HYDROGEOLOGIC PROFILE SASKATCHEWAN-MANITOBA BOUNDARY

Prepared for the
PRAIRIE PROVINCES WATER BOARD
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PRAIRIE PROVINCES WATER BOARD
CANADA ALBERTA, SASKATCHEWAN MANITOBA

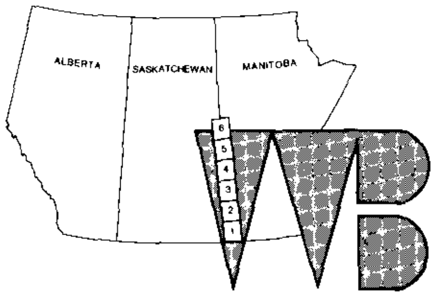
FOREWORD

In May 1985, the Prairie Provinces Water Board contracted with Geoscience Consulting Ltd. to construct a hydrogeologic profile along the Saskatchewan-Manitoba boundary.

The Consultant, in September 1985, completed the project and submitted to the Board a summary report including six map sheets as specified in the contract.

The map sheets provide general information and do not individually identify data points. They are intended for the use of people requiring a generalized knowledge of groundwater potential adjacent to the Saskatchewan-Manitoba boundary. More detailed information on the data points used to develop these maps can be made available, on request, by contacting the Prairie Provinces Water Board or any of the members of the PPWB Committee on Groundwater.

The report originally prepared by the consultant has been revised to incorporate comments from the PPWB Committee on Groundwater and has been edited by the PPWB Secretariat.



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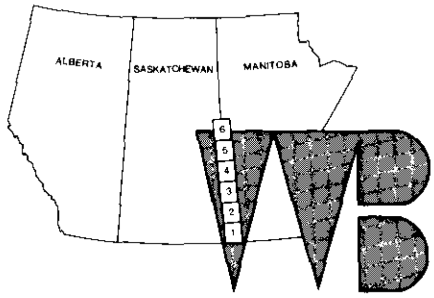


INTRODUCTION 1

A hydrogeologic profile to be used in groundwater management has been constructed from 49° 00' to 55 ° 00' N. Lat. along the Manitoba-Saskatchewan boundary. Six profiles were prepared on 1:250 000 horizontal scale and 1:5 000 vertical scale, with each profile covering one degree of latitude. The profiles extend from the U.S. boundary north to the Canadian Shield. Included on the profiles are relevant geology and principal aquifers, bedrock surface topography, base of groundwater exploration, and data control. A map showing bedrock topography and data control points accompanies each profile. All data control surface points within 19 kilometres of the boundary have been considered, with some additional data at greater distances from the boundary being obtained from existing hydrogeological and bedrock surface topography maps.

Maps and profiles are presented herein for the following areas:

Profile No. 1: Map 62F (Virden, Manitoba/Saskatchewan)
Profile No. 2: Map 62K (Riding Mountain, Manitoba/Saskatchewan)
Profile No. 3: Map 62N (Duck Mountain, Manitoba/Saskatchewan)
Profile No. 4: Maps 63C (Swan Lake, Manitoba/Saskatchewan) & 63D (Hudson Bay, Saskatchewan)
Profile No. 5: Maps 63F (The Pas, Manitoba/Saskatchewan) & 63E (Pasquia Hills, Saskatchewan)
Profile No. 6: Maps 63K (Cormorant Lake, Manitoba/Saskatchewan) & 63L (Amisk Lake, Saskatchewan)

ACKNOWLEDGEMENTS

The profiles and accompanying maps have been constructed using existing data and reports. No new testholes were drilled. The following individuals and organizations have been very helpful in providing information and assistance in the preparation of this report:

R.B. Godwin, Prairie Provinces Water Board, Regina
D.H. Pollock and J. Lebedin, PFRA, Regina
U.V. Roeper and T.W. Rey, Saskatchewan Water Corporation, Moose Jaw
L. Gray & M. Rutulis, Manitoba Dept. of Natural Resources, Winnipeg
B.B. Bannatyne, Manitoba Energy and Mines, Winnipeg

The assistance of these individuals and others is gratefully acknowledged.

PREVIOUS WORK

The Saskatchewan Research Council has prepared a series of geology and groundwater maps on a 1:250 000 NTS grid basis. Four of these maps, dating from 1969 to 1974, cover the Manitoba-Saskatchewan boundary from 49° 00' to 53° 00' N. Lat. The maps show bedrock topography, bedrock formations beneath the drift cover, and data control points along with bedrock elevation at these points. Major buried valleys have been identified and named, and marginal notes identify the major aquifers. Three or four geological profiles accompany each map with details such as electric log traces and testhole lithologies being shown on the accompanying cross-sections.

The Water Resources Branch of the Manitoba Department of Natural Resources has prepared a Groundwater Availability Map Series that also covers the four map sheets along the boundary from 49° 00' to 53° 00' N. Lat. Several maps are presented in the folder for each map sheet. These maps show bedrock geology, bedrock topography, drift thickness, surficial deposits, and water quality (total dissolved solids). A table of chemical analyses is included and a number of cross-sections are presented. The cross-sections show geological formations, borehole lithologies and electric log traces. Total dissolved solids in the well water on the line of section is shown, as is the pumping rate of any tests carried out and the transmissivity obtained from the test. There is no accompanying text in the Groundwater Availability Map Series.

