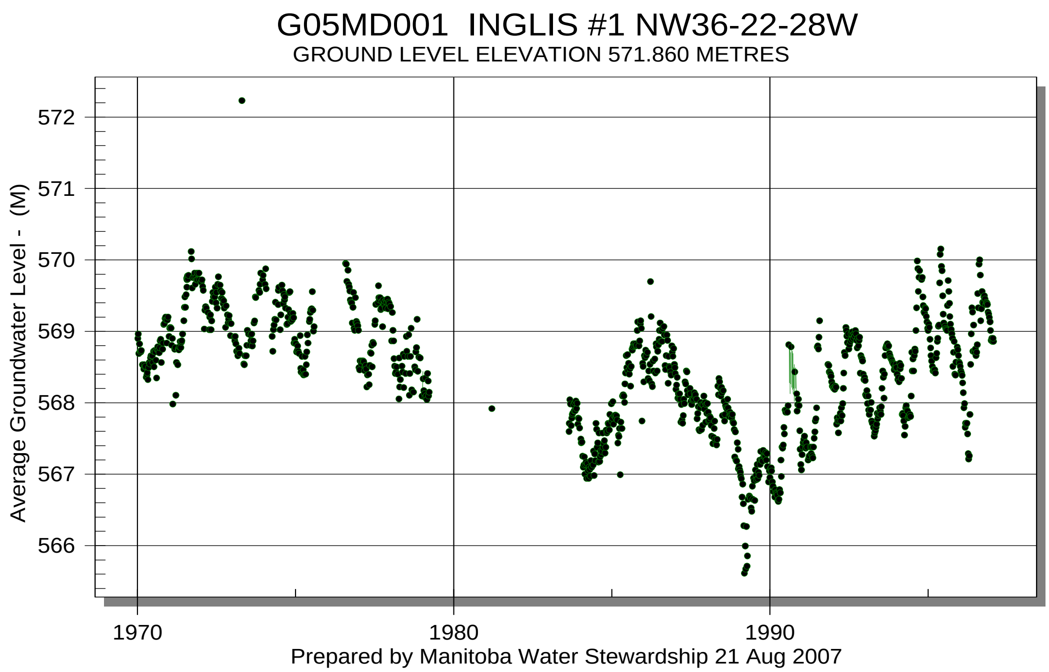

Figure 3 Groundwater elevations were manually monitored at station G05MD001, located at Inglis. This station operated from 1970 to 1997 and is completed into shale with perforations between 47 and 65 metres below ground into shale.

