GROUNDWATER RESOURCES OF THE

FISHER RIVER WATERSHED

GROUNDWATER MANAGEMENT SECTION

WATER SCIENCES & MANAGEMENT BRANCH

MANITOBA CONSERVATION & WATER STEWARDSHIP

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THE FISHER RIVER WATERSHED

The Fisher River Watershed is located in the Interlake Region of Manitoba bordering the west shore of Lake Winnipeg (Figure 1). The watershed area is made up of the Fisher River, Moose Creek and several smaller streams, which drain into Fisher Bay on Lake Winnipeg.

The Peguis Reserve is the largest population centre in the watershed and is also the largest First Nations community in Manitoba with a population of about 7340. The nearby Fisher River First Nation has a population of 1710 on the reserve, and 1390 in surrounding areas. Other communities in the watershed include the village of Fisher Branch (pop 450), Pine Dock (pop 110) and Matheson Island (pop 120). Land use includes agriculture, forestry, peat mining, aggregate mining and recreation, including cottages on Lake Winnipeg. Large areas of the watershed are covered by forest and wetlands. Fisher Bay Provincial Park, located on the islands and shores of Fisher Bay, has a back country designation.

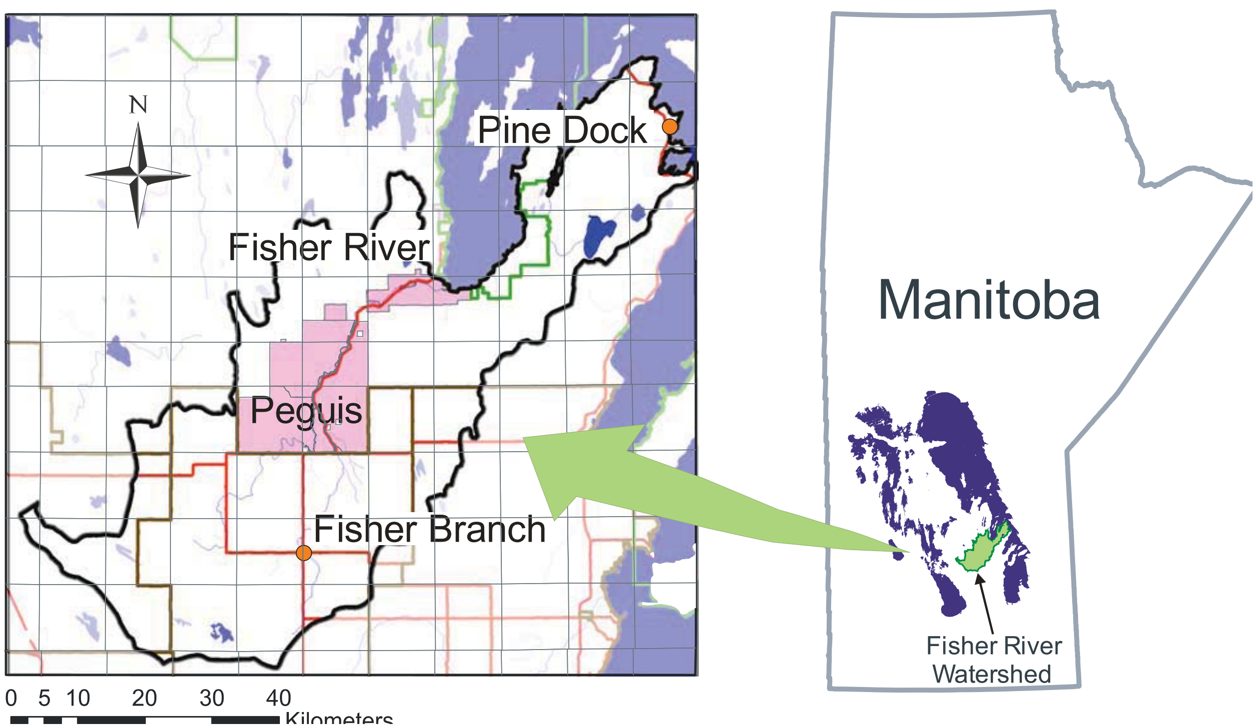


Figure 1. Location of Fisher River Watershed

The watershed has subdued relief, with a high point of 292 metres on its border west of Fisher Branch, to a low of 217 metres at Lake Winnipeg (Map #1). The elevated southwestern part of the watershed is above 245 metres and contains most of the agricultural lands and the village of Fisher Branch. The uplands terminate just northeast of Fisher Branch along a series of low, flat-topped limestone ridges between 245 and 255 metres elevation, which include Marble Ridge, Horseshoe Ridge and Sylvan Hill (Map #1). The ridges slope to the northeast, and Marble Ridge has a few small cliffs.

Most of the watershed is below 245 metres. The community of Peguis sits at 230 metres elevation, and the communities of Pine Dock and Fisher River are just a few metres above Lake Winnipeg. The lower reaches of the Fisher River and adjacent settlements are prone to flooding (AECOM 2009).

The land on the east side of Fisher Bay is low lying, and is often only several metres above Lake Winnipeg. This area is covered by bog, fen and swampy forest.

GEOLOGY AND AQUIFERS

OVERVIEW

In the Fisher River Watershed, geology includes drift materials, and the underlying limestone and dolomite bedrock.

Drift, or overburden, is the unconsolidated material found between the land topographic surface (Map #1) and the bedrock topographic surface (Map #2). Most of the drift was laid down by glaciers and is made up of units of clay till, clay and silt lake bottom sediment, sand beach ridges and glaciofluvial deposits. Some of the drift was deposited after glaciation in the form of peat and other swamp accumulations in low lying areas, and streambed sands and gravels, particularly along the Fisher River.

The thickness of the drift can range from 0 to 50 metres, but is mostly within the range of 5 to 20 metres (Map #3). In parts of the northeast and southeast, it is less than 5 metres, while in the southwest it may exceed 35 m. Drift is less than one metre thick and bedrock may be exposed in along the limestone ridge area found near Fisher Branch and Hodgson.

Within the watershed, drift is not a significant source of groundwater. In most situations the thickness of drift tells us the minimum depth we would need to drill before hitting prospective aquifer material in the bedrock. Pockets of thicker than normal drift are created by sinkholes, which pit the bedrock surface. They are too small in area to appear on the bedrock topography or drift thickness maps, but are locally significant.

The bedrock topography (Map #2) mostly resembles the surface topography. Bedrock consists of Paleozoic formations of carbonate rock, mostly limestone and dolomite of the Interlake Group, Stonewall Formation, Stony Mountain Formation and the Red River Formation (Map #4). Beneath the carbonate rock is Paleozoic sandstone of the Winnipeg Formation. The Winnipeg Formation rests on Precambrian igneous and metamorphic rock of the Canadian Shield (Figure 2).

The Formations dip toward the southwest. This causes the total thickness of carbonate rock to increase from just a few metres near Pine Dock to about 250 metres west of Fisher Branch. The depth through bedrock to the Winnipeg Formation top increases by the same amount, and the depth to the top of the Precambrian increases from less than 50 metres to about 290 metres.

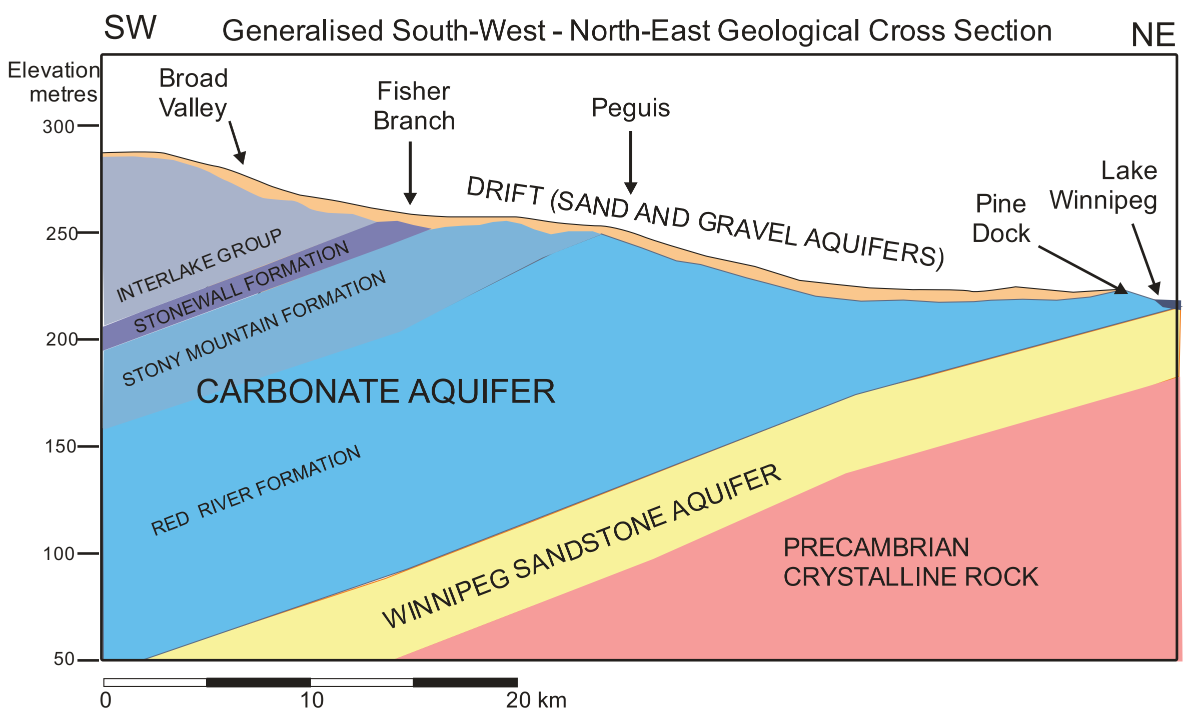


Figure 2. Generalised Regional Cross Section

Aquifers are geological units which are porous and permeable enough to supply appreciable amounts of water to well. They usually conform to geological formations, but are also controlled by variations in porosity and permeability.

Porosity is the void space where water is stored and permeability is the interconnectedness of the void space which allows water to migrate toward a well. Porosity and permeability are related to geology and are enhanced by fracturing, weathering or dissolving of the rock, or may be reduced by compaction.

Geological formations with good porosity and permeability will readily supply water to wells and are consequently good aquifers. Important aquifer materials include sand, gravel, sandstone and limestone. Aquitards are geological units that have insufficient porosity and permeability to supply a well, but will still allow water to pass. These include clay, shale, salt layers and granite.

Three types of aquifers are found in the Fisher River Watershed, all related to previously described geological units. They are near surface sands and gravel aquifers, the Carbonate aquifer and the Winnipeg Sandstone aquifer. The Precambrian crystalline rock is not an aquifer in this area. The Carbonate aquifer is the most commonly accessed aquifer unit. It is a regional unit, which is found widely throughout the watershed. The Winnipeg Sandstone aquifer is found throughout the area, but is found at shallow depths where it can be easily accessed only along the shore of Lake Winnipeg. Sand and gravel aquifers are found in a few locations and are of limited extent. The aquifers are described as follows:

SAND AND GRAVEL AQUIFERS

Map #5 shows the distribution of wells completed in sand and gravel aquifer. Sand and gravel deposits may be found as surface beach ridges, or as glaciofluvial units within or at the base of drift. Most of the wells are scattered across the central part of the watershed. Well depth ranges from 8 m to 38 m. This variability corresponds to drift thickness. Drift thickness is significant because there are more chances to encounter sand or gravel unit as drift thickens. Drift thickness is controlled by surface topography and by irregularities in the underlying bedrock surface. Well yields in the sand and gravel aquifers vary from 25 to 135 L/min (5 to 30 igpm). In general water quality is good.

In Fisher River Watershed there has been little exploration or development of sand and gravel groundwater sources and no major aquifer units have been identified. Sand and gravel aquifers are hit and miss, often of limited extent and have uncertain long term yields because of their small size. In contrast the underlying Carbonate aquifer is regionally available and has fairly reliable yields, making it the preferred target of well drillers.

CARBONATE AQUIFER

The Carbonate aquifer consists of limestone and dolomite bedrock. The Aquifer incorporates the Interlake Group and the Stonewall, Stony Mountain and Red River Formations, which subcrop at the base of the drift.