The Water Resources Branch in Manitoba has also produced a series of reports that cover areas smaller than a complete map sheet of the Groundwater Availability Map Series. These reports include much the same information as does the map series, but a text is included, and logs of wells and testholes are included in some reports. In addition to the above studies, the Geological Survey of Canada has prepared bedrock topography maps near the boundary, principally in Manitoba. These maps have been superceded by more recent provincial map series.

In the Saskatchewan map series, Saskatchewan Research Council testholes and measured outcrops have been used in obtaining the basic geologic framework. Geophysical logs, mainly electric logs (e-logs), of oil exploratory wells and structure testholes provided additional data. Other data control points were carefully selected to ensure that only reliable data were used in the map preparation. Only selected, carefully checked, water well drillers' logs were used since many drillers' logs were either contradictory or considered to be unreliable. The Saskatchewan maps provide a good geological foundation on which future hydrogeological work can be based. Chances of errors through the use of poor quality data are minimized. Data control points however are usually widely spaced resulting in correlations over long distances and, usually, a somewhat simplified interpretation of the actual situation.

In most areas close to the boundary, there were more control points on the Manitoba side than on the Saskatchewan side. Partly this is because both the Water Resources Branch of the Manitoba Department of Natural Resources, and the Geological Survey of Canada carried out major test drilling programs in those areas of Manitoba. The greater density of testholes provided a good check of water well drillers' logs, with the result that more water well records were considered sufficiently reliable to be included on the maps. In addition, some of the drillers involved in government testhole programs, continued to drill domestic wells in the area, and often provided lithologic logs which were superior to the logs supplied by drillers that had not been exposed to the identification techniques, terms and nomenclature used in the testhole programs.

DATA CONTROL AND METHOD OF PRESENTATION

The method of presentation used in this report closely follows the methods used by both the Saskatchewan Research Council and the Manitoba Water Resources Branch. Data control points were plotted on the working maps and actual values, such as bedrock surface elevation, were identified for each point. The data control, however, is not shown on the maps accompanying this report. Selected e-log traces are shown on the profiles.

Field work, such as test drilling and outcrop examination, was not carried out for this report. Existing data were used and evaluated in the office. Testholes drilled by various government departments such as the Saskatchewan Research Council, the Manitoba Water Resources Branch and the Geological Survey of Canada, and reports produced by these organizations, provided the basic framework for this study. Electric logs are available for most of these testholes. Electric logs of oil exploratory wells and structure testholes and some water wells were also obtained. Accompanying lithologic descriptions were usually available only for water wells, and identifications of the top of bedrock were made using the e-log characteristics. Difficult or questionable interpretations such as sand and gravel beds overlying sandy bedrock, or clayey till or clay overlying shale, were not used in the compilation. Only selected water well drillers' logs were used in these questionable areas.

The Saskatchewan Research Council, in its test drilling program, has described poorly consolidated bedrock materials without making any reference to their degree of lithification. Bedrock materials are described for example as clay, silt, sand, etc. (generally non-calcareous) rather than claystone, mudstone or shale, siltstone, sandstone, etc., although they may be slightly indurated. Some degree of induration is usually evident in outcrops and use of the terms for indurated materials is favored because it provides a ready distinction between drift and bedrock materials. Alternatively the descriptions could be improved by the addition of the word "bedrock", an age connotation such as Cretaceous, or a formation designation (eg. bedrock clay, Cretaceous clay, Swan River sand). Water well drillers will tend to follow the lead of the hydrologists and, if a clearly identified distinction between drift and bedrock is not made by the hydrologists, drillers may also not make this distinction, resulting in a loss of considerable valuable data. Even with the most careful logging, some uncertainties will arise, and mistakes may be made. The advantage of having generally reliable water well drillers' logs is that a great amount of information over a large area can be made available quickly without extensive and costly test drilling. Questionable or critical areas must still be checked.

In most cases, even with the addition of new data, there was either little need to change the existing mapping or only minor modifications were necessary. In some cases, however, buried valley trends were modified or extended.

Other changes in bedrock topography mapping can be seen by comparison with previous maps. Additional changes are anticipated as new data become available.

GEOLOGY AND HYDROGEOLOGY

Aquifers are found in both drift and bedrock sediments. Drift refers to loosely consolidated sediments (till, clay, silt, sand, gravel), mainly of Quaternary age. The term, because of the difficulties related to exact dating and identification, may also include some materials of Tertiary age. Potable water is usually found only in sediments in the upper part of each profile, but the cross-sections have been extended downwards into the Paleozoic in the southern two profiles, and the Precambrian in the northern four profiles. This was done because the deeper aquifers containing saline water, and often oil and gas pools, can be used both as sources of water for injection purposes in oil fields, and as waste disposal zones. Most of the oil exploratory wells in the southern part of the mapped area have not penetrated deeper than the uppermost Paleozic strata but the geological cross-sections are reasonably complete in terms of available geologic data down to, and including, that depth.