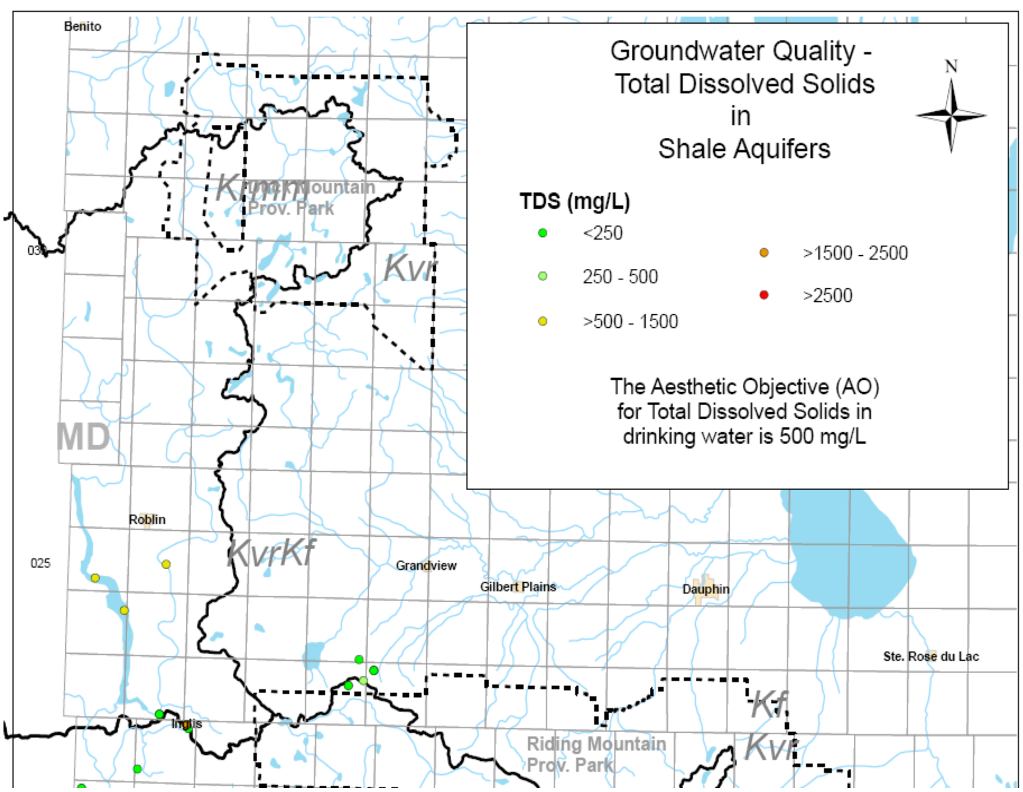

Figure 4. Display of total dissolved solids (TDS) in groundwater from shale wells within the watershed and surrounding area; few samples are available from within the watershed.

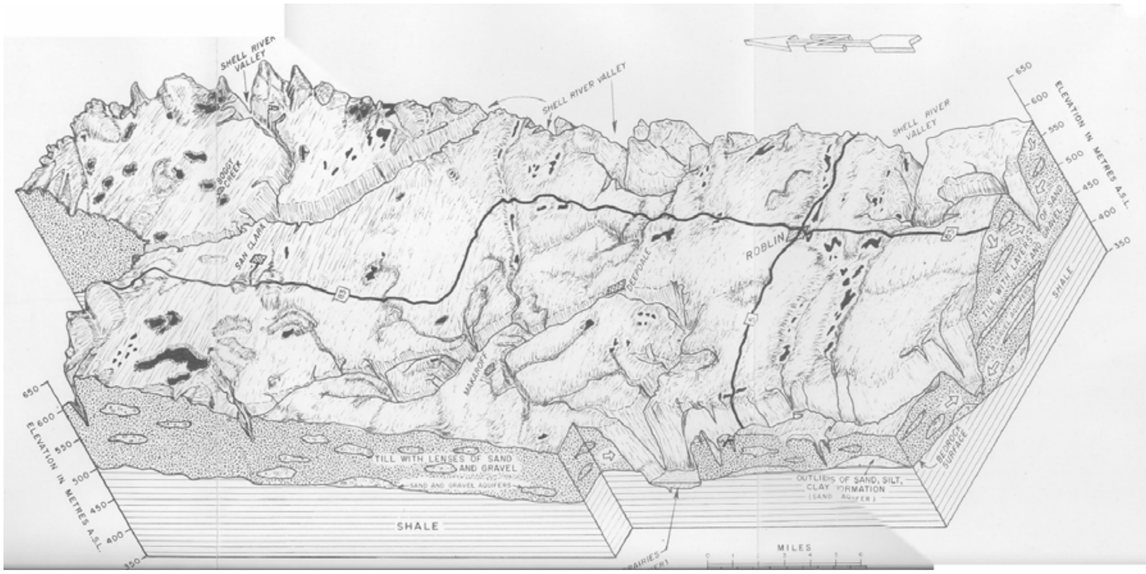

Figure 5. Block Diagram of the Roblin planning district showing a schematic depiction of sand and gravel aquifers in the area (Rutulis, 1986). Arrows indicate a generalized flow of fresh water into deeply incised valleys. Recharge to confined sand and gravel aquifers will be highly dependant upon the characteristics of the overlying glacial till.

Sand and Gravel Aquifers

Within glacial and recent sediments aquifers are formed as sand and gravel within or at the base of glacial till, surface or near surface outwash or alluvial sand deposited from modern or ancient rivers. Major buried sand and gravel aquifers are present within the central portion of the watershed and from Roblin to the southern boundary of the watershed. Within the Roblin area these aquifers are common from depths ranging between 50 to more than 100 metres (Figures 5 & 6). At some locations high capacity wells can likely be developed. Within the remainder of the watershed aquifers will consist of lenses or layers of various sizes within the glacial till. The recharge rate to most confined sand and gravel aquifers will be highly dependant upon the properties of the overlying glacial till material. Thicker till units will restrict the recharge rate but will provide a greater amount of protection to the underlying aquifers (Figure 7).