The aquifer has a wedge shape with a thickness of 250 m in the western part of the watershed thinning to just a few metres along the shore of Lake Winnipeg near Pine Dock. It is found at the base of drift throughout the watershed. The depth to the top of the Carbonate aquifer is equivalent to the drift thickness (Map #3). The surface elevation of the Carbonate aquifer is equivalent to the top of bedrock (Map #2). The Winnipeg Sandstone aquifer forms the base of the Carbonate aquifer.

The Carbonate aquifer nears the surface and is exposed at some locations, particularly in a 22 km long, two km wide, northwest to southeast trending ridge area located midway between Fisher Branch and Hodgson (Marble Ridge, Horseshoe Ridge, Sylvan Hill) . This exposure of the Carbonate aquifer likely constitutes a local groundwater recharge area. Evidence of this includes areas of springs, wetlands and wet forest found at the base of the ridges.

Each geological formation of the Carbonate aquifer has its own distinctive geological properties, which affects the aquifer porosity. While this is a modifying influence, weathering near the bedrock surface is the overriding factor in development of porosity and permeability. Prior to glaciation, the rock was exposed to surface conditions. During this time, weathering created fractures, solution cavities, caverns and sinkholes within the rock. This weathering has given the upper surface of the bedrock an irregular surface and the rock itself good aquifer properties.

The top few metres to tens of metres of rock constitute the main water bearing zone of the Carbonate aquifer. Deeper, non-weathered zones are less likely to produce satisfactory amounts of water.

The Carbonate aquifer is the primary water source for the region. The pores, fractures and cavities found in the limestone and dolomite provide a reliable water source that is accessible throughout the watershed. The exception is the Lake Winnipeg shoreline where the Carbonate aquifer is too thin to be useful and the Winnipeg Sandstone becomes the aquifer of choice. Wells in the Carbonate aquifer will almost always yield sufficient supply for household use and water quality is good. Yields are in the range of 20 to 225 L/min (4 to 50 igpm).

WINNIPEG SANDSTONE AQUIFER

The Winnipeg Sandstone aquifer underlies the Carbonate Aquifer throughout the area and it is comprised of the Winnipeg Formation. The unit is about 30 to 35 m thick. The depth to the aquifer thickens from 15 m (50 ft) near the north east and along Lake Winnipeg to 80 m (265 ft) in the southwest of the watershed. Map #4 shows the area where the Winnipeg Sandstone aquifer is shallow enough to be reasonably accessed by wells.

The Winnipeg Sandstone aquifer consists of poorly cemented white sandstone interspersed with a few shale beds. It has a six metre thick grey-green shale unit at the top. The top shale forms a pronounced aquitard, which separates the Carbonate aquifer from the Winnipeg Sandstone aquifer. As a consequence, groundwater quality can be quite different in the two formations. The aquifer is a dependable water source. Yields tend are in the range of 45 to 325 L/min (10 to 70 igpm). Water quality is generally good, but softer and with more salts than the Carbonate aquifer. Salt concentrations increase and water quality can be expected to diminish to the west as the aquifer gets deeper, eventually making it unsuitable for household use. Undesirable levels of arsenic have been found in some wells in the aquifer.

The Winnipeg Sandstone aquifer is used as a water supply along the western shore of Lake Winnipeg near Pine Dock and Matheson Island. In this area, the Carbonate aquifer is often less than 5 m thick, so that most wells drill through the Carbonate and are completed in the underlying sandstone. Farther west, the highly productive Carbonate aquifer provides good quality water at shallower depths at most locations. There are two domestic wells completed in the Winnipeg Sandstone aquifer, in central and western parts of the watershed. One is near Red Rose/Fisher River and one near Fisherton. The well at Fisherton was drilled in 1972 (PID 17688). It is not known if it is still active. The well near Red Rose/Fisher River was drilled by the Fisher River Indian Band in 1998 and is listed as active (PID 108696). Both sites lacked aquifers in the overlying drift and limestone rock. A third well was drilled in 2008 into the Winnipeg Sandstone aquifer at Fisher River by the Fisher River First Nation, but the sandstone contained saline water (PID 143603). In this well, the sandstone was sealed with cement and this well and subsequent wells were completed in the Carbonate aquifer.

PRECAMBRIAN CRYSTALLINE ROCK

Beneath the sandstone is Precambrian igneous and metamorphic crystalline rock of the Canadian Shield. It is found at depths of 40 metres near Lake Winnipeg to over 300 metres in the west. The Canadian Shield is water bearing only when fractured. Fractures most commonly occur in weathered horizons near the land surface. As a consequence, this zone is not considered to be an aquifer in this region. Outside this watershed, the Canadian Shield is only used for groundwater supply when no other options are available. The shield forms the base of the groundwater zone, in terms of both water supply and groundwater flow.

WELLS AND GROUNDWATER USE

WELL DISTRIBUTION BY AQUIFER

There are records for 1541 wells for this watershed in the groundwater database. These wells are not evenly distributed across the watershed, but are concentrated in the central agricultural area, along the Fisher River, and along the shore of Lake Winnipeg corresponding to settled areas (Map #5). Although the Province tries to keep as complete a record as possible, it is dependent on the cooperation of well owners and well drillers to record accurate information and to send in the drilling reports on newly completed wells.

The database shows about 94% of all wells on record were completed in the Carbonate aquifer. Wells completed in the Carbonate aquifer are found throughout inhabited areas of the watershed. The Winnipeg Sandstone aquifer was the second most common aquifer with just over 4% of wells. Wells in the Winnipeg Sandstone aquifer are concentrated on the shore of Lake Winnipeg. Sand and gravel wells were just over 1%. Sand and Gravel wells are few and are scattered suggesting that they are completed in features of local extent. A breakdown of wells by aquifer type is shown in Table 1.

Table 1 Number of Wells by Aquifer:

Aquifer Type	Number of Wells	% of Wells
All Aquifers (total)	1541	100
Sand and Gravel Aquifers	18	1.2
Carbonate aquifer	1451	94.1
Winnipeg Sandstone aquifer	66	4.3
Unknown or other	6	0.4

LICENSED WELLS

Licensed municipal water supply wells serve the communities of Fisher Branch and Pine Dock.

The Fisher Branch municipal well (PID 103821) and backup well (PID 103822) is located on the southwest side of the arena. The well is open hole from 46 m to 73 m (150 to 240 ft), completed in the Carbonate aquifer (Red River Formation). The well was drilled in 1997 and was tested at a rate of 1500 L/min (333 imperial gallons per minute / 400 US gpm) and was found to have a specific capacity of 72 US gpm/ft.

The Pine Dock municipal well is located immediately south of the water treatment plant. The well is screened from 24 to 30 m (80 to 100 ft) in Winnipeg Sandstone (PID 108491). The well was drilled in 1997 and was tested at a rate of 135 L/min (30 igpm). A back-up well was drilled a few metres to the east in 2012 (PID 173495).

A shared well with less than 14 connections is located in front (west side) of the Community Hall at Matheson Island. The well is 23 m (77 ft) deep, completed in the Winnipeg Sandstone Aquifer.

A small number of agricultural producers have licensed wells, which they use for stock watering.

Fisher River First Nation has a community water supply system constructed in 2009. The Community well is completed in fractured limestone in the Carbonate aquifer (Red River

Formation) at a depth of 66.5m to 69.5 m (218 to 228 feet) (PID 153536). A deeper test well was drilled into the Winnipeg Sandstone aquifer, but the water quality was found to be unsuitable. The well was drilled in 2009 and was tested at a rate of 945 litres per minute (208 imperial gallons per minute) (PID 143603). A backup well is completed nearby at the same depth zone (PID 153531).

FLOWING WELLS

Flowing wells are found in some parts of the watershed, mostly in the lower lying northeast regions along the main stem of the Fisher River from the Peguis First Nation to its mouth on Fisher Bay. In areas with flowing wells, the groundwater levels in the Carbonate aquifer are higher than the local land surface. The locations of the wells are shown in Map #6. Most are located adjacent to the Fisher River and are likely a consequence of converging flow from surrounding uplands. Betcher (2007) attributed the cause of the flowing wells to a lower permeability zone that slowed the eastward flow of groundwater from recharge areas to the west.

Flowing wells are a concern because of the uncontrolled discharge of water. The water resource is depleted, while going unused. The increased surface flow may flood drains, or saturate the ground, causing drainage problems. These problems can be avoided by ensuring that proper well drilling and construction methods are used, which can control the flow of water.

The areas affected by flowing wells are already prone to seasonal flooding. While flooding is primarily an issue of poor surface drainage, it can be aggravated by high water tables and increased runoff from wells.

GROUNDWATER QUALITY

OVERVIEW

Even when sufficient quantities of water are available, they may not be usable if quality is poor. Fresh, potable water is necessary for human consumption.

Groundwater begins as rainfall or surface water that soaks into the ground and makes its way to the water table, where it begins to flow. The ground acts as a filter, which removes bacteria, viruses and other surface contaminants. At the same time the water dissolves the rock matrix around it, picking up minerals and salts. The minerals that make up the rock vary with rock type and some are more soluble than others. Carbonate rock is somewhat water soluble and adds calcium, magnesium, sulphate and bicarbonate ions. The calcium and magnesium contribute to hardness. Sandstone is less soluble, but is more often associated with sodium and chloride ions and is generally soft water. Sands and gravels often have hard water and high iron.

The longer that water flows underground, the more mineralized it becomes. Shallow groundwater which is recharged locally tends to have the lowest amount of dissolved minerals and is the most desirable for human use. Groundwater with distant recharge sources has spent a long time underground. As a result total dissolved solids content or TDS increases, water quality diminishes. Water that is too mineralized to be used for a drinking water supply may still be useful for household purposes, stock watering or industrial and farmyard uses.

In the Fisher River watershed, groundwater in the Carbonate and sand and gravel aquifers are recharged mostly within the watershed boundaries or nearby. As a consequence, natural groundwater quality is good. With the exception of the region along Lake Winnipeg, the Winnipeg Sandstone aquifer has more distance recharge sources. This means the water tends to be poorer quality than in the overlying aquifers.

Groundwater contamination occurs when surface pollutants enter the shallow groundwater zone. Pollutants vary, but may include such things as manure or sewage, salts, oil, metals or chemicals. Contaminants such as nitrates, bacteria or petroleum products tend to be localized in nature. They generally come from surface sources that are local in extent and limited in time frame. If there are enough sources over a broad area over an extended period of time, cumulative impacts may cause a more regional effect.

Some dissolved metals, such as arsenic or iron are in most cases naturally occurring. Introduction of oxygen into the aquifer through pumping may change these metals into a more soluble form.

Groundwater is hard to clean up once contaminated. Groundwater contamination is best avoided through awareness and good management practices. Proper site considerations, construction and sealing of unused wells are important. Potentially risky activities can be curbed or prohibited in wellhead protection zone areas.

The *Manitoba Water Quality Standards, Objective and Guidelines* and the *Canadian Guidelines for Drinking Water Quality* sets limits on drinking water constituents. Some dissolved minerals such as calcium have no set health limit. Other constituents such as iron will affect taste and washing qualities and have a set aesthetic objective. Others which may be detrimental to health, such as nitrates or bacteria, will have a Maximum Allowable Concentration. Public and semipublic systems are covered under the Manitoba Water Protection Act.

Groundwater testing can be used to identify groundwater quality issues. Manitoba Conservation and Water Stewardship, Groundwater Management section has partnered with conservation districts to do water quality sampling.

There are approximately 55 routine water analyses on file for this watershed. Approximately 30 analyses are on file for dissolved metals.

MAJOR CONSTITUENTS

The *Guidelines for Canadian Drinking Water Quality* set the aesthetic objective for total dissolved solids (TDS) at 500 mg/L. This cut-off is rarely achieved for well water. Often for well water anything less than 1000 mg/L TDS is considered acceptable, although as much as 1500 mg/L may be tolerated for human consumption. Livestock tolerances are higher (. Recommended limits for TDS concentration are shown in Table 2 (Olkowski, 2009).

Table 2 Recommended limits of Total Dissolved Solids

TDS Concentration Limit mg/L	For Consumption By:
500	Humans (good)
1000	Humans (fair)
1500	Humans (poor)
2000	Poultry
2500	Dairy Cattle
4000	Beef Cattle, Horses, Pigs
5000	Sheep
10,000	Industrial Processes (varies with use)

In the Carbonate aquifer total dissolved solids in most of the wells is in the range of 300 mg/L to 500 mg/L which considered acceptable drinking water quality and exceptionally good for well water. In the Winnipeg Sandstone aquifer wells along the shore of Lake Winnipeg have total dissolved solids (TDS) values between 700mg/L to 900 mg/L. An average distribution of TDS in groundwater is shown in Map #7.