A line indicating the "base of groundwater exploration" is shown on the Saskatchewan groundwater resource maps. Groundwater below this base is considered to be too mineralized or saline for domestic and stock-watering purposes. The limit of mineralization is not stated on each map but, on most of the maps, a limit of 4000 mg/L (ppm) of total dissolved solids was used, and a limit of 5000 mg/L was used on others.

Stratigraphic nomenclature along the boundary area is shown in Table 1. Nomenclature of Cretaceous sediments along the boundary has been recently revised by McNeil and Caldwell (1981). Correlation with the names used on geological and hydrogeological maps, prior to 1981, is indicated in Table 1.

The drift cover contains important aquifers but has not been subdivided into units by most previous authors, although Klassen (1979), provided a stratigraphic nomenclature for drift deposits in the Riding Mountain and Duck Mountain map sheets. Glacial till is the main material in the drift but sand and gravel lenses may also occur within the till. There are also, in many places, stratified intertill sediments and stratified sediments between the till and the underlying bedrock. These stratified sediments may include the sand and gravel that forms the main aquifers within the drift. The stratified sediments between till and bedrock in many of the major buried valleys may be either glacial or preglacial in age and have been called the Empress Group, Whitaker and Christiansen (1971). The Empress Group may also be present in other locations at the base of the drift outside of the buried valleys. The Empress group is defined by Whitaker and Christiansen (1971) to be late Tertiary to Quaternary in age.

Stratified sediments of supposed Tertiary age overlying Cretaceous bedrock in upland areas, were informally assigned to the "Wynyard Formation" by Cherry and Whitaker (1969) in the Yorkton, Saskatchewan map sheets (62M and 62N) and by Little and Sie (1976), in the Duck Mountain sheet (62N), Manitoba. Correlations by Klassen (1979), suggest that this formation is much more extensive than Cherry and Whitaker (1969), Little and Sie (1976) and Christiansen (1981) indicated. Schreiner and Maathuis (1982), have used the term "Bredenbury Formation" for extensive sands and silts of supposed preglacial (Tertiary - Quaternary) age located in an upland area on the north side of the Melville,

Table 1 CORRELATION OF GEOLOGIC UNITS, SASKATCHEWAN - MANITOBA BOUNDARY, 49°00' to 55°00' N. Lat.

Unit of geologic time	Nomenclature, this report	Nomenclature previous hydrogeological maps, Saskatchewan	Nomenclature, previous hydrogeological maps, Manitoba	Distribution of units by map sheet. Formation beyond depth of profiles not shown.
Quaternary	*Undifferentiated drift*	*Undifferentiated drift*; *Empress Group 62F*; *Bredenbury Fm. 62K, N*; *Wynyard Fm. 62N*	*Undifferentiated Drift*; *Wynyard Fm. 62N*	*All map sheets*
Cretaceous	*Ravenscrag Fm.*	*Ravenscrag Fm.*		
	Frenchman Fm., *Whitemud Fm.*, *Eastend Fm.*	*Frenchman Fm.*, *Whitemud Fm.*, *Eastend Fm.*		
	Pierre Shale; *Odanah mbr.*	*Riding Mountain Fm.*: *Odanah mbr.*, *Millwood mbr.*	*Riding Mountain Fm.*: *Odanah mbr.*, *Millwood mbr.*	62F, 62K, 62N, 63C
	Niobrara Fm.; *Morden Shale*	*Vermilion River Fm.*	*Vermilion River Fm.*: *Pembina*, *Boyne*, *Morden*	
	Favel Fm.	*Favel Fm.*	*Favel Fm.*	
	Ashville Fm.; *Newcastle ss mbr.*	*Ashville Group*; *Fish Scales bed 62N 63D*; *Viking Fm. 62N, 63D*	*Ashville Fm.*; *Ashville sand*	
	Swan River Fm.	*Swan River Group*	*Swan River Group*	
Jurassic	*Undivided*	*Undivided*	*Melita Fm.*, *Reston Fm.*, *Amaranth Fm.*	
Triassic				
Permian				
Pennsylvanian				
Mississippian	*Undivided*	*Big Valley Fm.*, *Lodgepole Fm.*, *Bakken Fm.*	*Undivided*	
Devonian	*Undivided*: *Dawson Bay Fm.*, *Elk Point Fm.*, *Winnipegosis Fm.*, *Ashern Fm.*	*Big Valley Fm.*, *Torquay Fm.*, *Birdbear Fm.*, *Duperow Fm.*, *Souris River Fm.*, *Dawson Bay Fm.*, *Prairie Evaporite Fm.*	*Undivided*	
Silurian	*Interlake Group*		*Undivided*	
Ordovician	*Undivided*: *Stonewall Fm.*, *Stony Mountain Fm.*, *Red River Fm.*, *Winnipeg Fm.*		*Undivided*	
Cambrian				
Precambrian	*Undivided*		*Undivided*	63F, 63K

Saskatchewan mapsheets (62K and 62L) and extending into the Yorkton sheet. There is some difference of opinion as to the age, delineation, and correlation of the "Wynyard Formation", "Bredenbury Formation" and Empress Group. Consequently, these formations are not shown separately in the present study, and have been included as drift material.

