

GROUNDWATER RESOURCES IN THE  
WILLOWBEND CREEK WATERSHED

March, 1981  
Winnipeg, Manitoba

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## SUMMARY

- \* In the Willowbend Creek Watershed groundwater is available in most of the area south of the Trans-Canada Highway but only in a few small areas north of the Highway.
- \* The potable water aquifers in the Watershed are formed by layers or lenses of sand and gravel; the most common are shallow sand aquifers within the surface sand that covers much of the southern part of the Watershed.
- \* The yield of wells in most of the Watershed is low; in general, it is adequate only for domestic and farm requirements.
- \* In a few places aquifer conditions are favourable for moderately high capacity wells suitable for community water supply and similar requirements.
- \* Some of the shallow sand aquifers are severely affected by low groundwater levels in winter and particularly in periods of drought.
- \* Water supply problems in some of the very low yield aquifer areas could be alleviated by improved well design.
- \* Water quality in the potable water aquifers ranges from poor to good; in general, it is better in the shallow sand aquifers than in the deeper aquifers.
- \* Water in all water bearing zones in the bedrock is salty. The salty water has intruded nearly all sand and gravel aquifers above the bedrock in the northern part and in extensive areas in the southern part of the Watershed.
- \* In a few areas the water table of the shallow sand aquifers is at or near ground surface and interferes with agricultural practices.
- \* The total groundwater supply in the Watershed is adequate for present requirements and some new development. However, because of the uneven distribution of aquifers, groundwater is not available in nearly one half of the watershed.

## 1 INTRODUCTION

The purpose of this report is to provide an appraisal of the groundwater resources in the Willowbend Creek Watershed for the Whitemud River Conservation District Board.

The report is based on available information comprising a groundwater study in the Watershed and vicinity carried and by the Water Resources Branch (J. Little, 1979), geological and soils maps and groundwater data in the files of the Water Resources Branch of the Department of Natural Resources.

The International System of Units (SI), commonly referred to as the metric system, and the following symbols of the SI units are used in the report:

metre	m
square metre	m <sup>2</sup>
cubic metre	m <sup>3</sup>
kilometre	km
square kilometre	km <sup>2</sup>
litre	L
second	s
litre per second	L/s
cubic metres per year	m <sup>3</sup> /a (annum)
milligrams per litre	mg/L

All dimensions and quantities are also shown in commonly used Imperial units in parentheses.

## 2 PHYSIOGRAPHY

Based on major topographic features the watershed can be divided in two physiographic areas: The Lowland and the Upland. The two areas are separated by a low but fairly steep escarpment (Figure 1). The topography of the Lowland area ranges from very flat in the northern part to slightly undulating in the southern part. The topography of the Upland, which is some 60 m above the Lowland, is slightly hilly because of the sand dunes which are a common feature in the area.

### 3 GEOLOGY

#### 3.1. Geology and Groundwater

Rock formations and the unconsolidated deposits overlying the bedrock contain the openings through which groundwater flows and in which it is stored. Consequently the geology of an area has a significant effect on groundwater resources in it. Hence, the geological setting of the Willowbend Creek Watershed is described. The general geological setting of the Watershed is schematically depicted in Figure 1.

#### 3.2. Bedrock

The bedrock formations that underlie the Watershed consist of interbedded shale, limestone, gypsum, anhydrite and sandstone. In a small area near the southwestern corner of the Watershed the bedrock is interbedded shale and sandstone. Groundwater movement in these bedrock formations takes place mainly through the sandstone and limestone layers.

At some 200 m (650 ft.) below ground level the rock consists mainly of a thick sequence of carbonate rocks (dolostone and limestone). The carbonate rocks commonly contain highly permeable zones.

#### 3.3. Surficial Deposits

##### 3.3.1. Classification

The surficial deposits in the Watershed have been deposited mainly by glaciers and glacial lakes during the Ice Age and post glacial streams. Based on mode of origin and, in the case of the lake deposits, grain size the surficial deposits in the Watershed can be classified as follows:

- till,
- sand and gravel,
- clay and silty clay, and
- sand and silty sand.

### 3.3.2. Till

Till, which is a mixture of clay, silt, sand, gravel and boulders deposited by glaciers during the Ice Age overlies the bedrock throughout the watershed (Figure 1). The thickness of the till layer is about 20 m (65 ft.) at the northern end of the Watershed and up to 30 m (100 ft.) in the central and southern part. The permeability of till is low and, therefore, groundwater movement through it is slow. The till, however, may contain lenses of sand and gravel that can be water bearing.

### 3.3.3. Clay and Silty Clay

Throughout the Watershed the till is overlain by a thick layer of clay and silty clay. These deposits are exposed in extensive areas in the northern part of the Watershed (Figure 2) and in a few small areas elsewhere. The thickness of these deposits ranges from less than 10 m (30 ft.) to 60 m (200 ft.). Because these fine grained lake deposits have a very low permeability they inhibit groundwater movement and, consequently, have a negative influence on groundwater resources in the area.