When well water is sampled, it is most commonly analysed for major ions: calcium, magnesium, sodium, potassium, bicarbonate, sulphate and chloride, along with iron , fluoride, nitrate, pH, hardness and alkalinity. Bacteriological samples may also be taken.

Some routine parameters and their significance are shown in Table 3. Aesthetic objectives are set for most of these minerals in the *Guidelines for Canadian Drinking Water Quality* and high concentrations may affect palatability and personal tolerance for the water. The Canadian Maximum allowable concentrations are applied to constituents with specific health concerns. Council of Ministers of the Environment (CCME, 2005) sets water quality guidelines for agricultural uses. Because of the already low TDS concentrations in most wells in the Fisher River Watershed, most other natural constituents are also low and within recommended limits.

Often nitrate concentrations are too low to be determined by the laboratory and are below the *detection limit*. Rather than state that the amount is zero, the detection limit will be given. The detection limit may vary with the laboratory or the analytical method but is generally one hundredth of a mg/L or less. Within Fisher River Watershed, nitrate concentrations above detection limits are found in wells completed in the Carbonate aquifer and some in shallow sand and gravel wells in agricultural areas of the southern part of the watershed. Elevated nitrates are common in agricultural areas and usually arise from leaching of septic systems, manure or fertilizers into the groundwater. It is mostly caused by site-specific conditions, but the cumulative effect of a cluster of locations will raise the average for the region.

Nitrate-N in well water samples is shown in Map #8. Individual wells are shown rather than contoured because nitrate contamination is mostly a local phenomenon. The *Guidelines for Canadian Drinking Water Quality*, set a maximum allowable concentration for nitrogen, in the form of nitrates is set at 10 mg/L for nitrate-N or 45 mg/L for nitrate. Within our water chemistry database, the 10 mg/L MAC was exceeded in 12 domestic wells and three exploratory test wells. The higher levels of nitrates were found in the elevated agricultural areas in the south part of the watershed where drift is less than 10m thick, particularly around Fisher Branch and Marble Ridge. The thin layer of protective clay over the Carbonate aquifer and the downward movement of water into the aquifer make it more susceptible to contamination. The thin overburden translates into poor, thin soil in many areas and consequently land is used for grazing, which increases the input of manure.

In children less than one year old, nitrates may interfere with the ability of red blood cells to transport oxygen, causing blue baby syndrome, with symptoms of bluish skin, shortness of breath and fatigue.

Table 3 Some routinely tested parameters affecting suitability: Guidelines for Canadian Drinking Water Quality

Quality Constituent	Limit (mg/L)	Limit type (AO or MAC)*	Comment
TDS	500	AO	Usually for surface water supplies.
Hardness	200 poor; 500 bad	AO	Soap scum and scaling
Iron	0.3	AO	Iron stain, taste
Nitrate	10	MAC	Risks for infants
Fluoride	1.5	MAC	Brittle bones/teeth
Sulphate	500	AO	Laxative effect
Chloride	250	AO	Mildly corrosive
Sodium	200	AO	Blood pressure
Magnesium			Not a concern
Calcium			Not a concern
Bicarbonate			Not a concern
pH	Between 6.5 and 8.5	AO	Low pH can be corrosive. High pH can cause scaling

**Aesthetics Objective or Maximum Allowable Concentration*

MINOR CONSTITUENTS – TRACE METALS

Minor elements or trace metals, which have occasionally exceeded *Guidelines for Canadian Drinking Water Quality* in Manitoba, include fluoride, barium, boron and uranium. With the exception of fluoride, trace metals are usually not included in basic water well analysis and may require additional testing.

In the Fisher River Watershed, records show approximately 30 wells, which have been sampled for trace metals. Fluoride, barium and boron from samples within the watershed were within acceptable amounts for *Guidelines for Canadian Drinking Water Quality.* Although boron has locally exceeded drinking water standards within the Winnipeg Sandstone aquifer in parts of Manitoba, it has not been detected in significant concentrations in the Fisher River Watershed. Fluoride exceeding the allowable concentration was found in one Winnipeg Sandstone well on Matheson Island.

The Guidelines for Canadian Drinking Water Quality sets the maximum allowable concentration for arsenic at 0.10 mg/L. Arsenic at or above 0.10 mg/L was detected in two wells, one on Matheson Island and one at Fisher River, both in the Winnpeg Sandstone Aquifer. The Winnipeg Sandstone was sealed off at the Fisher River well. Detectable but safe amounts of arsenic in the range between 0.0002 and 0.0006 mg/L were detected in Winnipeg Sandstone aquifer wells, at Matheson Island, Little Bullhead and Fisherton. (Map #9)

Arsenic is naturally occurring or it may have sources related to human activity. In the Fisher River Watershed, the source of the arsenic is likely derived from naturally occurring sulphide minerals found in the Winnipeg Sandstone aquifer.

Arsenic is toxic in large doses and has been linked to several types of cancer, reproductive problems, diabetes, a weakened immune system, and developmental delays in children. Arsenic can be reduced or eliminated in tap water through treatment, or by relocating the water source to a location where arsenic is not present. Arsenic above the allowable concentration was found in Winnipeg Sandstone in a test well on the Fisher River First Nation. The well was subsequently sealed. Owners of wells completed in the Winnipeg Sandstone aquifer should consider testing for arsenic and other metals.

Testing for trace metals is recommended when drinking water samples are collected for routine analysis and sent to a lab that offers this service.

MICRO-ORGANISMS

Micro-organisms, particularly bacteria and viruses sometimes make their way into well water. Well water is generally considered clean and safe because the ground acts as a natural filter. When micro-organisms enter the ground, they are filtered, deprived of their food sources and die off with time.

Generally for micro-organisms to contaminate groundwater you need a source, usually fecal material and the water carrying the microbes must reach the well before they die off. The length of time that microbes can survive underground depends on the individual organism and environmental factors, such as temperature, water chemistry, availability of oxygen and carbon, other organisms and filtering capacity of the ground. Time is the overriding factor. A two year limit is set as a safeguard for municipal with surface water influence (Ontario Ministry of the Environment, 2001).

Rock materials with fine intergranular porosity (e.g. silt; sand; sandstone) are better at filtering out micro-organisms than rocks with fracture or cavity porosity (e.g. granite; carbonate). Carbonate rock is more susceptible to contamination because the pores in the rock are often large, and are well connected through open fractures and solution features, which are poor filters and water is transported quickly through large openings. In contrast, water moves more slowly and pores are smaller in sand or sandstone. Areas where bedrock is exposed at the land surface or is only thinly covered are at greater risk.

Contamination is most likely to move through conduits from the surface to the aquifer caused by well problems relating to construction, maintenance and hygiene. It can change over time and tends to be a localized problem when it occurs. Contamination can be prevented with good well construction practices, particularly maintaining a good seal between the well casing and the surrounding ground. Drainage should slope away from the well. Wells should be located away from possible contamination sources such as septic drains, stockyards and manure piles.

Bacteriological testing is usually done for total coliform bacteria and Escherichia coli (E. Coli). Coliform bacteria are a common bacteria and their presence in water is often an indicator of fecal contamination. The presence of E. Coli, a specific type of coliform bacteria is considered diagnostic of fecal matter. Parasites such as giardia and cryptosporidium are usually spread by fecal matter from livestock and wild animals and may be another concern.

Manitoba Conservation, Office of Drinking Water recommends annual testing for microbiological contaminants. Preferably, sampling should be done when the well is most vulnerable to contamination, such as during or after spring runoff or after a major storm or flood. Samples may be sent to private labs for analysis. For more information contact the Office of Drinking Water.

WATER TREATMENT

Well water is often treated to improve its quality. Water treatment systems may be installed to deal with particular problems if they are not too severe. Activated carbon filters may be useful for palatability, minor taste, odour and colour issues. They are most effective at removing organic compounds and sediment as well as some dissolved substances, such as hydrogen suphide. They are less suited for removing salts and certain other inorganic dissolved solids, microbes, sodium, nitrates, fluoride or hardness.

Hard water is usually treated with a water softener. Water softeners add salt to the water. The sodium in the salt replaces the hardness-causing calcium and magnesium removing them from the water. Water softeners will also remove minor amounts of iron and manganese. Because of the added sodium, softened water is generally not used for drinking. Specialized sand filters are available to deal with excessive iron. These will also deal with manganese and hydrogen sulphide.

Reverse osmosis successfully treats water with high dissolved solids including salts, metals, minerals, organic substances, most microorganisms including cryptosporidium and giardia and many inorganic contaminants. Many reverse osmosis systems use activated carbon pretreatment, which increases effectiveness against organic contaminants.

GROUNDWATER MONITORING

The Province of Manitoba through the Department of Conservation and Water Stewardship, Groundwater Management Section maintains a network of more than 800 groundwater observation wells in the province. Monitoring primarily involves continuously recording of water levels, plus occasional water quality sampling. This may be done in undeveloped areas to observe how the aquifer responds to the natural environment, or it may be done in developed areas to determine impacts on groundwater from major production wells. When water levels are compared from developed to undeveloped areas, it helps to distinguish the effects of pumping from natural fluctuations caused by changes in seasons and in the climate. This allows groundwater supplies to be carefully managed so that these resources are available in the long term.

Groundwater storage is a balance between recharge and discharge. In the long term this is relatively stable. In the shorter term, storage may increase when surface water is plentiful or it may decrease during drought. Water levels typically rise in spring and early summer and decline in fall and winter. In the longer term, they will generally increase over wet years and decrease over a period of dry years. The changes in water levels are usually recorded using monitoring wells.

In the Fisher River Watershed, there are two active provincial monitoring wells (Table 4). G05SD001 is located next to crop lands on the roadside about a mile southwest of Fisher Branch (Figures 3 and 4). It is 15.5m (51 ft) deep and takes continuous water level readings in the shallow Carbonate aquifer, at depths similar to many wells in nearby Fisher Branch. Because it is situated away from development well monitors natural ambient conditions.

Water levels vary within a 2 m range most years, and a 3 m range over multiple years. The water level chart shows annual seasonal cycles and longer term climatic cycles (Figure 5). During the annual cycle there is an early summer annual peak (June), a late summer seasonal low (September), a late fall seasonal peak (November) and a late winter annual low (March). The June peak is the cumulative effects of snow melt and spring rains entering the ground, combined with relatively low water consumption from vegetation. The September low results from warmer drier conditions and high vegetative consumption and evaporation. The late fall peak results from cooler temperatures, fall rain and dormant vegetation. The annual low occurs just before the snow melts after a winter of frozen ground and no groundwater recharge.

Figure 3. Groundwater observation well near Fisher Branch.

Groundwater levels were at their lowest in 2004 to 2005, during hot dry years. The wet years that followed caused a year to year gain in water levels, which reversed to a decline during dry periods on 2011-2012. Seasonal fluctuations within the 2 m range exceed the longer term changes of about one metre. In the long term, groundwater levels appear to be stable.

G05SD002 is used for water quality sampling of shallow groundwater in the Carbonate aquifer. The well is located adjacent to crop lands and bush, about three miles southwest of Fisher Branch (Figure 4). The well is situated upslope from Fisher Branch, allowing it to monitor water quality in a recharge area. The water quality for the well is good, with total dissolved solids under 400 mg/L and most other constituents being relatively low. The water is hard, which is expected in limestone. The well was tested for laboratory results in general chemistry, trace metals and nutrients in 2008 and was field tested for pH, conductivity and nitrogen in 2005.