REFERENCES

Bannatyne, B.B.; 1970; The clays and shales of Manitoba; Province of Manitoba Department of Mines and Natural Resources, Publ. 67-1.

Cherry, J.A., and Whitaker, S.H.; 1969; Geology and Groundwater resources of the Yorkton area (72M, N), Saskatchewan; Saskatchewan Research Council, Geological Div. Map No. 9.

Christiansen, E.A. Consulting Ltd., 1981. Quaternary geology of the Bredenbury area. Report prepared for Clifton Associate Ltd., 1981, Environmental impact of proposed Bredenbury project; Geology, ground and surface water. Draft report prepared for Potash Corporation of Saskatchewan. 70 p., maps, cross-sections.

Klassen, R.W.; 1979; Pleistocene geology and geomorphology of the Riding Mountain and Duck Mountain areas, Manitoba-Saskatchewan Geological Survey of Canada Mem. 396.

Little, J., and Sie. D.; 1976; Duck Mountain area (62N), Groundwater Availability map series; Manitoba Natural Resources, Water Resources.

Manitoba Mineral Resources Div.; 1979; Geological Map of Manitoba, Map 79-2 Scale 1:1,000,000.

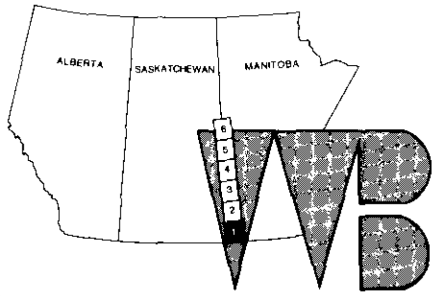
McCabe, H.R.; 1971; Stratigraphy of Manitoba, an introduction and review; The Geological Association of Canada, Special Paper No. 9.

Rutulis, M.; 1984; Groundwater in Manitoba; in Natural heritage of Manitoba - Legacy of the Ice Age, J.T. Teller, ed.; pp.175-193; Manitoba Museum of Man & Nature Publication.

Schreiner, B.T., and Maathuis, H.; 1982, Hatfield Valley Aquifer System in the Melville region, Saskatchewan; Report for Saskatchewan Environment by Saskatchewan Research Council, Geol. Div., SRC Publ. No. G-743-3-B-82.

Whitaker, S.H., and Christiansen, E.A.; 1972, The Empress Group in Southern Saskatchewan; Canadian Journal of Earth Sciences, vol. 9, No. 4, pp. 353-360.

Whitaker, S.H., and Pearson, D.E.; 1972; Geological Map of Saskatchewan; Province of Saskatchewan, Department of Mineral Resources map. Scale 1:1,267,200 (1" = 20 miles).



MAP 62F

62F Virden, Manitoba – Saskatchewan

2

Bedrock topography of the Manitoba portion of this map sheet has been mapped by Klassen and Wyder (1970), Klassen, Wyder and Bannatyne (1970), and by Betcher (1983). Bedrock topography of the Saskatchewan portion has been mapped by Whitaker (1974). Klassen & Wyder (1970), include comments on the nature of the drift materials. Betcher (1983), includes maps showing the underlying bedrock geology, drift thickness, and water quality, and presents cross-sections that show subsurface lithologies, the results of pumping tests and water analyses in selected wells. There is no text accompanying Betcher's report. Whitaker (1974), presents a map showing both bedrock topography and the underlying bedrock formations. Stratigraphic cross-sections and marginal notes accompany the map. Groundwater chemistry and major aquifers and their water supply possibilities are discussed briefly in the marginal notes.

A report by the Manitoba Water Resources Division (Planning Division) (1968), discussed groundwater availability of the southern part (tps. 1 to 6) of the Manitoba portion of this map sheet. The various aquifers, their yield capacity and water quality, were discussed and maps were presented showing bedrock topography and bedrock geology. The report included one cross-section.

Groundwater conditions in the adjoining portion of North Dakota were discussed by Randich and Kuzniar (1984), who also presented maps of bedrock topography and geology, and included several cross-sections. Their data were helpful in the contouring of bedrock topography along the southern edge of map sheet 62F.

The Odanah Member of the Pierre Shale (Riding Mountain Formation), unless eroded forms the underlying bedrock along the entire length of the Manitoba-Saskatchewan boundary on this map sheet. Hard siliceous shale makes up a portion of the Odanah member and may be sufficiently fractured and weathered to form a good aquifer. The Manitoba Water Resources Division report (1968), states that the hydraulic conductivity of the shale can range from 5.7 x 10^{-6} to 5.7 x 10^{-4} metres/sec. (10 to 1000 Imperial gallons per day per square foot). The report states that the water bearing beds usually occur within the upper 30 metres of the shale. Nearly all of the highly fractured and weathered shale beds occur adjacent to existing river valleys or bedrock valleys but the shale along the boundary is not fractured so it is unlikely that shale aquifers occur along that boundary. Whitaker (1974) is in agreement that the Pierre Shale does not form an aquifer either along the Manitoba boundary or farther west in Saskatchewan. He places the recommended base of groundwater exploration at the top of the Pierre Shale (Riding Mountain Formation). Johnston (1934), however, cites several examples of wells completed in shale near the boundary. These are probably very low-yielding wells but it is important to recognize their existance.