### 3.3.4. Sand and Silty Sand

Sand and silty sand deposits overlie the clayey deposits in most of the southern half of the Watershed (Figure 2). In the Lowland area the thickness of the sandy deposits ranges from zero to about 5 m (16 ft.). In the Upland the sand deposits are up to 50 m (160 ft) thick and are interbedded with layers of clay and silt. Isolated lenses of sand occur along the Willowbend Creek adjacent to the eastern boundary north of Macdonald. The sandy deposits are fairly permeable and they can contain and transmit groundwater.

### 3.5. Sand and Gravel

Sand and gravel deposits in the area occur as isolated lenses interbedded in the till, at the clay-till contact and at the base of the

till. In general, the buried sand and gravel deposits in the Watershed appear to be thin and small in areal extent. Indications are that the only area where they are somewhat more extensive extends from Rossendale and vicinity to Edwin. Surface sand and gravel deposits in the area are scarce and are found only along an ancient northwesterly trending strand line north of Trans Canada Highway (Figure 2). The sand and gravel deposits are permeable and, therefore, can store and transmit water.

## 4 GROUNDWATER

### 4.1. Aquifers

#### 4.1.1. Definition

In the discussion of the geology of the Watershed it was indicated that some of the surficial deposits and some kinds of the bedrock readily transmit and store groundwater. The rock formations and surficial deposits that yield water to wells at a rate sufficient for a water supply are called aquifers.

#### 4.1.2. Classification

Based on the materials forming them and their occurrence the following aquifers can be discerned in the Watershed:

- Shallow sand
- deep sand
- sand and gravel, and
- bedrock.

The areal extent of the aquifers or the areas where they may occur are indicated on the aquifer map in Figure 3.

#### 4.1.3. Shallow Sand Aquifers

The shallow sand aquifers are formed by the surface sand deposits that cover most of the Lowland in the southern part of the Watershed. Shallow sand aquifers may also occur in depressions in the Upland area. These aquifers are almost continuous over the whole sandy area. However, in some parts of the sandy area the saturated sand layer is not continuous and the aquifers are formed by isolated saturated lenses of sand surrounded by dry sand or saturated silty and clayey sand of low permeability that does not yield water. The saturated thickness of the shallow sand aquifers usually is less than 3 m (10 ft.) and saturated thickness of less than one metre (3 ft.) is not unusual. The yield of wells drawing water from the shallow sand aquifers usually is in the 0.1 L/s to 0.5 L/s range (1 - 6 I.G.P.M.). Where the aquifer conditions are exceptionally good the yield can be more than 1.0 L/s (13 I.G.P.M.).

Water levels in the shallow sand aquifers under normal conditions fluctuate 0.5 m to 1.5 m yearly (1.5 ft. to 5 ft.). The highest level

summer. Because of the thin saturated zone, the shallow sand aquifers are subject to drying up or severely reduced pumping rates in periods of drought. Whether or not the shallow aquifers would be totally dewatered in extensive periods of drought is indicated by the colour of the sand; if the sand near the base of the aquifer is grey or white, which indicates that it is not oxidized, it is a good indication that the aquifer will stay saturated even under severe drought conditions. On the other hand, brown and rusty (severely oxidized) sand at the base of the aquifer indicates that the aquifer dries up frequently.

Water quality in the shallow sand aquifers ranges from fair to excellent under natural conditions.

#### 4.1.4. Deep Sand Aquifers

The deep sand aquifers are formed by lenses of sand interbedded in clay, silt and silty sand in the Upland area. The depth to these aquifers is up to 50 m (160 ft.). The yield of wells in these aquifers ranges from low to moderate (0.1 L/s to 5 L/s or 1 - 65 I.G.P.M.). In a few places conditions could be favourable for a yield of 10 L/s (130 I.G.P.M.) or more. Water quality in the deep sand aquifers likely ranges from fair to excellent. Water supply from the deep sand aquifers is not likely to be seriously affected by periods of drought or seasonal fluctuations of water level in the aquifers.

#### 4.1.5. Sand and Gravel Aquifers

The sand and gravel deposits that occur within the glacial till and at the base of it are water bearing. However, in most of the Watershed the water in these aquifers is salty. Only in a fairly wide belt between Rossendale and Edwin and in a few other areas as indicated on the aquifer map (Figure 3) the water is potable and the deep sand and gravel aquifers form the best or the only source of potable water. Most of the sand and gravel aquifers are thin and small in areal extent. Consequently, several test holes may be required to find these aquifers and they may not exist at the site where the well is required. Because the areas where the sand and gravel aquifers may occur are overlain by thick clay deposits, the depth to the aquifers usually is more than 20 m

is around one litre per second (13 I.G.P.M.) or less. However, at some locations the sand and gravel aquifers could yield up to 10 L/s (130 I.G.P.M.). Water quality in the sand and gravel aquifers ranges from good to very poor.

#### 4.1.6. Bedrock Aquifers

As indicated in Figure 1 the bedrock contains layers of limestone and sandstone. The limestone and sandstone beds usually are water bearing but the water is too salty to be used for water supply. Consequently, the bedrock surface is the base of exploration for potable water.