Figure 4. Locations of groundwater monitoring wells near Fisher Branch

Table 4 Provincial Observation Wells in the Fisher River Watershed

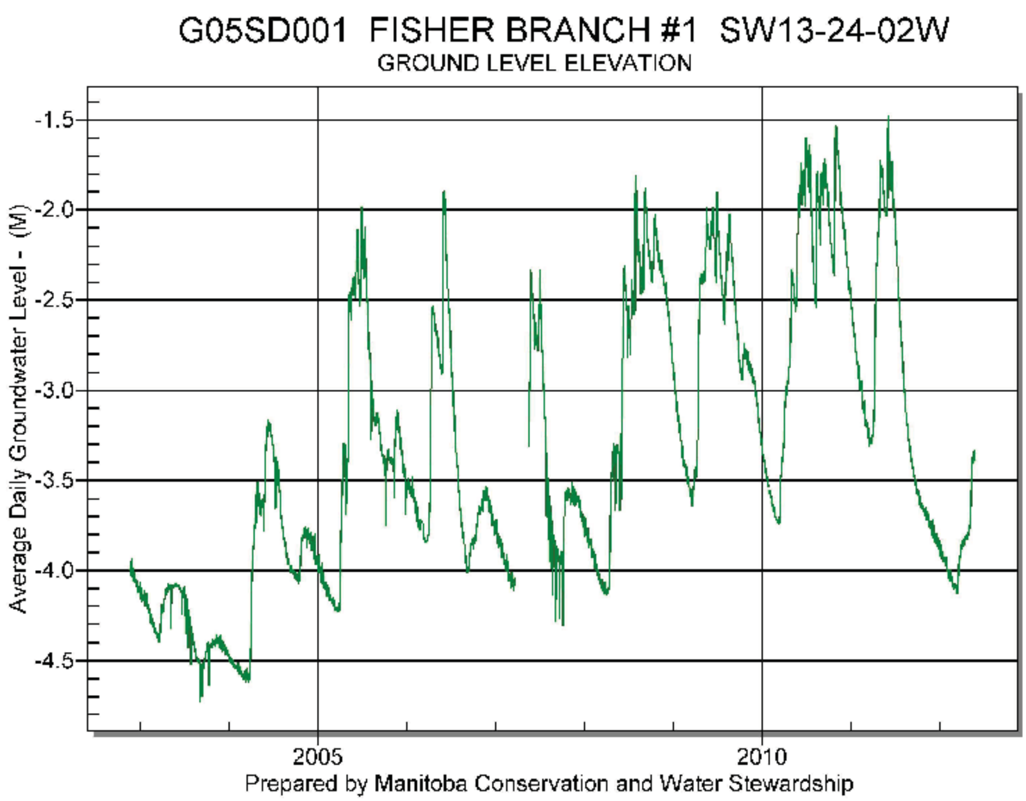
Well Name	Land Location	Aquifer	Depth m/feet	Monitoring Record	Status	Type
G05SD001 FISHER BRANCH 02-1 PID 121083	SW-13-24-2W	Carbonate	15.5 m 51 ft	2002-present	Active	Water Levels
G05SD002 MRGQI WQC5 PID 113303	NE-10-24-2W	Carbonate	12.2 m 40 ft	2001-	Active	Water Quality

Water Quality Results in mg/L

Year	TDS	Hard	pH	Ca	Mg	Na	HCO_3	SO_4	Cl	Fe	NO_3-N	F
2008	366	376	7.6	65	52	13	420	28	2	<0.01	0.38	0.22

Figure 5

Hydrograph for the Fisher Branch #1 provincial groundwater observation well. It monitors mainly ambient conditions and illustrates response to seasonal effects and to periods of wet and dry years. Groundwater levels were low from 2002-2004 due to drought conditions. Higher precipitation from 2005-2011 caused an overall rise in water levels. A drop is seen in 2011-2012 due to drought conditions.



GROUNDWATER FLOW

Groundwater flows from topographic highs toward topographic lows. Groundwater basins generally resemble surface water basins, but are modified by local and regional geology and are not identical. Groundwater is recharged in upland areas and rises to the surface in lowland areas. Groundwater moves from areas of recharge toward areas of discharge. It returns to the surface through springs, by feeding into the bottoms of streams, lakes or wetlands, or is taken up by vegetation. As a consequence, groundwater is critical in maintaining minimum surface water levels and stream baseflow throughout the year. In recharge areas, the water table is often deeper and levels vary more than you would find in a discharge area.

Water enters the ground and recharges groundwater most readily in areas where permeable deposits are found at the ground surface. Once it reaches the water table, groundwater can flow a few centimeters to a few meters a day in sand or gravel aquifers, and even tens of meters a day or more in some highly fractured bedrock aquifers. In some aquitards, the water may move less than a few millimeters in a year.

Most groundwater recharge occurs in springtime, when melting snow, seasonally high rainfall and dormant vegetation allow significant amounts of water to reach the water table. In summer, vegetation intercepts much of the rainfall before it can reach the water table. Often it takes a prolonged rain or heavy storm to cause recharge. Recharge may increase in late fall, when vegetation goes dormant, but stops once the ground is frozen. This pattern is commonly seen in groundwater monitoring well hydrographs (Figure 5)

The central portion of the Interlake is an elevated region where fresh water recharge to aquifers occurs. From the central high area, groundwater flows west to Lake Winnipegosis and Lake Manitoba and east to Lake Winnipeg. The Fisher River Watershed is found on the east side of the divide. Groundwater flow is generally east toward Lake Winnipeg. The elevated margins of the river basin, particularly high areas on the western margin, act as recharge areas to the upper aquifers in the watershed. Limestone uplands including Marble Ridge near Fisher Branch, Sylvan Pasture and Horseshoe Ridge near Hodgson are also sources of recharge. This local recharge is the source of the good quality water in sand and gravel aquifers and in the Carbonate aquifer. Deeper portions of the Winnipeg Sandstone aquifer may be influenced by more regional flow systems, originating from further west. As a consequence the water tends to be more saline.

Betcher (2007) noted that recharge to the Winnipeg Sandstone aquifer is inhibited by the shale aquitard at the top of the unit, which separates it from the overlying Carbonate aquifer. The isotopic content of the groundwater in that aquifer indicates that it is very old groundwater without much dilution from modern recharge. Where the aquifer approaches the surface, near Lake Winnipeg, recharge may be local, more direct and at a higher rate.

Land use changes, such as clearing for agriculture or forestry, the establishment of drains and dewatering of peat operations can all affect groundwater recharge, discharge and storage. In general, such land modifications will increase surface runoff. In recharge areas water will drain away faster and be less likely to enter the ground. In discharge areas, drainage will lower the water table. In both cases, storage is reduced. Increased surface runoff may increase the magnitude of flooding and the potential for erosion and increased turbidity in surface water.

Land clearing may increase groundwater storage when water consuming vegetation is removed. Actively growing vegetation will consume water from the ground, thereby lowering the water table in both recharge and discharge areas. Water tables and consequent storage may rise in both recharge and discharge areas because less water is being consumed. This effect will only take place for a few months in the summer.

GROUNDWATER AND LAND COVER

OVERVIEW

Vegetative land cover and related ecosystems develop in relationship to groundwater, determined mainly by reliability, depth of water table, and groundwater chemistry (Map 10).

In general, groundwater recharge areas are upland or hilly areas. Water at the land surface is taken into the ground and moves to deeper zones. The water table is usually deep. These areas may permit ponding of water in springtime, but are characteristically dry later in the season as water leaves the area through infiltration, runoff or evapotranspiration. Nutrients important for plant growth will tend to leach away and are hard to maintain and the pH may be low. Recharge areas are often forested with drought tolerant vegetation such as jack pine. The unreliable water supply and poor nutrient supply means that recharge areas are generally poor for agriculture. Wells in these areas will have low static water levels that fluctuate with the seasons.

Groundwater discharge areas are low lying areas where groundwater rises to the surface. Discharge areas will typically have permanent surface water bodies, springs, wetlands and a high water table. Calcium deposits, salts or quick ground may be present. Groundwater flowing into the discharge area will bring in dissolved nutrients and minerals and pH tends to be high. Some nutrients and minerals will be important for plant growth, but calcium and salts also dissolved in the groundwater may be detrimental to plant growth if concentrated enough. Agricultural limitations may occur as a result of poor drainage, persistently wet fields and in some cases, salt buildup. Wells in these areas will have a high static water level, sometimes to the point of being flowing well. These wells are less subject to seasonal fluctuations.

Midzone regions between groundwater recharge and groundwater discharge zones tend to be moderated in terms of water supply, nutrient supply and drainage. These areas are more favoured for agricultural production and forestry.

PEAT LANDS

Much of the low lying area of the Fisher River Watershed is covered by wetlands, mostly in the form of peat-forming bogs and fens. Peat wetlands differ from most groundwater zones because the water table is located within a top organic peat layer, rather than within the underlying drift or bedrock. These wetlands are often poorly drained at the surface and may be poorly connected to underlying aquifers. Bogs obtain their water supply from rainfall which is stagnant or slowly flows within the peat to lower lying areas. The water is acidic and nutrient-poor, which deters most plant growth apart from peat moss. Fens are found where there lateral and upward movements of groundwater, while marl springs are found in focused discharge zones. Fens and marl springs contain nutrients and minerals obtained from deeper groundwater zones. Fens are still peat lands, but are more biologically diverse. They host a variety of mosses, such as feather mosses, shrubs and small trees. These wetlands are home to specialized flora including carnivorous plants and orchids (Figure 6).

Peat harvesting operations are in progress near Pine Dock. Mine sites favour bogs over fens because the sphagnum moss is relatively pure. Fens are avoided because there is too much inconsistent herbaceous and woody material.

Figure 6 Groundwater-fed fen found at the base of the Sylvan Pasture alvar.

ALVAR

The Fisher River Watershed is home to a rare type of geologically controlled ecosystem called an alvar.

Alvars are rare on a worldwide scale and are found mainly in northern Europe and the Great Lakes region of North America. The world's largest alvar, found on Oland Island in Sweden is a UNESCO World Heritage Site. The Fisher River watershed is home to Manitoba's largest alvar. It is located in a 22 by 2 km wide, northwest to southeast trending zone between Fisher Branch and Hodgson (Map #10). The alvar consists of a limestone and dolomite ridge known as Marble Ridge, eroded into flat tablelands by the glaciers. A few smaller alvars are found in and immediately south of the Fisher River watershed. The Sylvan Community Pasture is located east of Fisher Branch and Horseshoe Ridge alvar, east of Hodgson. Manitoba Conservation and Water Stewardship, and the Nature Conservancy of Canada are working to protect 4000 ha of this land.

Alvars form on flat areas with soils less than 10 cm thick over limestone and dolomite bedrock. Alvars have poor surface drainage and are typically flooded after spring snowmelt or heavy rains, but dry out rapidly. The effect of too much, or more often, too little moisture creates a stressful environment that limits the number of plant species that can survive and generally stunts the growth or those that do. The stressful environment eliminates many competitive plants, allowing rare or unusual species or plants, birds and invertibrates. The Marble Ridge alvar is home to rare ferns (Figure 7).

Alvars in the Fisher River Watershed appear to be groundwater recharge areas. The areas are raised above the surrounding landscape and have poor surface drainage. The flat surface area prevents overland drainage. Water ponds on the surface where it creates seasonal wetlands, which form after spring melt or large storms, but dry out later in the season. The water slowly recharges the underlying Carbonate aquifer or is lost to evaporation.

Extensive groundwater-fed marl spring fens are found at the eastern bases of the Sylvan Pasture and Horseshoe Ridge alvars (Figure6). A strip of forested wetland is found along the base of Marble Ridge, and is home to a variety of native orchids including yellow lady's slipper (Cypripedium parviflorum), showy lady's slipper (Cypripedium reginae), ramshead lady's slipper (Cypripedium arietinum), Venus slipper (Calypso bulbosa) and striped coralroot (Corallorhiza striata), hooded ladies tresses (Spiranthes romanzoffiana) and long green bracted orchid (Coeloglossum viride). These wetlands are biologically rich and are hydrogeologically continuous with the alvar.

Conservation plans for alvar should incorporate the associated groundwater discharge wetlands, which originate from the alvar.

Figure 7

Alvar at Marble Ridge, near Fisher Branch - Hodgson

GROUNDWATER MANAGEMENT

REGULATION

Groundwater in Manitoba is regulated under a number of Acts and Regulations*:* The *Environment Act*; The *Water Safety Act*; The *Water Rights Act*; The *Ground Water and Water Well Act* and The *Health Act*. Groundwater management is under the jurisdiction of the Department of Conservation and Water Stewardship, which includes a Groundwater Management Section and Water Use Licensing Section.

The *Environment Act* provides legislation protecting groundwater quality, while The *Water Rights Act* provides for the sustainable development of groundwater use. The *Ground Water and Water Well Act* introduced in 1963, deals with water well regulation and with water wells completed by a drilling contractor. With the exception of controlling flowing wells and pollution prevention, the Act does not cover household wells dug by the well owner with their own equipment.