The Frenchman, Whitemud and Eastend Formations overlie the Pierre Shale in Saskatchewan, and total an estimated 30 metres in thickness for 20 km west of the Manitoba boundary in the south part of township one. As shown by Whitaker (1974), and Meneley (1983), these formations are truncated eastwards by erosion until they become completely eroded some 5 km. west of the boundary. The Tertiary Ravenscrag Formation overlies the cretaceous Frenchman Formation farther to the west in Saskatchewan. Meneley (1983) has termed the Eastend to Ravenscrag Formations the Bienfait Aquifer. Meneley states that channel sands in this aquifer have probable yield ranges of 0.06 to 0.6 L/s, while wells completed in fractured coal or hard fractured sandstone could yield up to 2.9 L/s. The water "...is highly mineralized..." (Menelay, 1983) with many wells yielding sodium chloride/bicarbonate water or sodium bicarbonate/chloride water. The approximate eastward limit of this aquifer is shown on the bedrock topography-geology map.

Drift cover is quite thick, varying from about 35 to 130 metres over the entire area close to the Manitoba-Saskatchewan boundary as shown on the profile, but till is the predominent material, and there are few aquifers. Occasional sand lenses within the till provide a low yield to wells locally, and in some areas even these are rare. Rutulis (1980 and 1976), outlined an area along the boundary from township 4 to 9 in which groundwater possibilities are rated as "poor to none," and there are "no aquifers or water saline or of very poor quality. Satisfactory sources are very difficult or impossible to find." Groundwater possibilities over the remainder of the boundary shown on this map sheet are stated by Rutulis (1980) to be variable.

Various high-yielding buried valley aquifers are known to be present in places some distance from the boundary. Valleys which have been named are the Estevan Valley (Whitaker - 1974), and the Pierson, Medora and Virden Valleys (Klassen & Wyder - 1970). There are other, as yet unnamed, valleys, some of which may prove to contain important aquifers. The eastward extent of the Estevan Valley is in question as discussed below. MacKay and Hainstock (1936), had outlined a portion of a buried valley in tp. 2, rge. 31W1 that may be part of the eastward extension of the Estevan Valley. Meyboom (1966), used this interpretation, but could not, because of lack of data, extend the valley eastward beyond tp. 2, rge. 30W1. Whitaker (1974), has been more cautious in his interpretation and does not extend this valley east of tp. 3, rge. 32W1. There are very few good data control points on the Saskatchewan side of the boundary to indicate the eastward trend of this valley. Considerable drilling, has, however, been carried out on the Manitoba side of the boundary by both the Geological Survey of Canada and the Manitoba Water Resources Branch. The north-south trending Pierson Valley has been well delineated, but there is no evidence of another major valley joining it from the west. The best likelihood of such a connection, if it exists, is believed to be a few km. south of Tilston. Data control in North Dakota is much sparser, but there is no evidence, as shown by maps of Randich and Kuznier (1984), that the Estevan Valley turns and trends southward into that state. Additional drilling may be required in Saskatchewan to better delineate the extent of the Estevan Valley east of tp. 3, rge. 32W1, but there is sufficient information available now to indicate that the alluvial materials of the valley do terminate in Saskatchewan near the Manitoba boundary. The absence of valley alluvium east of tp. 3, rge 32-W1 is attributed to glacial scouring.

Rutulis (1976) states that aquifer tests at Pierson (tp. 3, rge. 29W1) and at Souris (tp. 7, rge. 21W1), show that wells in buried valley aquifers at these locations may be capable of yields of up to 35 L/s. Yields of the same order of magnitude have been obtained from aquifers in the Estevan Valley in Saskatchewan (Walton, 1970). Water quality from the deep valley aquifer at Pierson is considered to be marginal. One sample of this water had a total dissolved solids content of 1684 mg/L and 475 mg/L of chloride.

REFERENCES 62F

Betcher, R.N.; 1983; Groundwater availability map series Virden area (62F); Manitoba Natural Resources, Water Resources.

Johnson, W.A.; 1934; Surface deposits and groundwater supply of Winnipeg map-area, Manitoba; Geological Survey Canada, Mem. 174. - maps surficial geology and discusses aquifers west to the Saskatchewan boundary.

Klassen, R.W. and Wyder, J.E.; 1970; Bedrock topography, buried valleys and nature of the drift, Virden map-area, Manitoba; Geological Survey of Canada Paper 70-56.

Klassen, R.W., Wyder, J.E., and Bannatyne, B.B.; 1970; Bedrock topography and geology of Southern Manitoba; Geological Survey Canada Paper 70-51.