#### 4.2. No Potable Groundwater Areas

In most of the area north of the Trans-Canada Highway and in a few areas south of it, the upper layer of the surficial deposits consists of clay that contains no aquifers and water in lenses of sand and gravel in the till that underlies the clay and in the bedrock is salty. Consequently no sources of potable water exist in these areas. These areas are indicated in Figure 3.

#### 4.3. Groundwater Flow Systems

Groundwater constitutes the underground component of the water that flows through the Watershed. Part of the groundwater that flows through the Watershed originates as precipitation outside the Watershed and enters it as subsurface inflow. This inflow may have originated hundreds of miles west of the Willowbend Creek Watershed and is called the regional flow system. The flow systems that originate within the Watershed and, in some places, just outside it are called local flow systems; in areal extent they may cover a large part of the Watershed or less than one square kilometre. The main trends of groundwater flow systems in typical sections through the Watershed are indicated in the diagram in Figure 1.

Because groundwater dissolves the minerals in the strata through which it moves, the water of the regional flow system that arrives in the Watershed after travelling a long distance is considerably more mineralized than water in the local flow systems. Water in the regional flow system is very salty and it is the source of the salty water in the Watershed.

The local flow systems originate in the Upland area and in the sandy areas on the Lowland. Because groundwater in most of the local flow systems has travelled through the subsoil only a short distance, it is fresh and its quality ranges from fair to excellent.

The flow systems have strong influence on groundwater quality in the Watershed; in places or depth zones where the local flow systems dominate it is fresh and where the regional system is dominant it is saline. In some areas the waters of the two flow systems merge and mix. In these areas groundwater is likely to be of poor quality and the quality may vary considerably from place to place or with depth below ground level.

The regional flow system dominates in the bedrock aquifers. Consequently, water in the bedrock is salty throughout the Watershed.

The local flow systems dominate the groundwater flow in the surficial deposits in the Upland and in the surface sand areas in the Lowland.

The regional flow system seems to be intruding the sand and gravel aquifers in till in most of the Watershed. Consequently, salty and very poor quality water is common in these aquifers.

#### 4.4. Recharge

In the discussion of the groundwater flow systems in the Watershed it was indicated that the fresh or potable groundwater originates as precipitation that infiltrates the substrata within the Watershed. Hence, the fresh groundwater supply in the watershed to a large extent depends on the infiltration of precipitation or aquifer recharge from precipitation in the Watershed.

Under normal conditions groundwater recharge in Manitoba is mostly from snow melt and early spring rains. Precipitation during the summer usually is returned to the atmosphere by evapotranspiration before

it can contribute to the recharge of aquifers. Groundwater level observations, however, indicate that exceptionally heavy rainfall in the summer and particularly in the fall can be a significant factor in groundwater recharge.

Observations of groundwater level fluctuations in shallow sand and gravel aquifers in Manitoba and, in particular, in shallow sand aquifers in adjacent watersheds indicate that on the average the yearly recharge in sandy areas of the Watershed is equal to about 0.1 m (0.3 ft.) of water over the recharge area.

Assuming that the recharge area is equal to the surface sand area the total recharge area of the Watershed is  $280 \text{ km}^2$  (108 square miles) or  $280 \times 10^6 \text{ m}^2$ . The total local recharge then is  $28 \times 10^6 \text{ m}^3$  (23,000 acre-feet) a year. However, not all of this recharge would be available for consumption.

#### 4.5. Total Supply

In the Willowbend Creek Watershed the total supply of potable groundwater depends on local recharge. Water in the deep regional flow systems is salty, and therefore, deep aquifers are of no consequence in respect to fresh water supply.

Although the estimated total yearly recharge is about  $28 \times 10^6 \text{ m}^3$  (23,000 acre-feet) a large part of it is lost by evapotranspiration and because the shallow sand aquifers are scattered over a large area and their saturated thickness in many places is minimal, not all of the shallow aquifers would be practical to develop.

Consequently, for a conservative estimate it can be assumed that the total supply available for development is one half of the total recharge or  $14 \times 10^6 \text{ m}^3$  (11,000 acre-feet) a year. This is equivalent to a sustained pumping rate of 444 L/s (5900 IGPM).

#### 4.6. Well Yield

In the shallow sand aquifer areas well yield generally is low and yield of less than 0.5 L/s I.G.P.M.) is common.

In the deep sand aquifer areas the well yield can be somewhat

higher because usually there is more available drawdown than in the shallow sand areas.

The yield of wells in the sand and gravel aquifers usually is less than 1.0 L/s (13 I.G.P.M.) but in some places it can be more than 10 L/s (130 I.G.P.M.), if the wells are properly designed and installed.

#### 4.7. Irrigation

In general, the aquifers in the area are not suitable for water supply for large scale irrigation. In a few places in the Upland area groundwater conditions probably are suitable for small scale irrigation. In a few places dewatering wet areas probably could provide water for irrigation of nearby dry areas. In all cases considerable testing would be required to determine whether or not irrigation using groundwater is feasible and how much land could be irrigated.

#### 4.8. Quality

Groundwater quality in the Watershed ranges from excellent to very salty. The terms used for quality description are defined in Appendix "A".