Groundwater is managed sustainably when the rate of water removal does not cause long term, irreversible declines in water levels or other undesirable impacts. A budget is determined by estimating the amount of groundwater stored in an aquifer, based on well tests and hydrogeological mapping, as well as the amount of water entering and leaving the aquifer through recharge and discharge.

When groundwater budgets are not known, it is still possible to manage the resource on a well by well basis, providing that the cumulative demands of the existing wells are not causing long term detrimental effects on surrounding wells or groundwater features.

Groundwater pumping tests are carried out when a well is required for more than simply domestic use and a license is required. Groundwater pumping tests are done to determine the maximum sustainable pumping rate of the well and to assess the potential effects on water levels in surrounding wells. The results of the pumping test determines the long term effects of drawdown and radius of influence to provide assurance that groundwater development is within the ability of the aquifer to supply this water without there being adverse effects on the aquifer and surrounding users. Groundwater monitoring may be mandated at specific sites in licenses or permits issued under the *Environment Act* or licenses issued under The *Water Rights Act.*

WATER WELL CONSTRUCTION AND MAINTENANCE

It is the responsibility of the owner of water well to ensure their well and water distribution system is properly constructed and maintained and that the well provides water that is safe for drinking. Well water contamination is often caused by improper or poorly constructed or maintained wells. Wells and water distribution systems also deteriorate over time and at some point will need repair or replacement.

The following measures are recommended to help reduce the risk of well water contamination:

- Retain an experienced and licensed well drilling contractor for the drilling and construction of water well.
- Locate the water well at a safe distance from potential sources of contamination and in an area away from surface runoff from potential sources. Separation distances from well to septic are not legislated in Manitoba. Ontario, Alberta and Nova Scotia do regulate distances. Based on what is used in these jurisdictions, it is suggested that drilled wells with at least a 6.1 metre surface casing should be a minimum or 15 metres from a septic system. For dug or bored wells, a suggested distance is 30 metres. For a septic system to operate effectively the drain field should be a minimum of two metres above the water table and have a percolation rate of around one cm/min.
- Ensure an experienced and licensed contractor completes the hook-up of the water well to the water distribution system.
- After the water well has been completed but before it is put into operation, ensure the well pump and water distribution system are disinfected to kill any bacteria that may be present.
- Wells within any designated flood area within the watershed should have adequate well head protection to ensure flood waters do not enter directly into the well.
- Ensure old wells are properly sealed to the guideline recommended in Manitoba's Guide of Sealing Abandoned Water Wells (Manitoba Conservation, 2002)

The above measures could be incorporated into future source water/well head protection plans for the watershed. If these items are covered by an updated groundwater act and regulations, the new legislation will supersede these recommendations.

AQUIFER AND WELLHEAD PROTECTION

Aquifer protection may be accomplished through good land use and well construction practices. Aquifer contamination may occur when there is a contaminant present and there is a pathway into the aquifer.

The Fisher River Watershed encompasses rural and agricultural areas. Sources of contaminants mainly include livestock manure, inadequate septic systems, road salts or spills of petroleum products and spills or application of fertilizers or agricultural chemicals. These may enter vulnerable aquifers, or by pathways along abandoned or inadequately sealed wells.

A variety of methods have been developed to determine aquifer vulnerability. Generally in Manitoba, if the top of an aquifer is within six metres of ground surface it is considered vulnerable.

Shallow, drilled, dug or bored wells are more at risk of being contaminated than deeper drilled wells. Good well completion is important. The outside of the well casing should be sealed above the well screen to the surface with bentonite grout.. Well pits should be replaced with pitless adaptors. Wells that are no longer in use should be properly sealed. The well needs to be securely capped and any items entering the well should be disinfected.

Good surface management practices should be maintained. The ground around the well should be graded so that water drains away from the well casing. Possible sources of contamination should be kept away from the immediate vicinity of the well.

Where possible, surface water should be managed so that the well is protected from seasonal flooding.

Wellhead protection programs may be put in place to protect community water supplies. Source protection for community wells generally encompasses larger areas and is more comprehensive than is used for individuals. For community wells, the simplest approach is to set a fixed radius around the well. The area within the radius may be examined for objects, infrastructure or activities that may pose a hazard to the water source. Risks to the groundwater may be reduced by limiting or eliminating hazards. For example, storage of chemicals may be moved outside of the buffer zone. Bylaws and zoning restrictions may be used as part of the process. However, the intrinsic susceptibility should be examined before limiting development through bylaws.

As part of the planning process, the Fisher Branch public water supply well was strategically located west of the village upslope and away from developed sites.

SUMMARY

Water supply in the Fisher River Watershed is primarily obtained from groundwater.

Groundwater supply is readily available throughout the watershed, with the vast majority of wells obtaining their supply from the upper part of the Carbonate aquifer, which is found throughout the region. Along the shores of Lake Winnipeg, the Carbonate aquifer is thin and the underlying Winnipeg Sandstone aquifer is the main source of water in this area. A small number of wells are completed in localized sand and gravel aquifers. Most residents are on private wells. Public water systems are in place at Fisher River (Carbonate aquifer), Fisher Branch (Carbonate aquifer) and Pine Dock (Winnipeg Sandstone aquifer). Groundwater monitoring near Fisher Branch, shows that water levels fluctuate seasonally, but have remained stable in the longer term.

Water quality is good in the Carbonate aquifer. Winnipeg Sandstone aquifer water is more saline and development is limited to the shore of Lake Winnipeg where water quality in this aquifer is improved. Elevated levels of arsenic may be an issue in some Winnipeg Sandstone aquifer wells and appears to have a natural source. Regular testing of these wells is recommended. Because of the shallow water table, shallow wells and the fractured nature of the Carbonate aquifer groundwater is susceptible to contamination. Well owners should test for bacteria annually and maintain their well. Source area protection for community water wells should be incorporated into municipal planning.

Groundwater is recharged along the height of land in the central Interlake region and localized uplands within the watershed such as Marble Ridge. The nearby sources of recharge account for the low total dissolved solids of groundwater found in the watershed. Marble Ridge is an example of alvar, an unusual geological and ecological feature with moisture stressed limestone uplands and wetland areas at the base. Groundwater discharge is more prominent in low lying areas along the Fisher River, evidenced by flowing wells and toward Lake Winnipeg, evidenced by large tracts of wetlands.

Groundwater in the Fisher River Watershed is widely available and of good quality. Supply exceeds the demands of the area. Good well water management practices are recommended to ensure that the water source remains clean and plentiful for the future.