MacKay, B.R., and Hainstock, H.N.; 1936; Preliminary report, groundwater resources of the Rural Municipality of Argyle No. 1, Saskatchewan; Geological Survey of Canada Water Supply Paper No. 5.

Manitoba Water Resources Division (Planning Division); 1968; Groundwater availability in the Melita area; Groundwater availability studies, Report No. 1.

Meyboom, P.; 1966; Groundwater probability, Virden (west half), west or principal meridian, Saskatchewan-Manitoba; Geological Survey Canada Map 1157A.

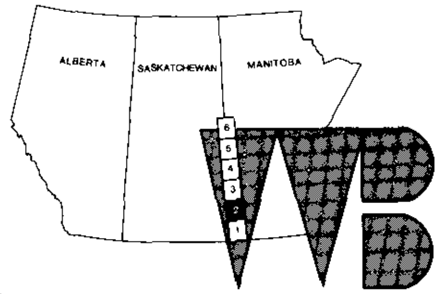
Meneley, W.A.; 1983; Hydrogeology of the Eastend to Ravenscrag Formations in Southern Saskatchewan; report by W.A. Meneley Consultants Ltd. for Saskatchewan Environment.

Randich, P.G., and Kusniar, R.L.; 1984; Groundwater resources of Bottineau and Rolette Counties, North Dakota; County groundwater studies 35-part III, North Dakota Geological Survey Bull. 78 - part III.

Rutulis, M.; 1976; Groundwwater resources in the Souris Basin in Manitoba; Province of Manitoba, Department of Mines, Resources and Environmental mangement, Water Resources Division, May, 1976.

Rutulis, M.; 1980; Groundwater Potential, Manitoba; Manitoba Water Resources Branch, Groundwater section - map.

Whitaker, S.H.; 1974; Geology and groundwater resources of the Weyburn area, (62E, F), Saskatchewan; Saskatchewan Research Council Geological Division Map No. 21.



MAP 62K

62K Riding Mountain, Manitoba – Saskatchewan

3

Klassen (1966) mapped the bedrock topography on both sides of the Manitoba-Saskatchewan boundary. The Saskatchewan portion has been mapped by Christiansen (1971), and by Schreiner and Maathuis (1982). The Manitoba portion has been mapped by Klassen, Wyder and Bannatyne (1970), and by the Manitoba Water Resources Branch (1978).

The Pierre Shale forms the bedrock immediately underlying the drift. Hard, siliceous shale makes up a large part of the Odanah Member, which occurs in the upper part of the Pierre Shale. The Odanah shales are often well fractured and locally comprise low-yielding aquifers. The Odanah Member does not extend along the boundary north of township 15. The remaining lower part of the Pierre Shale (previously called the Millwood member of the Riding Mountain Formation) is made up of soft relatively impermeable marine shales that do not form useable aquifers.

The "Bredenbury Formation" is an informal name applied by Christiansen (1981) and by Schreiner and Maathuis (1982) to a sand unit of preglacial age that has a stratigraphic position on the shale upland above the major buried valley in the north part of map sheet 62K. The formation is believed to be of Quaternary - Tertiary age. Locally it forms a major deposit made up largely of fine to medium grained sand interbedded with fine-grained sand and silt. This formation is not present at the Manitoba-Saskatchewan boundary on this map sheet, although it is shown by Schreiner and Maathuis (1982) to be present close to the boundary at the north end of the map sheet. There is difficulty in differentiating this formation from the Empress Group sediments in uplands areas. The "Bredenbury Formation" therefore is not delineated on the accompanying bedrock topography-geology map although, locally, its importance to Saskatchewan is recognized.

Drift cover is generally quite thick along the boundary, exceeding 50 metres in most places, to a maximum of about 100 metres, but is as locally thin as 10 metres in some local areas. Major aquifers are found in, and adjacent to, the two major buried valleys that cross the boundary. These valleys were named the Hatfield Valley and the Rocanville Valley by Christiansen (1971). The Empress Group of sediments forms the primary fill in these valleys. It rests directly on bedrock, is made up of interbedded sand, gravel, silt and clay, of fluvial, lacustrine and colluvial origin. It is overlain by glacial till and may attain a thickness of over 50 m in some places. The Empress Group is present not only within the major buried valleys, but also in the adjacent uplands (Schreiner and Maathuis (1982).

Schreiner and Maathuis (1982), have divided the Empress Group into various aquifers based on geographic position. The Rocanville Aquifer occupies the Rocanville Valley and the Hatfield Valley Aquifer is located in the Hatfield Valley. A slightly higher level deposit of the Empress Formation, located along the south side of the Hatfield Valley is named the Basal Aquifer, and includes the Welby Aquifer cited by Meneley (1972). The Hatfield Valley Aquifer crosses the boundary in townships 22 and 23 and the north part of township 21. The Basal Aquifer is located adjacent to the boundary in township 20 and the south part of township 21, while the Rocanville Aquifer according to Schreiner and Maathuis (1982), does not extend eastward as far as the provincial boundary. Empress Group sediments, however, appear to be present along the boundary from townships 15 to 17. They are believed to be part of the Rocanville Aquifer.