Alluvial aquifer deposits of silt, sand and gravel are associated with rivers and streams such as the Assiniboine River. These deposits will be restricted to each valley. Materials in alluvial deposits are commonly quite variable in vertical and horizontal extent. In this type of setting there may be interconnection between groundwater and surface water.

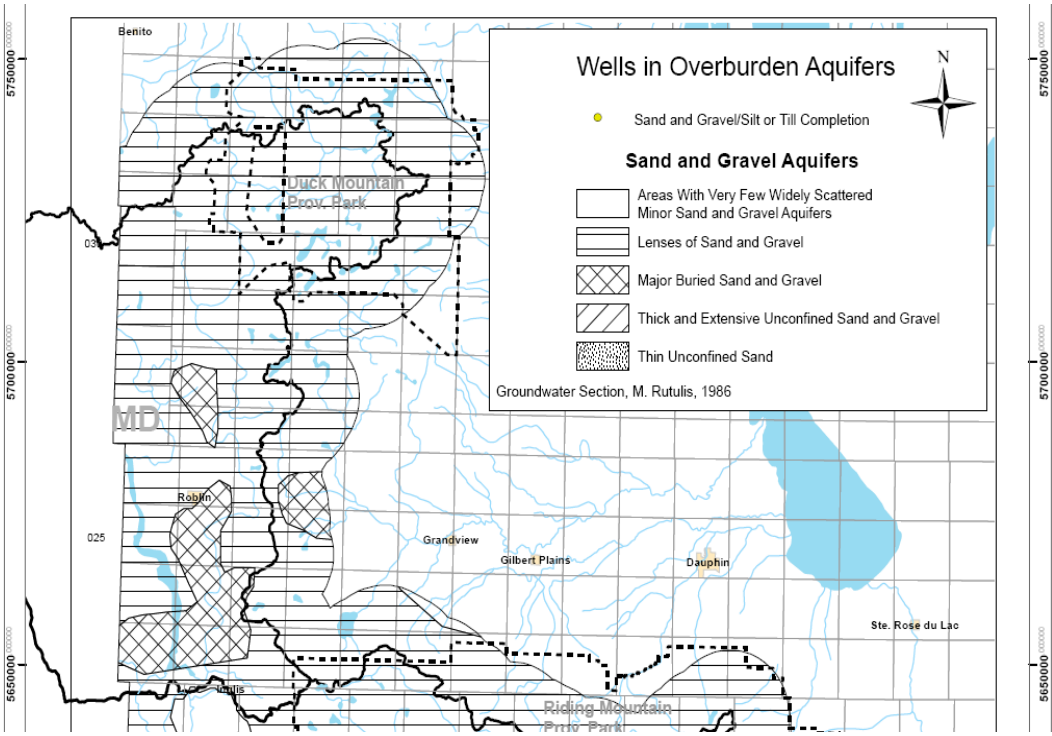

Figure 6. Diagram showing locations of major sand and gravel areas and where minor or scattered smaller aquifers are expected (after Rutulis 1986).