PREPARED BY DAVID TOOP, P. GEO AND M. IQBAL

GROUNDWATER MANAGEMENT SECTION, MANITOBA CONSERVATION AND WATER STEWARDSHIP, 2013

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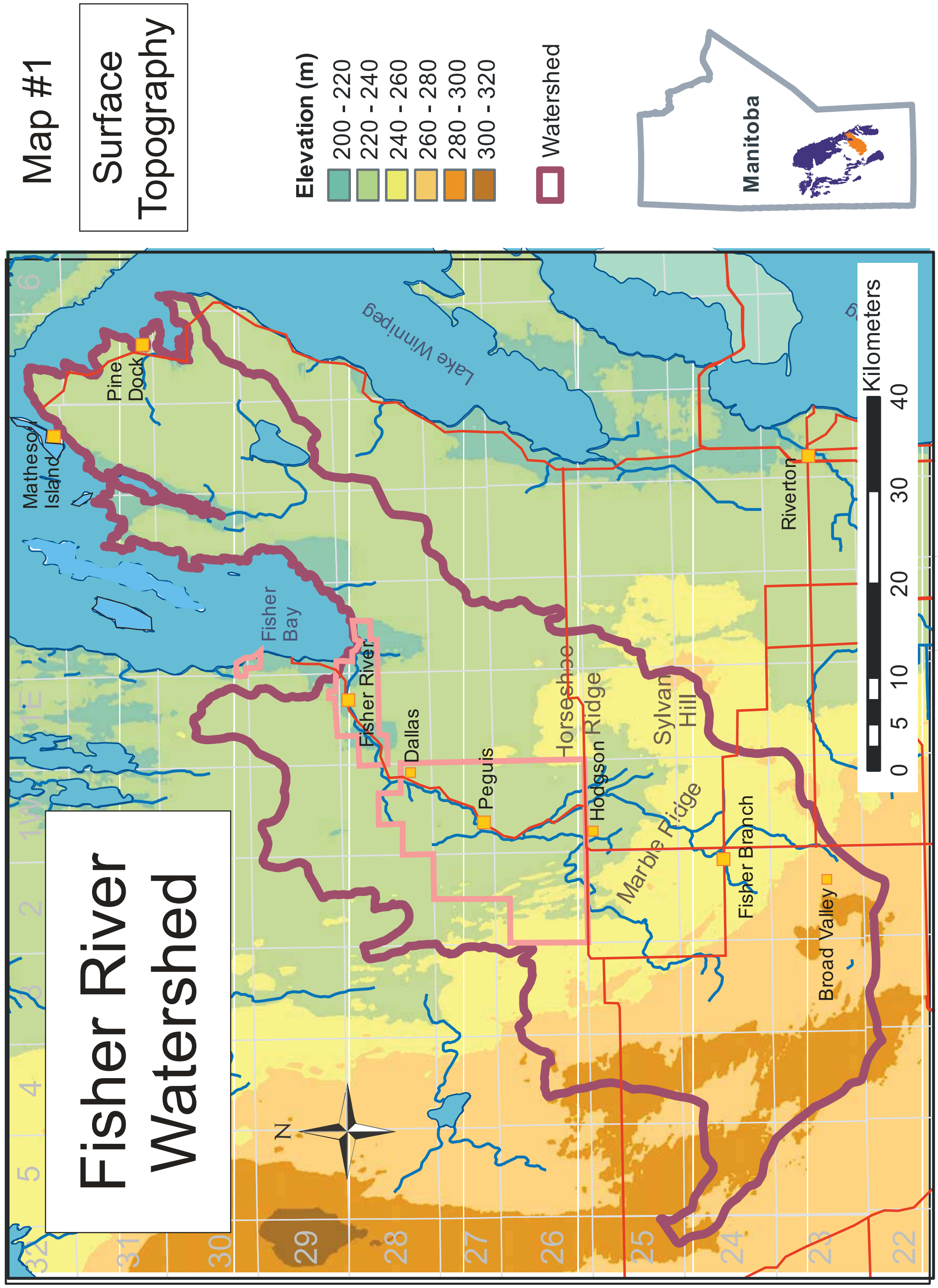
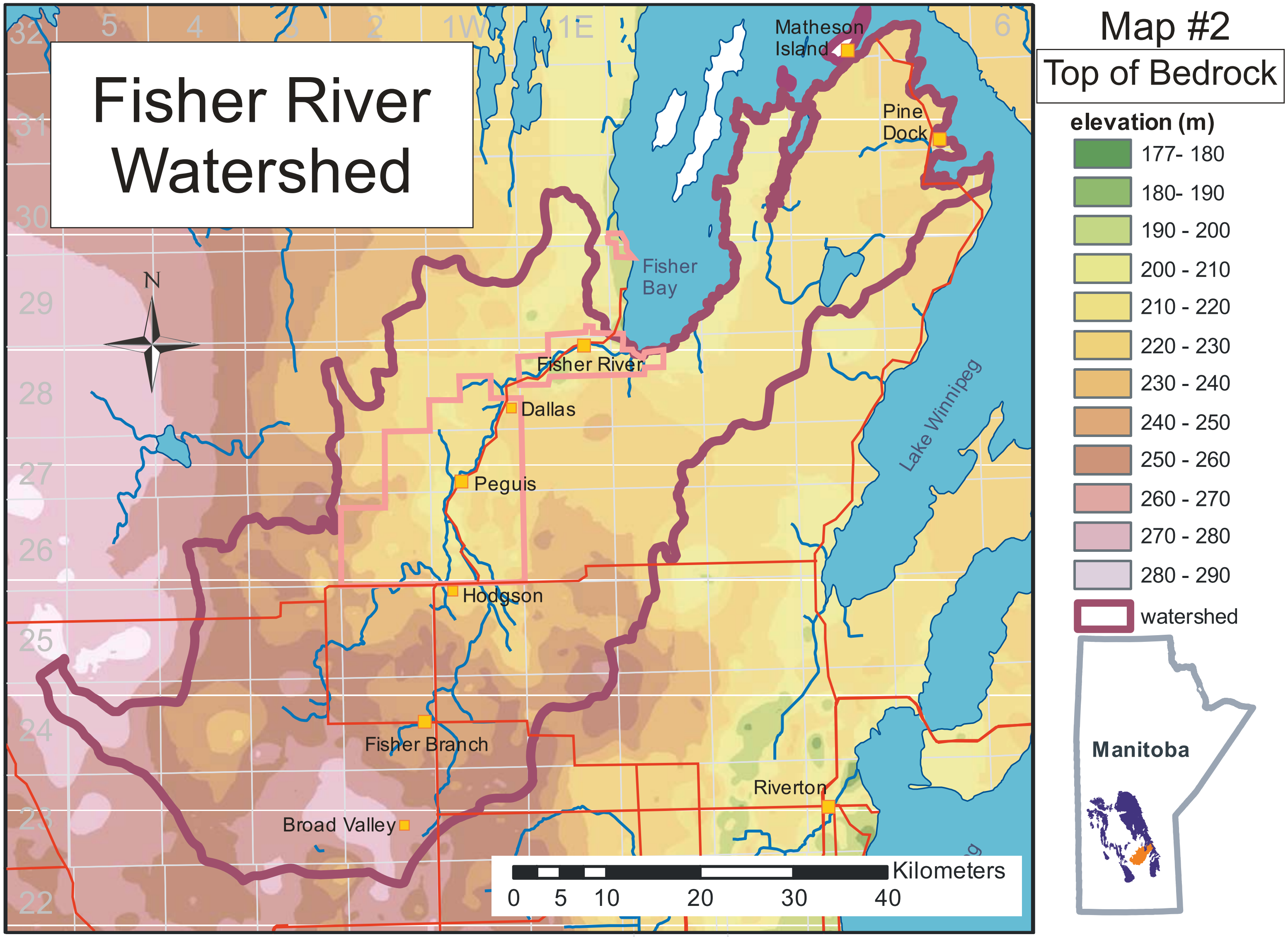
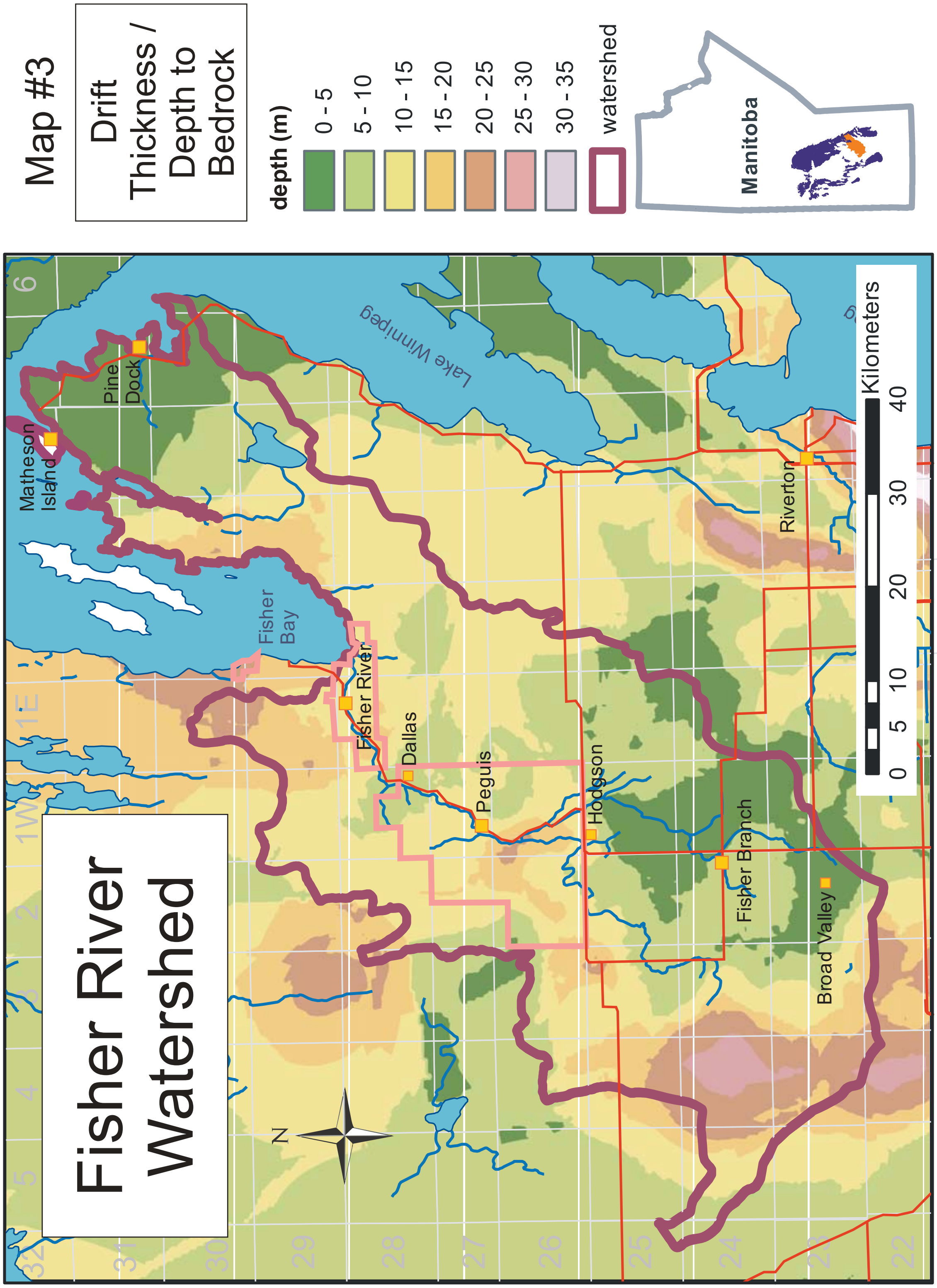
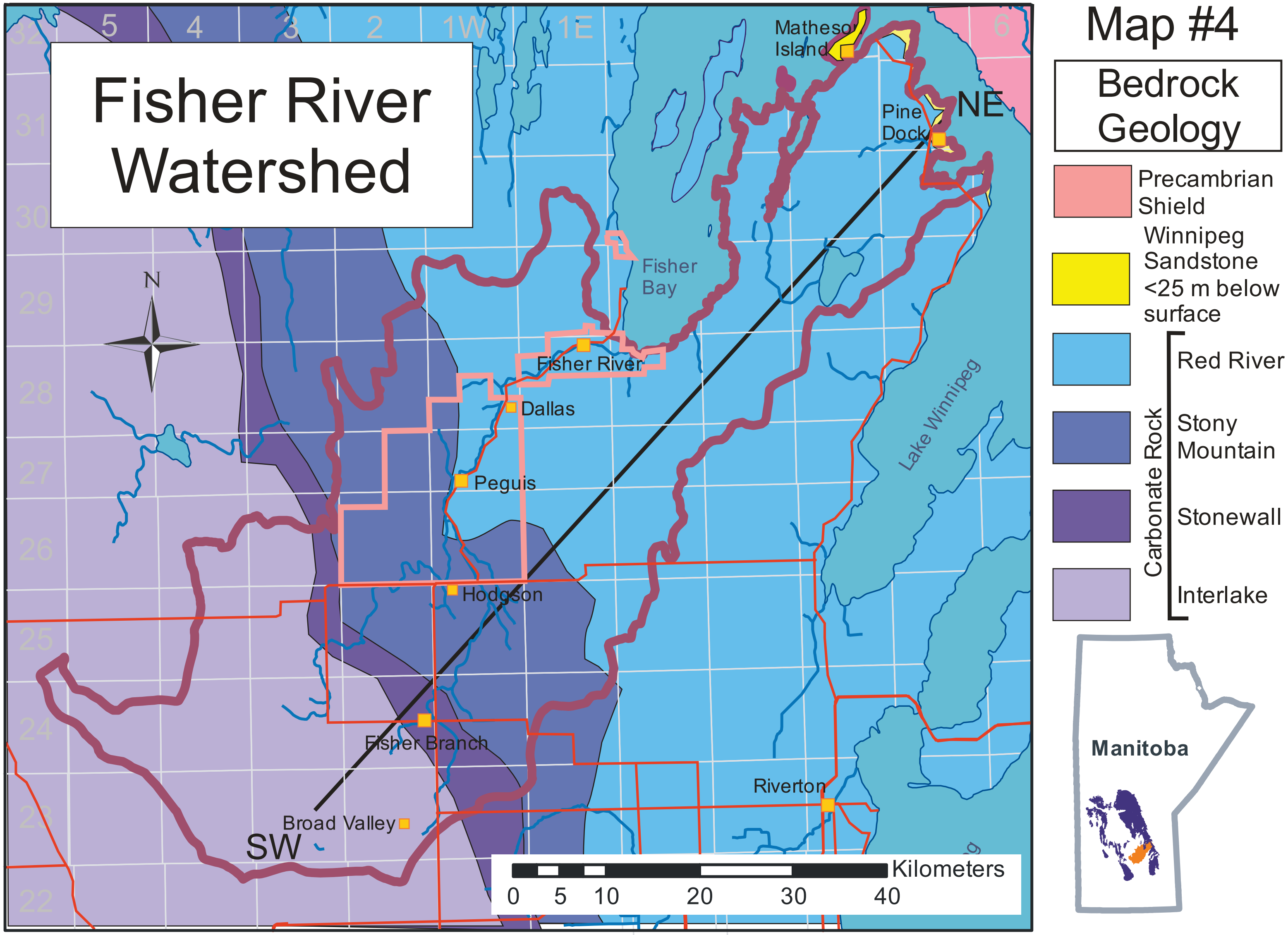
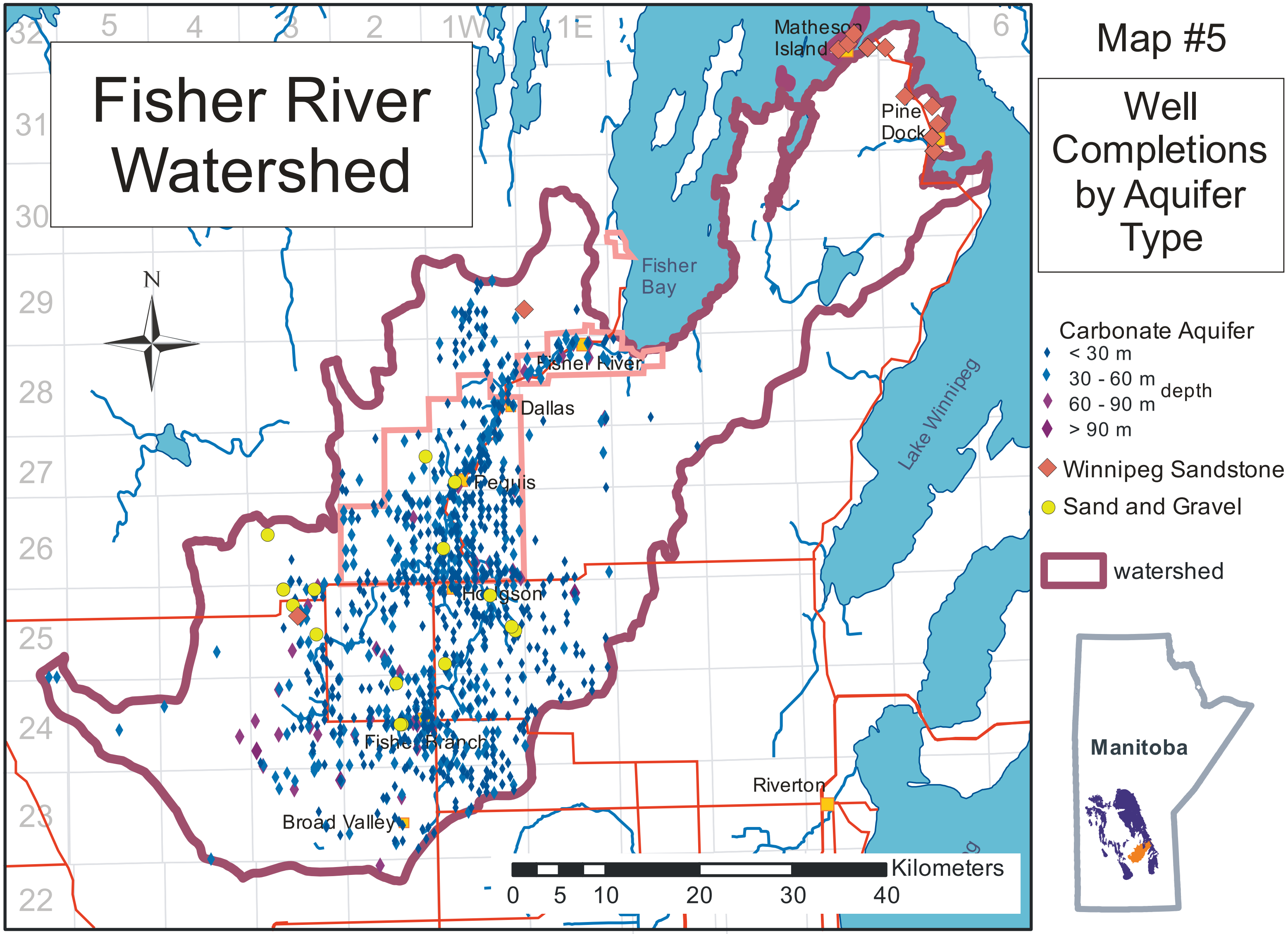