Fair to excellent quality water is available in the Upland area and in the shallow sand areas in the southern part of the Lowland. In most of the northern half of the Lowland and in some areas of the southern part shallow aquifers do not exist and water in deep aquifers, e.g., sand and gravel in till, limestone and sandstone, is salty. These areas are indicated as no potable water aquifer areas on the aquifer map (Figure 3). In the areas where the only aquifers are sand and gravel lenses interbedded in till, the quality generally is fair to very poor. A few exceptions do occur, e.g., water in the community well at Rossendale, which draws water from a sand and gravel aquifer at 49 m (160 ft.) is of good quality.

#### 4.9. Availability

The availability of groundwater in an area depends on the kind of aquifers that exist there. Hence, the aquifer map in Figure 3 can be used to indicate groundwater availability in the Watershed.

The Watershed can be divided into areas (1) where groundwater is readily available, (2) where it is available with some difficulty, and (3) in areas where fresh groundwater is not available.

As areas where groundwater is readily available can be considered those parts of the Watershed where aquifers are continuous over large areas and one can be reasonably certain that adequate supply for domestic and farm use can be obtained at practically any point underlain by the aquifers. In the Willowbend Creek Watershed these conditions exist only in the deep sand aquifer area indicated in Figure 3.

Groundwater is available with some difficulty in areas where aquifers are small, discontinuous and scattered randomly throughout the area. In these areas groundwater even for domestic use is not available at every point and test drilling may be required to find a suitable source. These conditions exist in the shallow sand and the sand and gravel aquifer areas (Figure 3). In these areas on some small properties, e.g., town building lots, potable water aquifers may not exist or supply may not be adequate.

Areas where potable groundwater is not available are those parts of the Watershed where water in all water bearing formations is salty. These areas are shown as no potable aquifer areas in Figure 3.

#### 4.10. Present Consumptive Use

In the Willowbend Watershed groundwater is used mainly for domestic and farm water supply.

Because the Watershed covers parts of several municipalities, reliable statistics about population and livestock for estimating present use are not available. Based on available consumption figures for similar areas, the estimated groundwater consumption in the Watershed is about  $675 \text{ m}^3/\text{d}$  (150,000 gpd), which is equivalent to a sustained pumping rate of  $7.5 \text{ L/s}$  (100 I.G.P.M.). The total yearly consumption is  $2.5 \times 10^5 \text{ m}^3$

(203 acre-feet).

The estimated yearly consumptive use is only a fraction of the estimated total yearly supply of about  $14 \times 10^6 \text{ m}^3$  (11,000 acre-feet).

## 5 WELL DESIGN AND RELATED PROBLEMS

During the investigation of water resources in the Almassippi sand areas (J. Little, 1979) it was determined that in the shallow sand aquifer areas the lack of adequate water supply often is related to poor well design, inadequate investigations for selecting well sites, inadequate number of wells or too close spacing of wells where several wells existed.

Experimental well installations indicated that in areas where the saturated thickness is minimal and the permeability of the sand varies considerably from place to place, considerable test drilling is required to find the best well site. The experiments also indicated that in some areas where lack of water was chronic, adequate supply could be obtained by installing properly designed wells. If several wells are installed, which in some cases may be necessary to provide an adequate supply, the wells should be adequately spaced to prevent serious interference.

It seems that the water supply on many, and probably most, farms in the shallow sand aquifer areas could be improved by installing new wells of better design at better locations. Basically it means adequate test drilling and installing screened or perforated and filter sand packed wells and using proper construction methods.

## 6 WET SAND AREAS

### 6.1. Definition

In some parts of the sandy areas of the Watershed (Almassippi soil areas), the water table of the shallow sand aquifers is at or near ground surface and interferes with agricultural land use. These sandy high water table areas are referred to as wet sand areas.

### 6.2. Causes

Very little research has been done to determine the exact cause of the wet sand conditions. However, based on the hydrogeological conditions in the shallow sand area it can be visualized that the wet sand areas could be caused by the following conditions:

1. Irregularities in the clay or till surface that underlies the sand. These irregularities in effect form dams that restrict groundwater movement and cause impoundment of groundwater which results in high water table above the "dam" (Figure 4,A).
2. Low permeability zones in the sand deposits. The low permeability zones restrict groundwater movement and cause ponding of groundwater upgrate from them (Figure 4,B). As the permeability of the sand likely varies considerably from place to place, this may be a fairly common cause of the wet sands.
3. Depressions in the sand surface. This condition simply reduces the distance between the ground~~water~~ surface and the water table as shown in Figure 4,C. As a result the water table can be at or near ground surface and cause the wet sand conditions.

### 6.3. Drainage

It appears that conditions in the wet sand areas caused by the restrictions in the groundwater flow could be improved by installing surface or subsurface drains through the clay or till "dams" or through the low permeability zones. To lower the water table in the wet sand areas in depressions also would cause lowering water table in the

surrounding area. This could cause other problems while solving the wet sand problem, e.g., dewatering of wells, too dry condition on adjacent land and waste of groundwater resources.