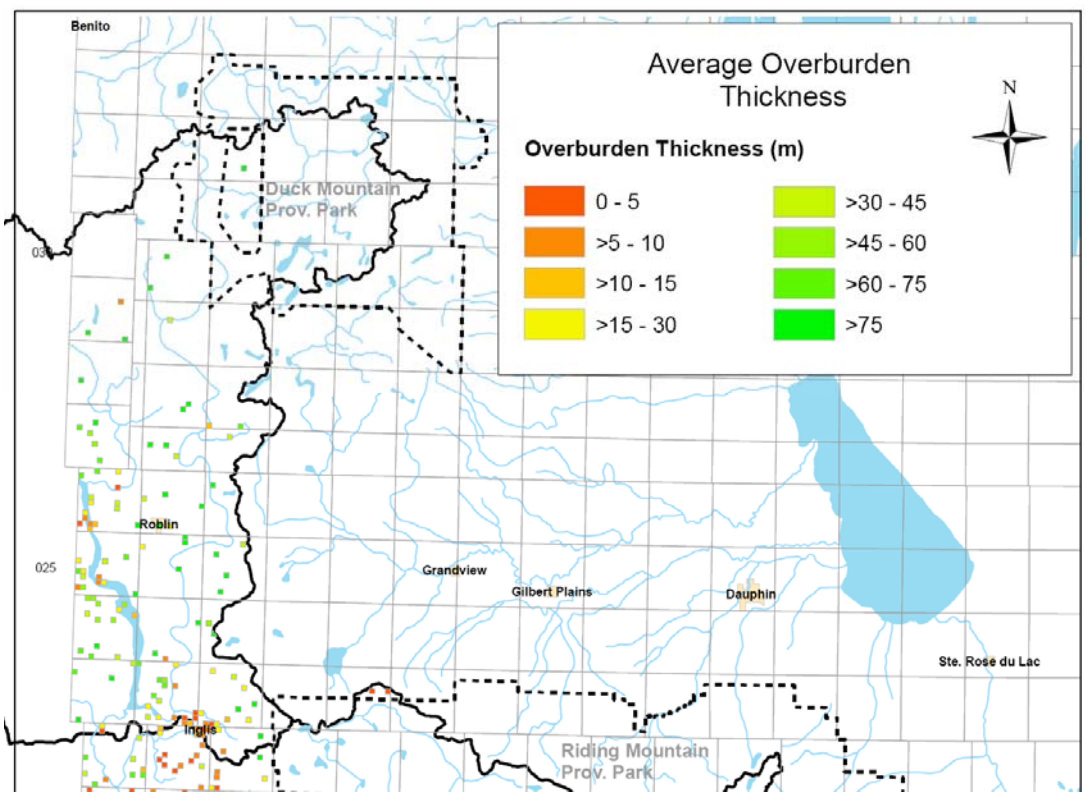

Figure 7. Diagram showing the average overburden (drift) thickness where bedrock was encountered in a drill hole. Throughout most of the watershed the overburden is greater than 30 metres.

Most sand and gravel aquifers (Figure 1) are accessed by drilled wells and only about ten percent of the wells recorded are wide diameter. Wide diameter (bored) wells are most commonly used where the well yield in shallow aquifers is low and additional storage within the well is required. Sand and gravel aquifer well yields are variable, but generally quite adequate for individual domestic uses. The average well yield reported from drillers is 1.6 Ls^{-1}. The average total depth of wells completed into sand and gravel aquifers is 40 metres and the average depth to the top of the aquifer is almost 20 metres; although, these depths are highly variable.

Because of the wide variety of aquifer depths and conditions the chemistry of water from sand and gravel aquifers is also highly variable. The total dissolved solids (TDS) ranged from less than 300 mgL^{-1} to greater than 2,000 mgL^{-1}, with an average concentration around 840 mgL^{-1} (Figure 8). There is not a simple relationship between well depth and TDS of the water; relatively shallow water can have as high dissolved content as groundwater from much deeper aquifers. The hardness averages around 660 ppm $CaCO_3$ with a range from less than 100 to 4,000. Values greater than 200 are considered poor for drinking water and values over 500 are generally considered undesirable for most domestic purposes. The dissolved solids predominantly consist of calcium (Ca), magnesium (Mg), bicarbonate (HCO_3) and sulphate (SO_4) with a lesser number of samples with higher proportions of sodium (Na) and chloride (Cl).

Approximately four percent of the 57 nitrate measurements are above the drinking water guideline of 10 mg nitrogen per litre. Measurable values of nitrate are more common in the shallower wells; however some nitrate was measured in wells up to approximately 50 metres total depth.

Total coliform bacteria are commonly detected in private well water. The presence of coliform bacteria is an indicator that the factors may exist where there are pathways for well water to be contaminated with water from the ground surface or from near surface. Twelve percent of the 26 samples had detectable coliforms. E. coli is an indicator of contamination from a fecal source; 6% of 31 samples had measurable E. coli. Well owners that have had positive coliform results need to assess their well for security and maintenance. Fact sheets are available from the province to help in sampling and interpreting the results of tests.