Map #1
Surface Topography
Elevation (m)
200 - 220
220 - 240
240 - 260
260 - 280
280 - 300
300 - 320
Watershed
Manitoba
Fisher River Watershed
Lake Winnipeg
Pine Dock
Matheson Island
Fisher Bay
Fisher River
Dallas
Peguis
Horseshoe Ridge
Hodgson
Sylvan Hill
Marble Ridge
Fisher Branch
Broad Valley
Riverton
N
Kilometers
0 5 10 20 30 40

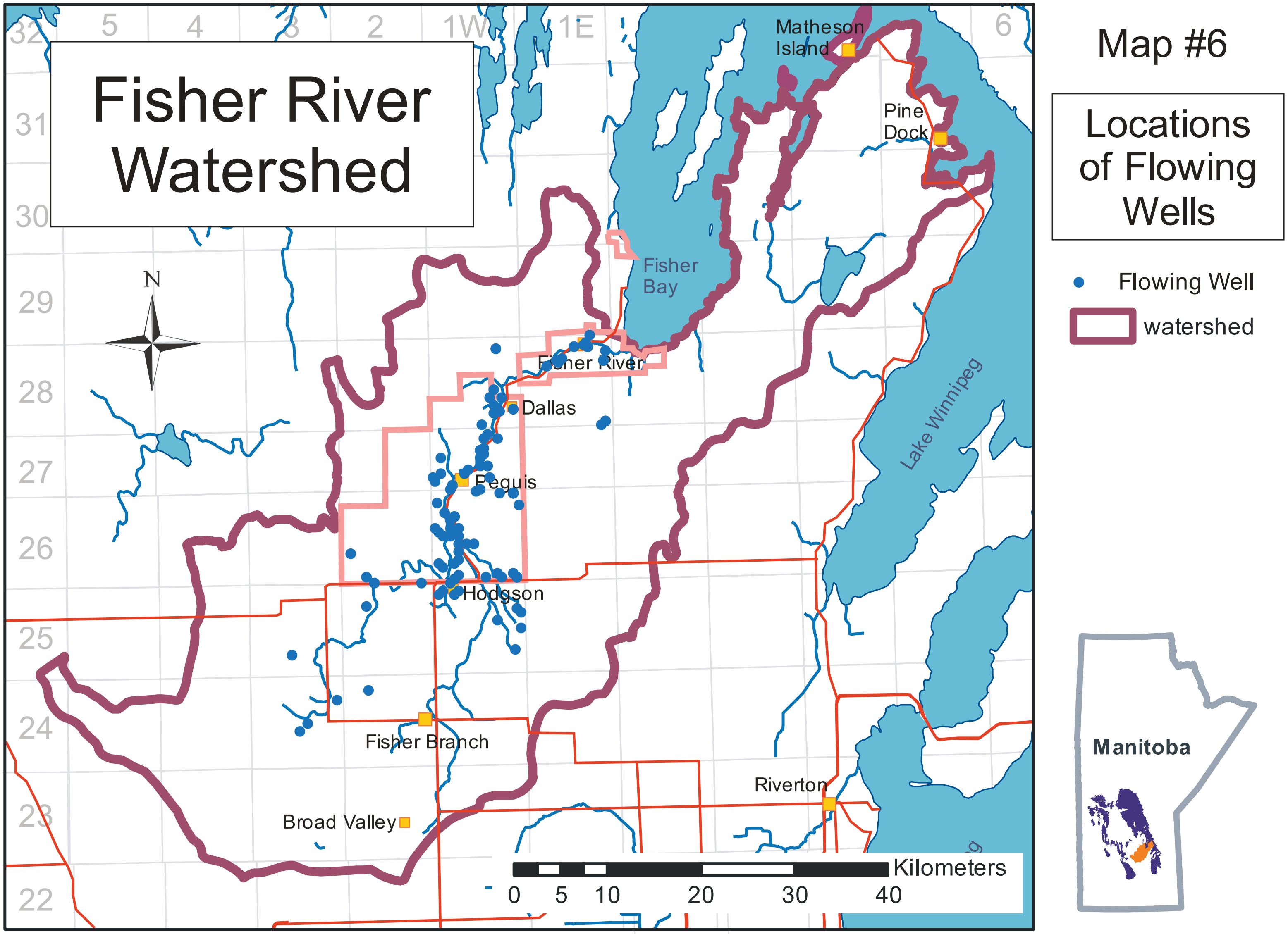

Map #2
Top of Bedrock
elevation (m)
177- 180
180- 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
250 - 260
260 - 270
270 - 280
280 - 290
watershed
Manitoba
Fisher River Watershed
N
Matheson Island
Pine Dock
Fisher Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Lake Winnipeg
Kilometers
0 5 10 20 30 40

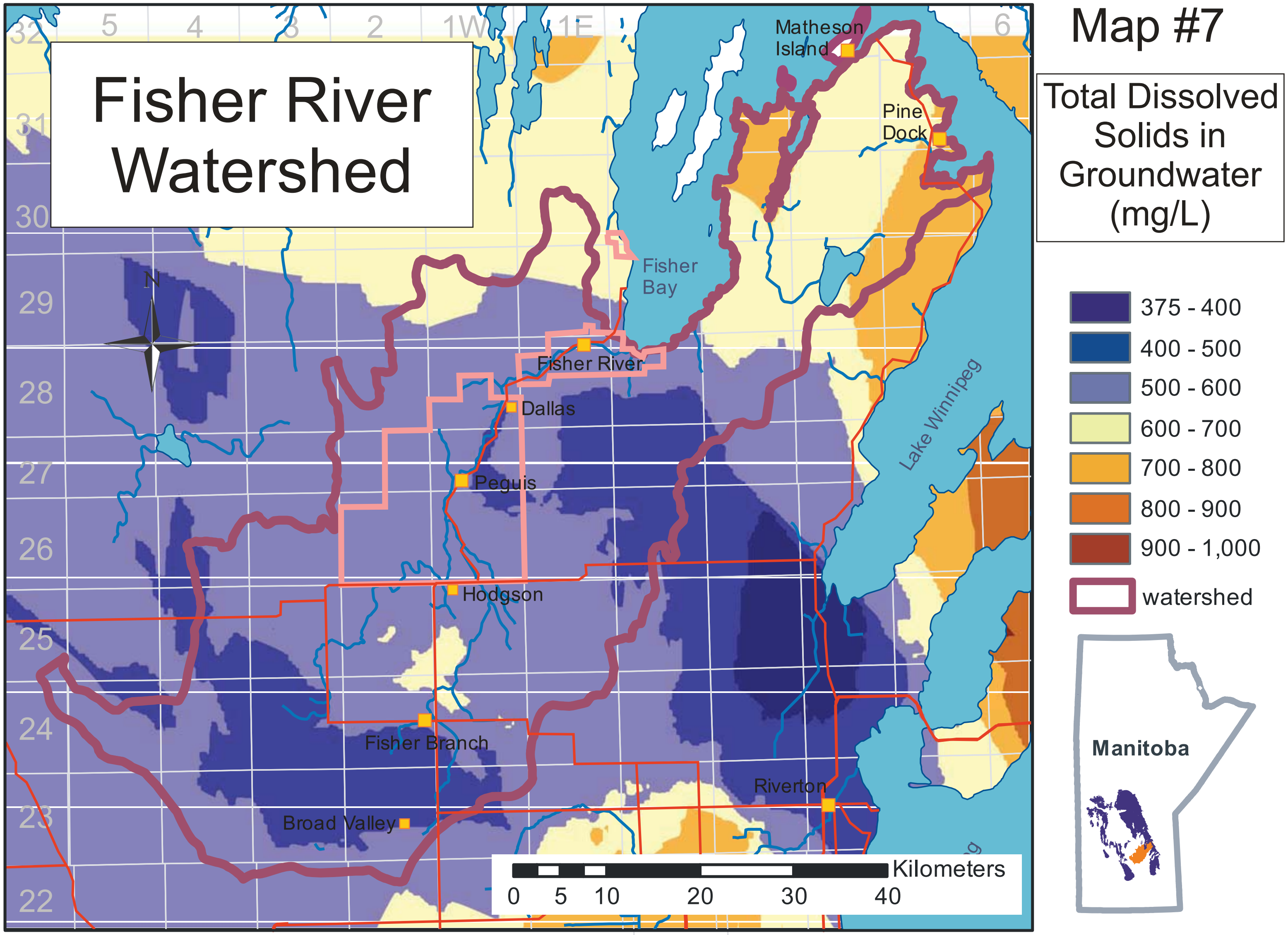


Fisher River Watershed
Map #3
Drift Thickness / Depth to Bedrock
depth (m)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
watershed
Manitoba
Matheson Island
Pine Dock
Lake Winnipeg
Fisher Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Kilometers
0 5 10 20 30 40
N