Considerable research will be required to determine if and when drainage of wet sands is feasible and to find the best methods for draining the wet sands without adversely affecting groundwater conditions in adjacent areas.

## 7 GROUNDWATER, SALINE SOILS AND DRAINAGE

Saline soils usually are found in places where groundwater reaches or is near ground surface and evaporates or is used up by plants. As the water is removed from the soil the salts dissolved in it remain in the soil and increase soil salinity. The salinity of soils is likely to be more severe in areas where, in addition to the above conditions, groundwater is highly mineralized.

Because the salinity of soils is caused by salts that are carried upward to the rooting zone by groundwater, the accumulation of salts in soil can be stopped and reduced by reversing net groundwater movement near ground surface, i.e., inducing infiltration of fresh water. The fresh water then dissolves the salts and carries them away from the top soil and rooting zone. The removal of the salts or leaching may be fairly fast in sandy soils, but in heavy clay soils leaching is so slow that it may take 30 to 60 years before salinity is significantly reduced (Manitoba Department of Agriculture, 1969).

The downward movement of groundwater can be induced by artificial drainage; both open drains and subsurface drains may be used. The question arises whether or not artificial drainage, particularly buried tile drains, will be effective in reducing soil salinity in the Watershed. In areas where the salinity is caused by upward seepage of very saline water through clay and glacial till, to reverse the flow direction closely spaced drains would be required and the leaching process would be very slow. Hence, it is very doubtful that improved drainage will be effective for desalinization of soils in all parts of the Watershed. Artificial drainage may be effective only in areas where soil salinity is caused by a high water table in sand deposits at surface. Because in some places improved drainage may reduce recharge of local groundwater flow systems that, in turn, may result in saline water intrusion in shallow aquifers or dewatering of some of the shallow sand aquifers, it cannot be taken for granted that the net result of draining the high water table areas will always be beneficial.

Because it is not certain that improved drainage will always result in better soil conditions or will not interfere with groundwater

supply, the hydrogeological conditions in a particular area should be evaluated before drainage projects to reduce soil salinity are undertaken. It appears that it would be unreasonable to assume that artificial drainage would effectively solve all saline soil problems in the Watershed.

## REFERENCES

- Ehrlich, W.A., Poyser, E.A., L.E. Pratt, 1957, Reconnaissance soil survey of Carberry map sheet area; Manitoba Soil Survey, Soils Report No. 7.
- Little, J. 1979, Groundwater Availability Study, Almassippi Soils Area, Manitoba Department of Natural Resources, Water Resources Branch. In preparation.
- Manitoba Department of Agriculture, 1969. The Nature and Management of Saline Soils: Manitoba Department of Agriculture Publication No. 360, Revised.
- Milne, R.A., and Rapp, E., 1968, Soil Salinity and Drainage Problems: Canada Department of Agriculture Publication 1314.

APPENDIX A  
GROUNDWATER QUALITY DESCRIPTION

To describe groundwater quality the terms excellent, good, fair, poor and combinations and modifications of them are used in this report. Unless other uses are specified these terms indicate how acceptable the water is for domestic use. The quality description is based on the total dissolved solids, the concentration of the common ions that affect quality, hardness, appearance, taste and odour of the water.

The meaning of the terms used for groundwater quality description is as follows:

1. Excellent: The water has no objectionable properties and treatment of it to improve quality is not necessary; the total dissolved solids concentration is less than 500 mg/L and hardness less than 250 mg/L.
2. Good: The water has higher mineral concentration than the excellent water and is rated less than excellent mainly because of higher hardness; the total dissolved solids concentration ranges from 500 to 1000 mg/L and hardness is from 250 to 500 mg/L. The hardness is likely to cause incrustation of kitchen utensils. The water can be used without treatment or, if desired, the hardness can be readily reduced.
3. Fair: The water has one or more objectionable properties and fairly commonly may require treatment to improve quality. The most common undesirable property is high hardness; it ranges from 500 to 1000 mg/L. The hardness can be reduced to acceptable level with conventional water softeners. The water may have high enough sulphate, iron and chloride ion concentration to slightly impair the taste or, in the case of sulphates, have a laxative effect on persons not used to it. The total dissolved solids of the water is from 1000 to 2000 mg/L.
4. Poor: The water has one or more serious undesirable properties and it is difficult to impossible to improve the water quality by conventional water treatment. The water commonly is very hard (more than 1000 mg/L) and it may be difficult (also expensive) or impractical to reduce the hardness with conventional

water softeners. The water may also have a very high sulphate ion concentration (500 to 2500 mg/L). In some places the water may be rated as poor quality because of high sodium chloride (salt) concentration, which makes it taste salty. The water may be also less than desirable in appearance and may have an unpleasant odour.