Over 50% of the samples exceed the aesthetic objectives for iron (0.3 mgL^{-1}) and manganese (0.05 mgL^{-1}), 10% exceed the aesthetic objective of 500 mgL^{-1} for sulphate; fluoride was below the guideline value in all results. There are very few analyses of complete chemistry; only two samples include comprehensive metal analysis. Aluminum, antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, selenium, uranium and zinc were all below drinking water guideline concentrations in both these samples.

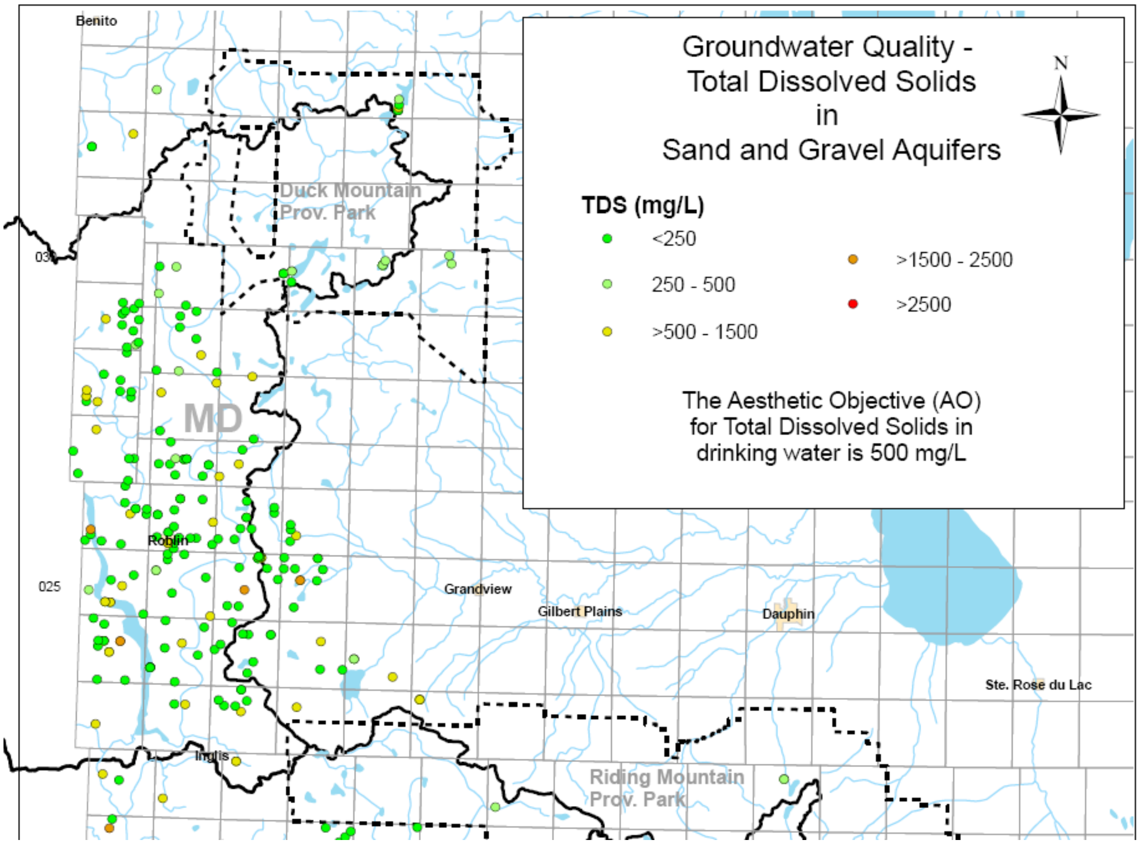

Figure 8. Distribution of total dissolved solids (TDS) in sand and gravel aquifers. TDS is a measure of the minerals and salts dissolved in the water; most groundwater has relatively low concentration.

Groundwater Use

Driller logs specify the intended water use for new production wells; well use can be recorded as single or multiple uses. Within the Shell River watershed the following water uses are recorded (Figure 9): 495 domestic, 49 livestock, 247 combined domestic and livestock, 10 municipal, 9 industrial, 11 irrigation and other uses. Over 90% of the wells provide water to private domestic uses.