Differences in permeability and available head result in differences of well yields from these various aquifers. Schreiner and Maathuis, have calculated continuous single-well yields for a well or well-field of 63 L/s for the Hatfield Aquifer, 25 L/s for the Basal Aquifer, and 1.6 L/s for the "Bredenbury" Aquifer. There was not sufficient data for a similar calculation for the Rocanville Aquifer. Water quality within both the Hatfield Valley Aquifer and the Basal Aquifer is relatively poor. The results of 10 analyses from the

Hatfield Valley Aquifer indicate total dissolved solids in excess of 2000 mg/L, sulfates in excess of 900 mg/L, and hardness in excess of 500 mg/L. Schreiner and Maathuis (1982) state that water from the Basal Aquifer "...is generally unfit for a municipal drinking water supply, and it is classified as very poor for domestic use, and as poor but useable as a water supply for livestock." Two water analyses are quoted by Schreiner and Maathuis (1982) for the Rocanville Aquifer. These show total dissolved solids values of 1335 and 1595 mg/L, with the water stated to be fit as a municipal drinking water supply and of good quality for domestic use.

The present-day Qu'Appelle and Assiniboine River valleys contain thick valley fill sediments. Only the Qu'Appelle Valley crosses the boundary on this map sheet. Klassen (1975), indicates that valley fill along the Qu'Appelle River is generally from 45 to 60 metres thick, although it is considerably thicker in some stretches. The fill can contain considerable sand, such that major aquifers might be present along this river channel.

REFERENCES 62K

Christiansen, E.A.; 1960; Geology and Groundwater Resources of the Qu'Appelle area, Saskatchewan; Saskatchewan Research Council, Geology Division Report No. 1.

Christiansen, E.A.; 1971; Geology and Groundwater Resources of the Melville Area (62K, L), Saskatchewan; Saskatchewan Research Council Geology Division Map No. 12.

Christiansen, E.A. Consulting Ltd., 1981. Quaternary geology of the Bredenbury area. Report prepared for Clifton Associate Ltd., 1981, Environmental impact of proposed Bredenbury project; Geology, ground and surface water. Draft report prepared for Potash Corporation of Saskatchewan. 70 p., maps, cross-sections.

Klassen, R.W.; 1966; Bedrock topography, Riding Mountain, Manitoba-Saskatchewan; Geological Survey of Canada Map 2-1966.

Klassen, R.W.; 1975; Quaternary geology and geomorphology of Assiniboine and Qu'Appelle Valleys of Manitoba and Saskatchewan; Geological Survey of Canada Bull. 228.

Klassen, R.W.; 1979; Pleistocene geology and geomorphology of the Riding Mountain and Duck Mountain areas, Manitoba-Saskatchewan; Geological Survey of Canada Mem. 396.

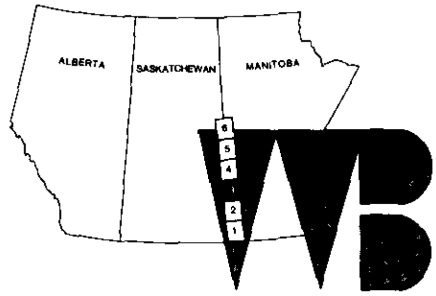
Klassen, R.W., Wyder, J.E. and Bannatyne, B.B.; 1970; Bedrock topography and geology of southern Manitoba; Geological Survey of Canada paper 70-51 (Map 25-170).

MacKay, B.R., Hainstock, H.N., and Bugg, P.D., 1936; Preliminary report, Groundwater Resources of the Rural Municipality of Rocanville No. 151, Saskatchewan; Geological Survey of Canada Water Supply Paper No. 85.

Manitoba Water Resources Branch, Planning Division; 1978; Riding Mountain Map Sheet 62K, Groundwater Availability Study Report No. 16.

Meneley, W.A.; 1972; Groundwater resources in Saskatchewan, in Water Supply for the Saskatchewan-Nelson Basin, Appendix 7, Section F, pp. 673-723, Saskatchewan-Nelson Basin report, Ottawa.

Schreiner, B.T., and Maathuis, H.; 1982; Harfield Valley Aquifer System in the Melville Region, Saskatchewan; Report for Saskatchewan Environment by Saskatchewan Research Council, Geology Division, SRC Publ. No. G-743-3-B-82.



MAP 62N

62N Duck Mountain, Manitoba – Saskatchewan

4

The Duck Mountain upland is the dominant topographic feature along the Manitoba-Saskatchewan boundary on this map sheet. There is a very thick drift cover over the upland. The cover usually exceeds 100 metres and can be up to 200 metres thick. This cover can still be quite thick to the south of Duck Mountain, although here it is less than 80 metres. It becomes thin at the north end of the map sheet in the Swan River lowland where it is less than 30 metres thick. The Pierre Shale forms the underlying bedrock over most of the boundary area, while the Niobrara Formation and Morden Shale are the subcropping formations in the Swan River area. Useable aquifers are not present in these bedrock formations.