5. Very Poor: The undesirable properties of the water are just below a tolerable maximum limit.



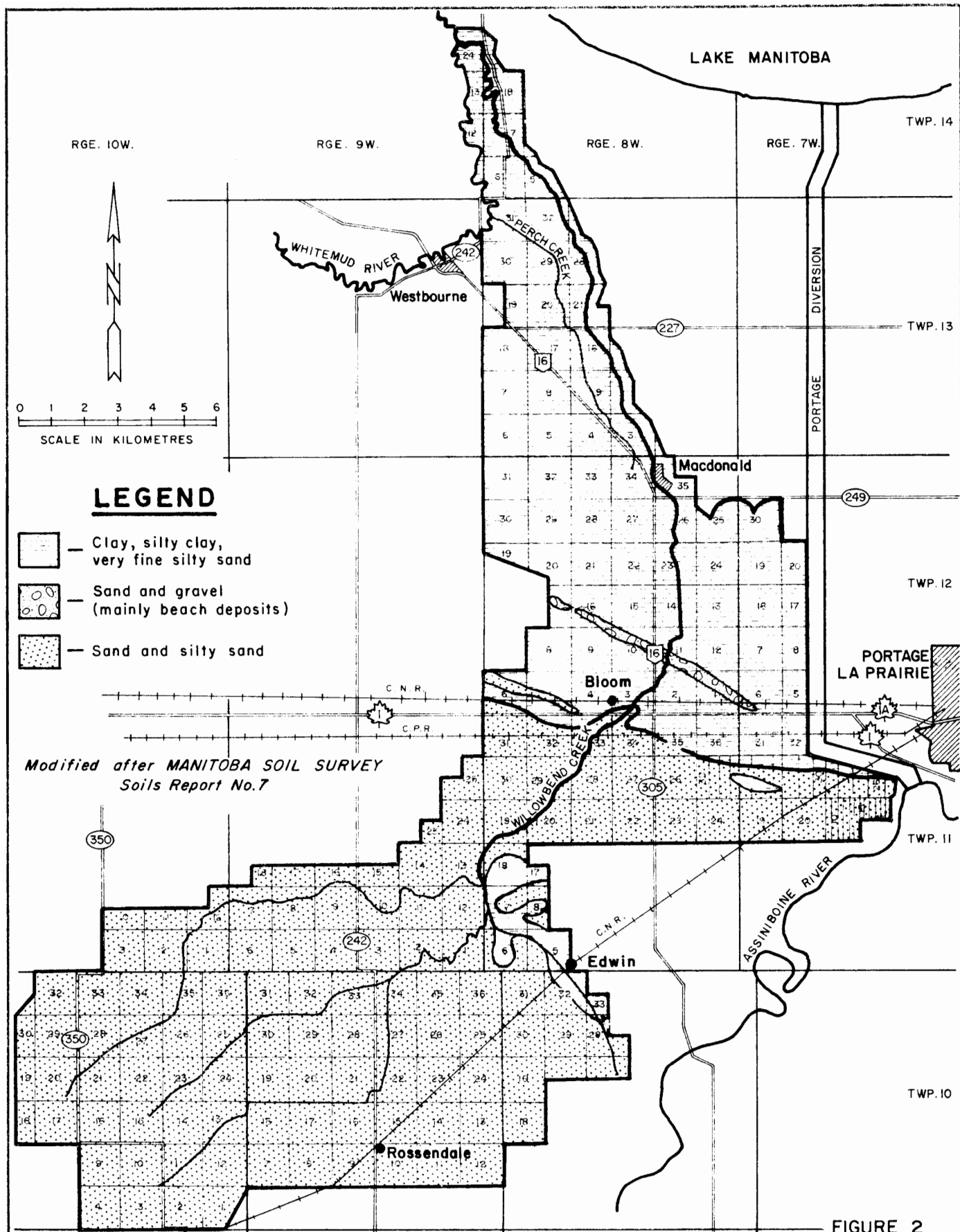
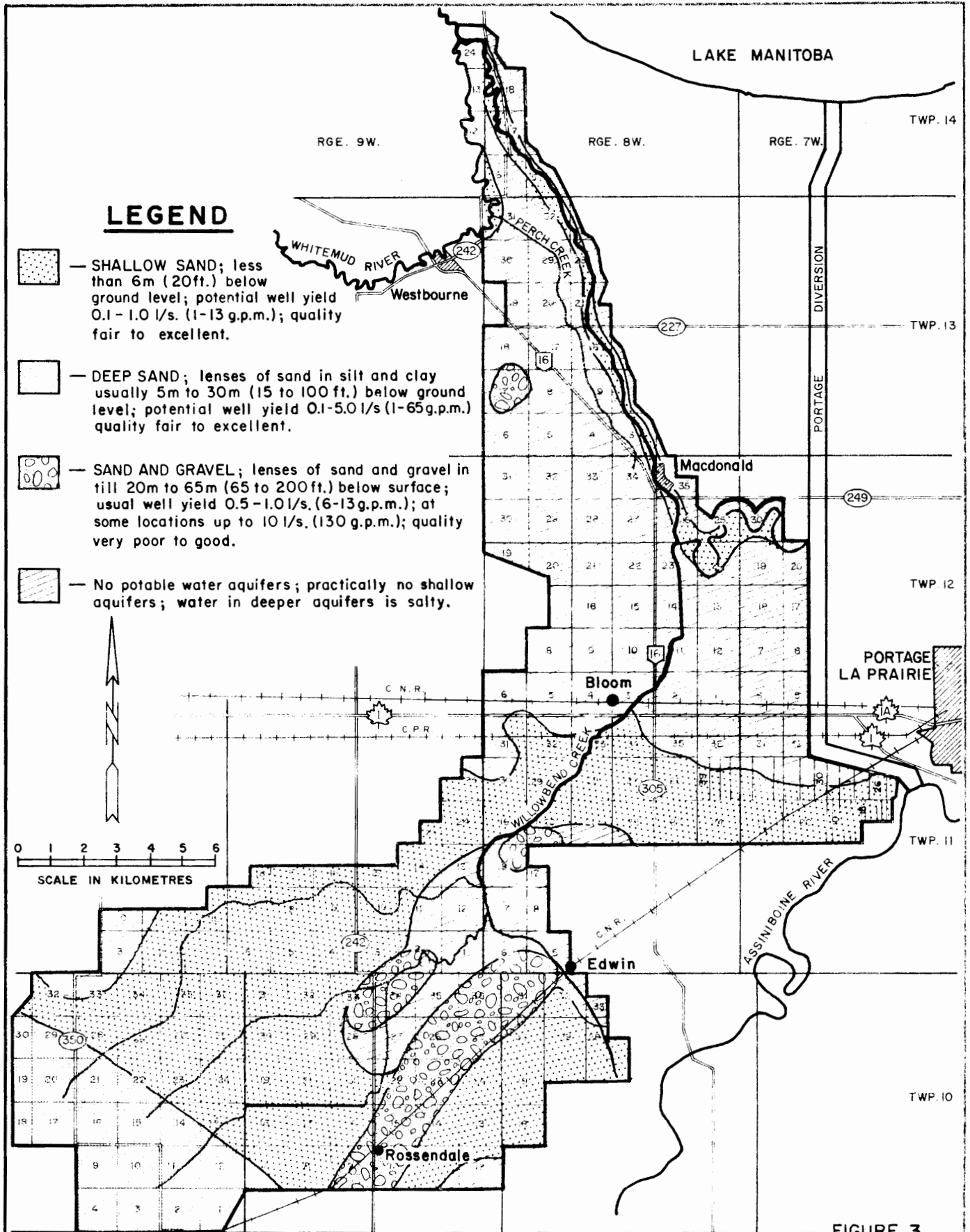