Figure 10 shows the historic record of well drilling activity within the watershed. Based on the provincial well database, the greatest number of wells was drilled during the 1970’s. It should be noted that reporting well logs has only been a requirement since the mid 1960’s. Well logs on file prior to that time have come from a number of sources.

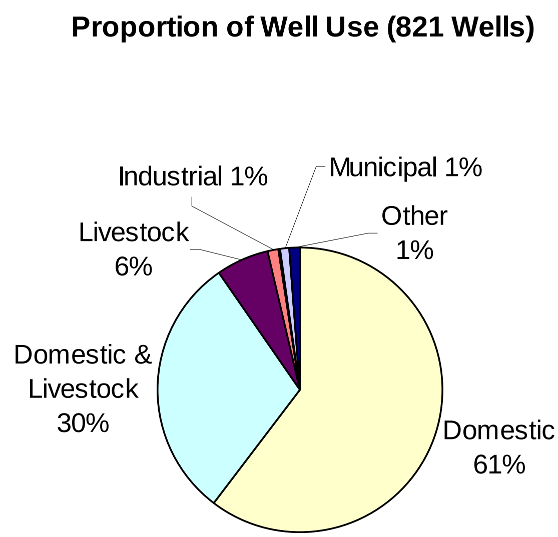

Figure 9. Proportion of production well use within the watershed: 91% of the wells provide private domestic water supplies.

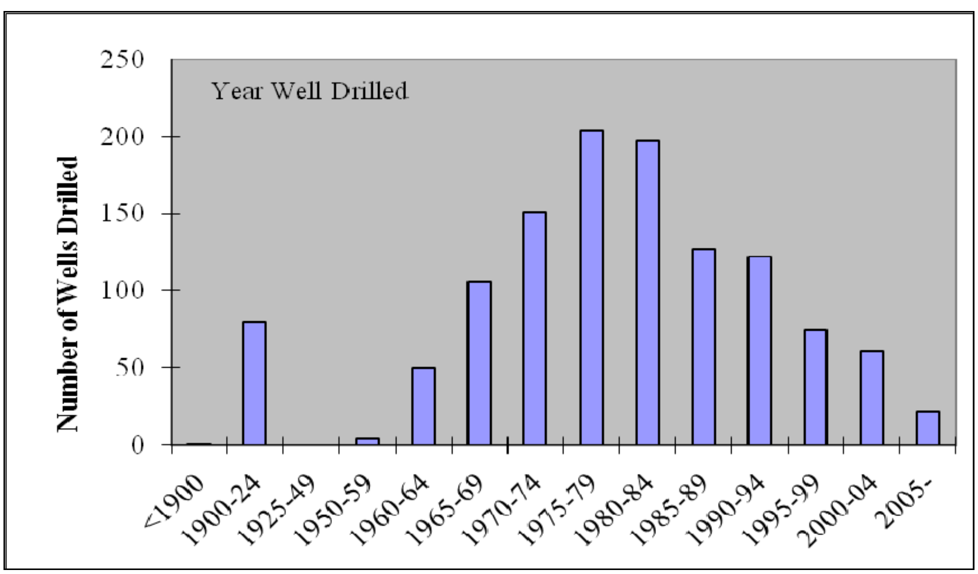

Figure 10. Proportion of well use within the watershed: 91% of the wells provide private domestic water supplies.

Availability of Data and Information Gaps

Well log and groundwater information is stored by the Groundwater Management Section. Results from past well surveys indicate that only about half of the wells in service are recorded and the accuracy of the location of the majority of wells is to the quarter section on which it is drilled. Wells are often located in areas of convenience, in the same general areas as potential contamination sources and neglected, abandoned or unused wells can act as a direct conduit for contaminants from the surface to enter aquifers. Abandoned, unused wells located in these areas should be sealed to lessen the potential spread of contaminants to an aquifer. The knowledge of accurate well location is an important step in identifying sites for future well sealing. The province does not have access to well surveys conducted by other organizations; additional information on wells and locations would be beneficial in managing the provinces groundwater resources.

Groundwater forms the baseflow to streams. When run off from the land surface ceases the water sustaining the flow the streams comes from groundwater. The contribution of baseflow to streams and rivers has not been well quantified nor has any water quality impact from these waters.