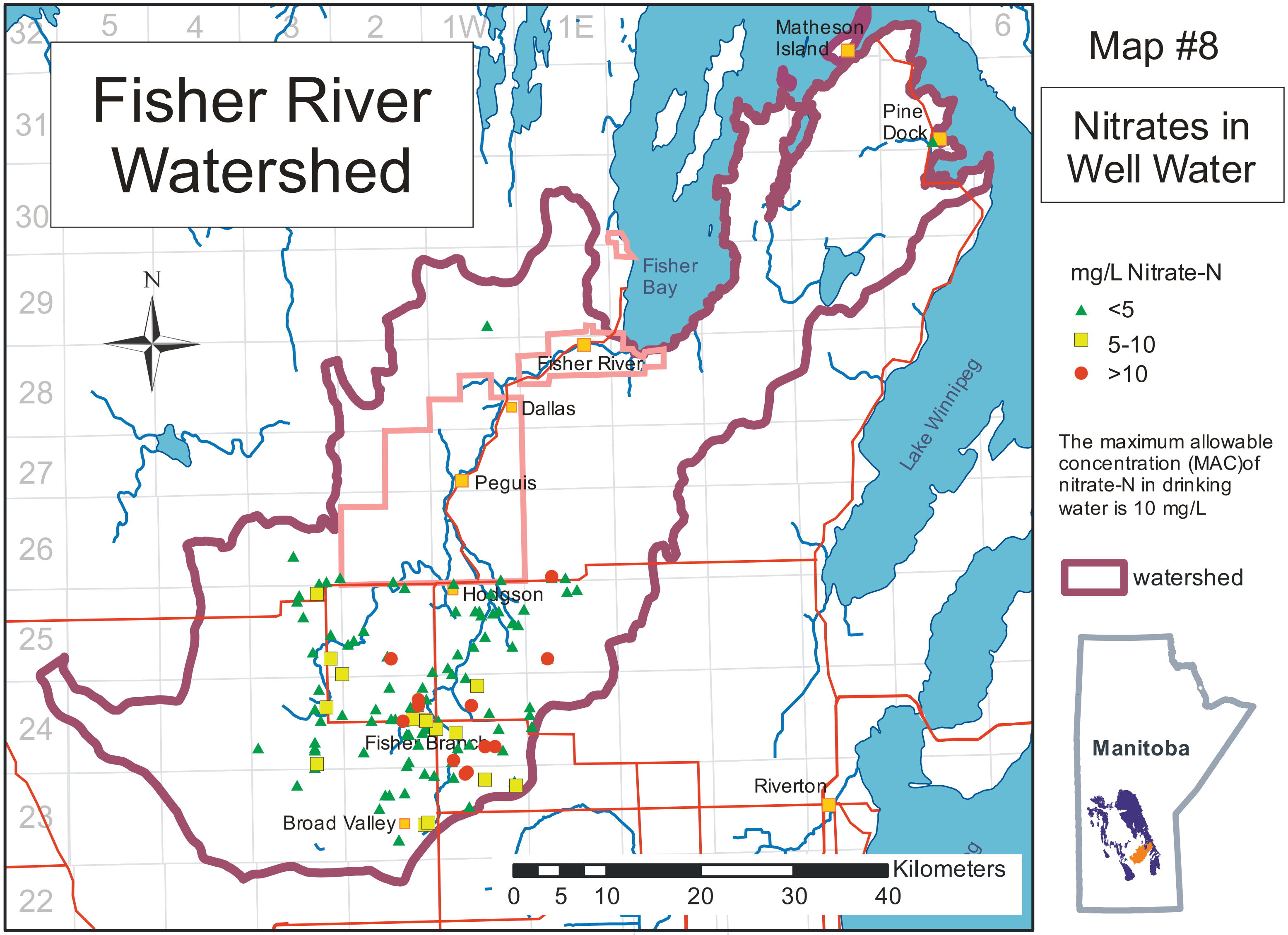

Fisher River Watershed
Map #4
Bedrock Geology
Precambrian Shield
Winnipeg Sandstone <25 m below surface
Red River
Stony Mountain
Stonewall
Interlake
Carbonate Rock
Manitoba
Matheson Island
Pine Dock
NE
SW
Fisher Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Lake Winnipeg
N
0 5 10 20 30 40
Kilometers
5 4 3 2 1W 1E 6
32 31 30 29 28 27 26 25 24 23 22

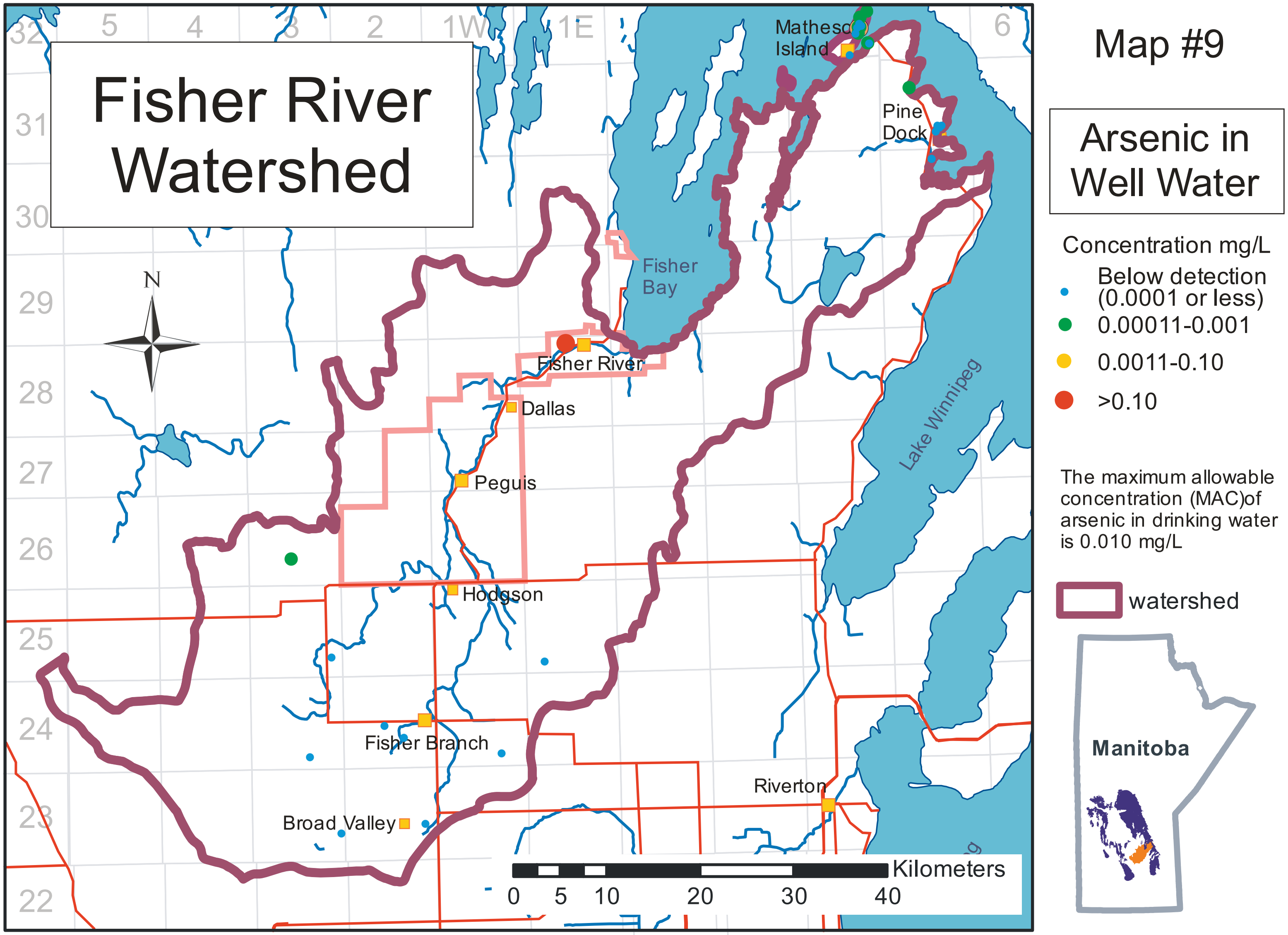

Fisher River Watershed
Map #5
Well Completions by Aquifer Type
Carbonate Aquifer
< 30 m
30 - 60 m
60 - 90 m
> 90 m
depth
Winnipeg Sandstone
Sand and Gravel
watershed
Manitoba
Kilometers
0 5 10 20 30 40
N
Matheson Island
Pine Dock
Fisher Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Lake Winnipeg
32 31 30 29 28 27 26 25 24 23 22
5 4 3 2 1W 1E 6

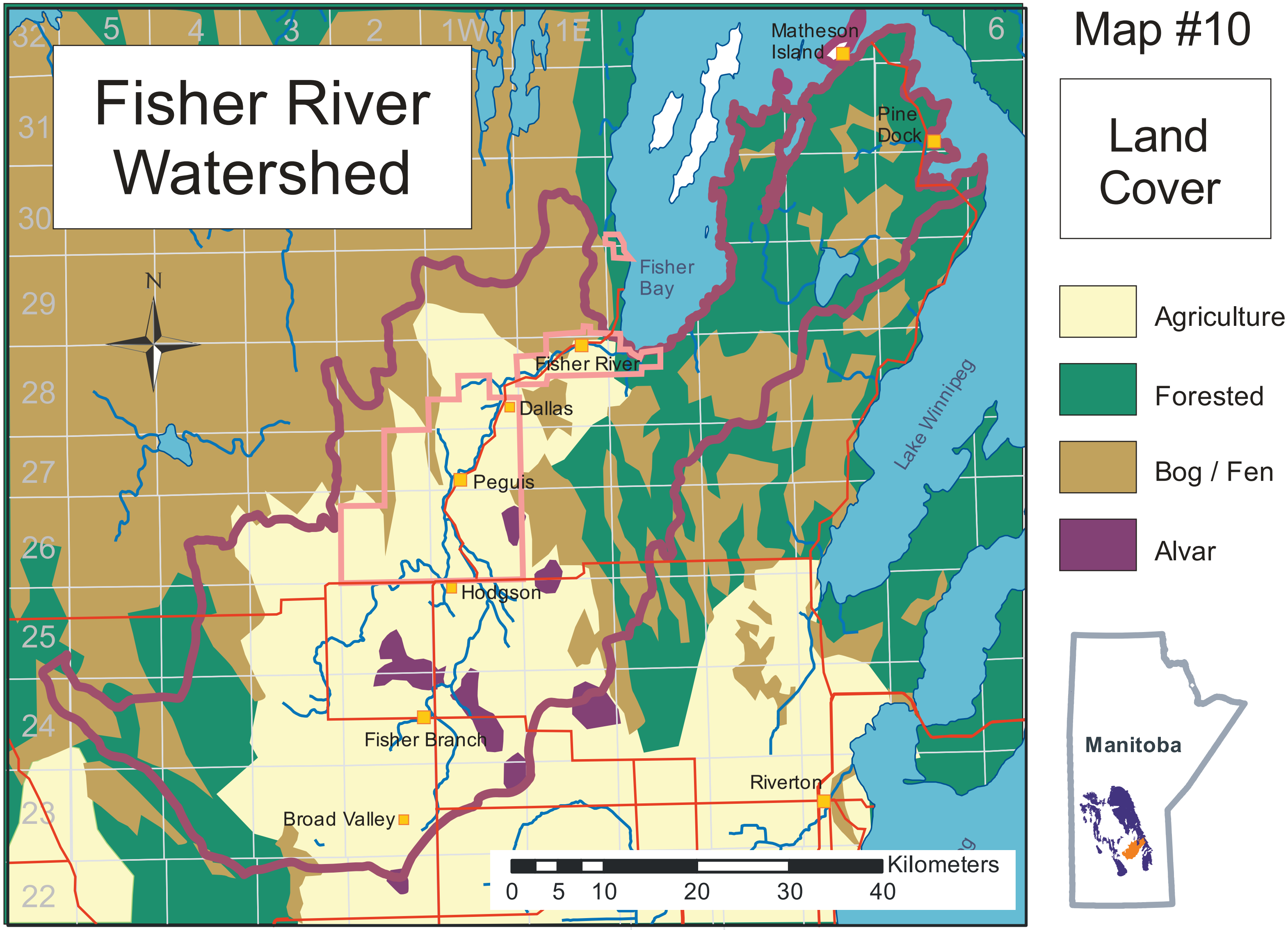

Fisher River Watershed
Map #6
Locations of Flowing Wells
Flowing Well
watershed
Matheson Island
Pine Dock
Fisher Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Lake Winnipeg
Manitoba
N
Kilometers
0 5 10 20 30 40
5 4 3 2 1W 1E 6
32 31 30 29 28 27 26 25 24 23 22



Fisher River Watershed
Map #7
Total Dissolved Solids in Groundwater (mg/L)
375 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1,000
watershed
Manitoba
Matheson Island
Pine Dock
Fisher Bay
Lake Winnipeg
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
N
Kilometers
0 5 10 20 30 40
32
5
4
3
2
1W
1E
6
31
30
29
28
27
26
25
24
23
22


Fisher River
Watershed
Map #8
Nitrates in
Well Water
mg/L Nitrate-N
<5
5-10
>10
The maximum allowable concentration (MAC)of nitrate-N in drinking water is 10 mg/L
watershed
Manitoba
Matheson Island
Pine Dock
Fisher Bay
Lake Winnipeg
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
N
Kilometers
0 5 10 20 30 40
5
4
3
2
1W
1E
6
32
31
30
29
28
27
26
25
24
23
22


Map #9
Fisher River Watershed
Arsenic in Well Water
Concentration mg/L
Below detection (0.0001 or less)
0.00011-0.001
0.0011-0.10
>0.10
The maximum allowable concentration (MAC)of arsenic in drinking water is 0.010 mg/L
watershed
Manitoba
N
Matheson Island
Pine Dock
Fisher Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Lake Winnipeg
Kilometers
0 5 10 20 30 40
5 4 3 2 1W 1E 6
32 31 30 29 28 27 26 25 24 23 22


Fisher River
Watershed
Map #10
Land
Cover
Agriculture
Forested
Bog / Fen
Alvar
Manitoba
Matheson
Island
Pine
Dock
Fisher
Bay
Fisher River
Dallas
Peguis
Hodgson
Fisher Branch
Broad Valley
Riverton
Lake Winnipeg
N
Kilometers
0 5 10 20 30 40
32
31
30
29
28
27
26
25
24
23
22
5
4
3
2
1W
1E
6