FIGURE 2

PROVINCE OF MANITOBA DEPARTMENT OF NATURAL RESOURCES WATER RESOURCES BRANCH				WILLOWBEND CREEK WATERSHED			
<b>SURFACE DEPOSITS</b>							
PREPARED M.R.	DRAWN F.R. CHECKED	SUBMITTED	APPROVED	SCALE AS SHOWN	DATE 80 06 20	SHEET OF	FILE NO 80-1-7-1030



**LEGEND**

- 
 — SHALLOW SAND; less than 6m (20ft.) below ground level; potential well yield 0.1 - 1.0 l/s. (1-13 g.p.m.); quality fair to excellent.
- 
 — DEEP SAND; lenses of sand in silt and clay usually 5m to 30m (15 to 100 ft.) below ground level; potential well yield 0.1-5.0 l/s (1-65g.p.m.) quality fair to excellent.
- 
 — SAND AND GRAVEL; lenses of sand and gravel in till 20m to 65m (65 to 200 ft.) below surface; usual well yield 0.5 - 1.0 l/s. (6-13g.p.m.); at some locations up to 10 l/s. (130 g.p.m.); quality very poor to good.
- 
 — No potable water aquifers; practically no shallow aquifers; water in deeper aquifers is salty.

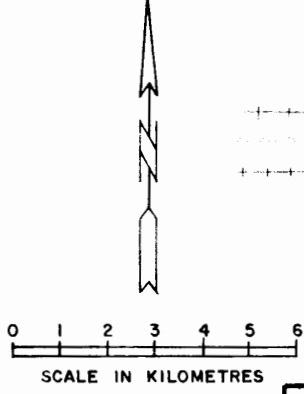
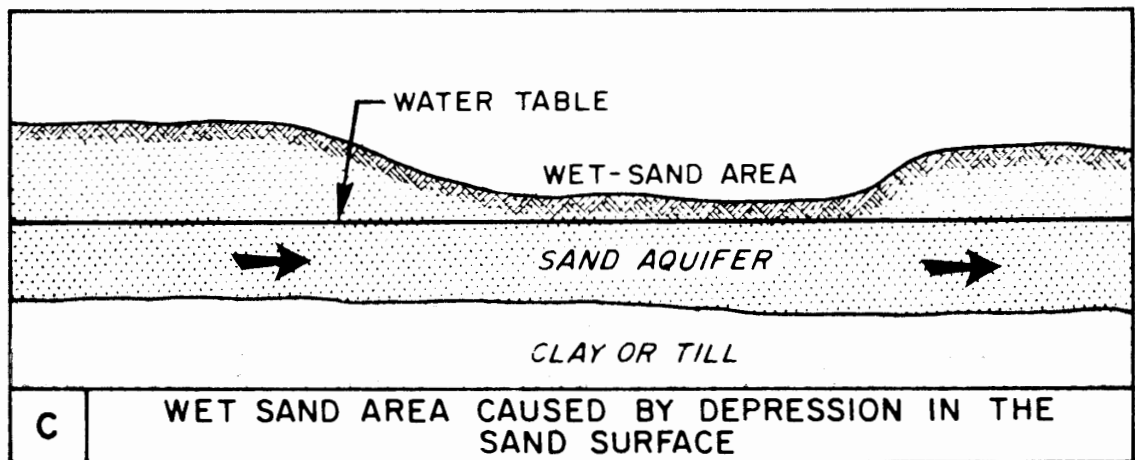
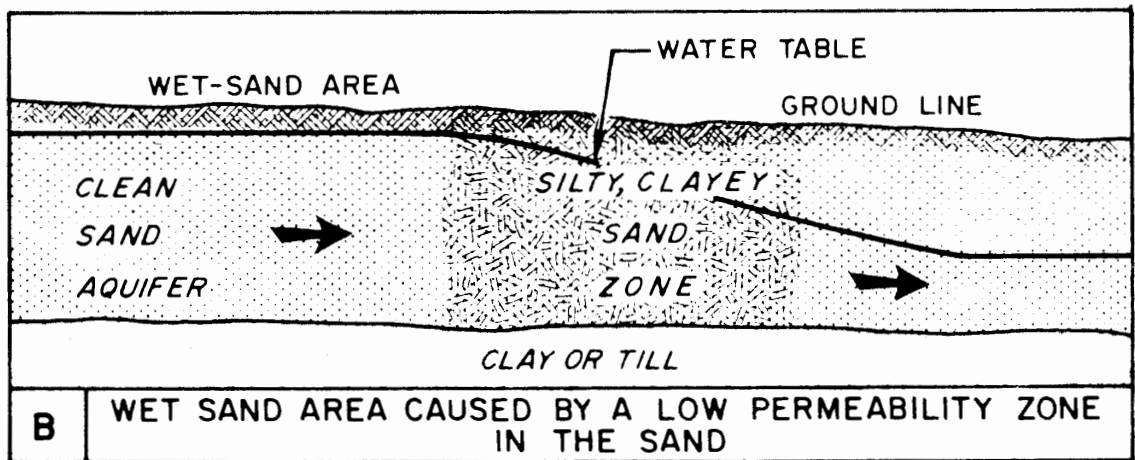
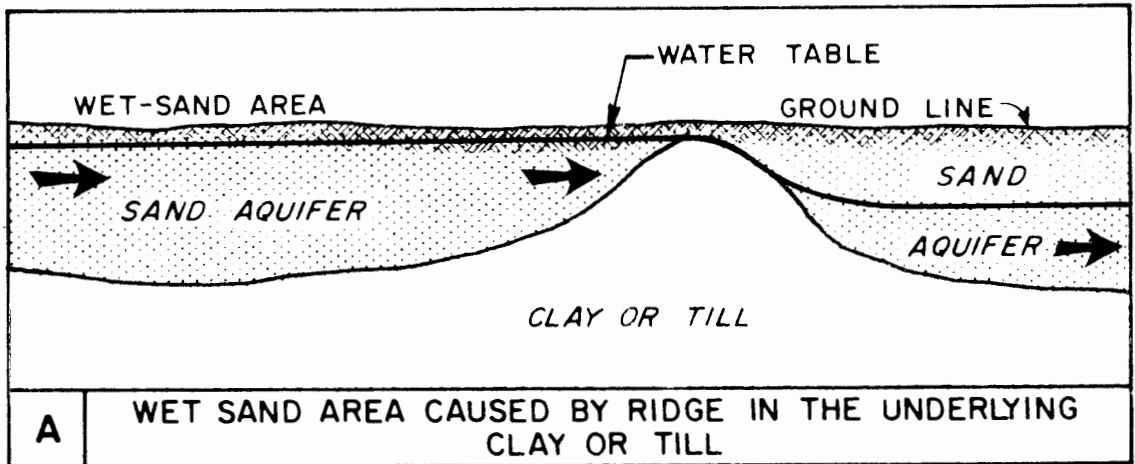


FIGURE 3

PROVINCE OF MANITOBA DEPARTMENT OF NATURAL RESOURCES WATER RESOURCES BRANCH				WILLOWBEND CREEK WATERSHED <b>AQUIFERS</b>			
PREPARED M. R.	DRAWN F.R. CHECKED	SUBMITTED	APPROVED	SCALE 45 SHOWN	DATE 80 06 20	SHEET OF	FILE NO 80-17-1030



➔ — DIRECTION OF GROUNDWATER MOVEMENT

FIGURE 4

PROVINCE OF MANITOBA DEPARTMENT OF NATURAL RESOURCES WATER RESOURCES BRANCH				WILLOWBEND CREEK WATERSHED <b>BASIC CAUSES OF          WET-SAND AREAS</b>			
PREPARED M.R.	DRAWN F.R. CHECKED	SUBMITTED <i>[Signature]</i>	APPROVED <i>[Signature]</i>	SCALE AS SHOWN	DATE 80 06 20	SHEET OF	FILE NO 80-17-1030