The province has undertaken groundwater investigations within this watershed resulting in a number of test holes being completed; however, there currently are no groundwater monitoring points established. There is also a lack of information on many water quality parameters for some of the groundwater sources.

Issues, Concerns and Recommendations

- Shallow aquifers and aquifers of limited extent will be more prone to prolonged droughts.
- High use groundwater withdrawals require assessment on an individual project basis.
- In cooperation with CD a well inventory should be completed. It should include a well inventory, GPS coordinates, information on construction and rudimentary water quality.
- Comprehensive groundwater chemistry is lacking from this area including many solutes with drinking water guidelines. This could be completed on wells selected during the well inventorying process.
- The Groundwater Management Section is currently evaluating the provincial monitoring well network to determine where there are redundancies or areas that could benefit from new or additional monitoring locations. This watershed will be included in that evaluation.

- Regional scale stratigraphic and hydrogeologic mapping and compilation would be beneficial in providing an increased knowledge of the extent, properties and relationships between stratigraphy, aquifers and surface water.
- The Groundwater Management Section is committed to completing new set of digital maps based on the watershed scale.

Vulnerable Groundwater Areas / Well-head Protection

Previous well surveys by Manitoba and other provinces show that well location, construction and maintenance are important factors in man-made water quality problems. Many of the parameters measured that lead to less than desirable potable water quality such as TDS or hardness, occur naturally and not the result of man's influence on the environment. However there are local impacts commonly measured in well water throughout the province and the watershed authority should encourage owners of private wells to self-assess or have their well assessed for physical conditions that may affect water quality such as poor wellhead conditions, well construction, location or maintenance. Water testing should be encouraged for all drinking water sources on a regular basis.

Community or municipal wells require well specific assessment to determine the vulnerability during the development of well head protection policies. As a minimum the individual characteristics of each well, aquifer and geology should be considered to assess vulnerability.

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Appendix A

Definition of Terms

Definitions

Alluvial	Sediment deposited by running water.
Aquifer	A porous and permeable geologic formation that is saturated and capable of producing useful quantities of water to wells or springs.
Aquifer, confined	An aquifer that is overlain by a layer of material with considerably lower permeability. The water within the aquifer is under pressure so that it rises above the top of the aquifer material in a well drilled into the aquifer; synonym: artesian.
Aquifer, unconfined	An aquifer where the water table forms the upper boundary.
Aquitard	A saturated low permeability unit that does not yield water readily.
Bedrock	Material that is older than the Quaternary period; it may be very well consolidated (rock) or only poorly consolidated.
Drift	or glacial drift = glacial deposit
Hardness	A property of water that reduces the effectiveness of soap. It is primarily caused by calcium and magnesium ions; expressed in ppm (parts per million) $CaCO_3$, or as gpg (grains per gallon U.S.) where one gpg equals 17.1 ppm.
Hydraulic conductivity	The rate that water moves through water is able to move through a permeable material.
Hydraulic gradient	The change in hydraulic head over a given distance in a direction which produces the maximum rate of decrease of hydraulic head.
Hydraulic head	The total water pressure, generally expressed as elevation.
Lacustrine sediment	Sediment deposited within lakes.
mg/L	milligrams per litre; a common unit of measure for solutes in most groundwater, it is equivalent to a part-per-million.
Outwash	Stratified sand and gravel washed out from a glacier by meltwater streams and deposited in front of an active glacier.
Overburden	Unconsolidated material overlying bedrock. In Manitoba overburden is derived during glaciation or more recent time.

Permeability	The property or capacity of a porous rock, sediment or soil to transmit water, it is a measure of ease that water will flow.
Quaternary	The period of geologic time most noted for glaciation beginning between 2 and 3 million years ago and extending to the present.
Specific capacity	It is an expression of the productivity of a well obtained by dividing the rate of discharge of a well per unit of drawdown during pumping.
Total Dissolved Solid	(TDS) a measure of the concentration of dissolved minerals in water expressed in mg/L or ppm.
Water table	The surface where all the pore space is filled with water and can be observed by measuring the water level in shallow wells installed into the zone of saturation.
Well yield	The volume of water discharged from a well, frequently determined during short-term pump tests immediately after drilling the well.