Because of difficulties of differentiation, some sediments that may be Tertiary in age have been included within the drift on the cross-section for map sheet 62N. Empress Group sediments, that are glacial in age, occur between glacial till and the bedrock surface south of the Lake of the Prairies, within the buried Hatfield Valley. Sediments in a similar stratigraphic position, but at a higher elevation, in the Duck Mountain upland were assigned to the "Wynyard Formation" of probable Tertiary age, by Klassen (1979). The presence of glacial sediments which are similar in appearance to the "Wynyard Formation" and the presence of till units directly above the sand and gravel member of the "Wynyard Formation" makes correlations difficult. For these reasons, the "Wynyard Formation" has not been differentiated on this map sheet, but is included within the drift. Few well tests have been carried out in the sand aquifers of either the glacial sediments or of the "Wynyard Formation". They show that the total dissolved solids content is variable, but is generally less than 1600 mg/L in the deeper aquifers.

Relatively shallow wells completed in sand in the Swan River lowland, at depths of less than 30 metres contain water of good quality, with a total dissolved solids content of less than 800 mg/L.

REFERENCES 62N

Cherry, J.A., and Whitaker, S.H.; 1969; Geology and groundwater resources of the Yorkton area (62M, N), Saskatchewan; Saskatchewan Research Council, Geology Division Map No. 9.

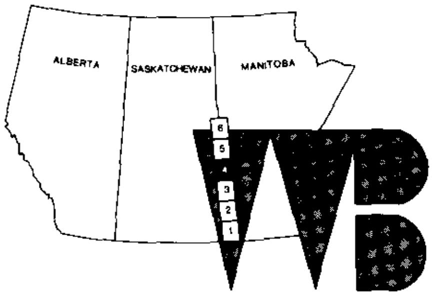
Klassen, R.W.; 1979; Pleistocene geology and geomorphology of the Riding Mountain and Duck Mountain ares, Manitoba-Saskatchewan; Geological Survey of Canada Mem. 396.

Klassen, R.W., Wyder, J.E., and Bannatyne, B.B.; 1970; Bedrock topography and geology of southern Manitoba, Geological Survey of Canada Paper 70-51 (map 25-1970).

Little, J. and Sie, D.; 1976; Duck Mountain area (62N), Groundwater Availability map series; Manitoba Natural Resources, Water Resources.

Meneley, W.A.; 1972; Groundwater resources in Saskatchewan, in Water Supply for the Saskatchewan-Nelson Basin, Appendix 7, Section F, pp. 673-723.

Schreiner, B.T., and Maathuis, H.; 1982; Hatfield Valley Aquifer System in the Melville Region, Saskatchewan; Report for Saskatchewan Environment by Saskatchewan Research Council, Geology Division, SRC Publ. No. G-743-3-B-82.



MAPS 63C & 63D

63C Swan Lake, Manitoba

63D Hudson Bay, Saskatchewan

5

The Porcupine Hills are the dominant topographic feature along the Manitoba-Saskatchewan boundary on this map sheet. Although data is limited, drift cover appears to be generally very thick over the upland area where it may approach 200 metres in thickness, and almost always exceeds 50 metres. Bedrock outcrops, however, are common on the lower slopes at the north end of the hills.

Sands and gravels within the drift are probably the only useable aquifers in the upland area. This area is unsettled, and there is little information on well yields or water chemistry. A relatively high yield appears to be possible from a 15 metre thick sand aquifer at Smallfish Lake, which was tested for six hours at 2.3 L/s and showed only three metres of drawdown during the test. A chemical analysis is not available.

The drift is underlain by various Cretaceous shale units, from the Pierre Shale beneath the upland, to the Ashville Formation on the lower flanks of the upland and in the southern part of the profile. Moran and Whitaker, (1969) state that the Viking sandstone forms an aquifer within the Ashville Formation on the north side of the Porcupine Hills. The one water analysis available to them indicates a total dissolved solids content of 2000 mg/L of sodium bicarbonate water. Small quantities of water, adequate for domestic supplies only, can be obtained from this sand unit. The Viking sandstone has also been referred to as the Newcastle Sandstone Member by McNeil and Caldwell (1981).

A well in NE34-37-29W1 was completed within the Favel Formation. An aquifer transmissivity of 9.9 x $10^{-5} m^2/sec$ (573 igpd/ft.) was calculated for this well by Little (1973). The water has a total dissolved solids content of 2224 mg/L, and is of the sodium bicarbonate/chloride type. Chloride content is 660 mg/L.

The Swan River Formation subcrops beneath the drift in the lowland area north of the Porcupine Hills where it forms a useable aquifer. Two wells have been drilled into this formation at two locations south of the hills. The water at these two locations is very salty, as indicated below:

Location	Depth (Metres)	TDS (mg/L)	Na (mg/L)	Cl (mg/L)
SW17-36-28W1	114	9836	3812	5150
NE15-37-29W1	97	9012	4131	5500

Moran and Whitaker (1969) state that the Swan River Formation forms an aquifer capable of yielding 0.52 to 52 L/s of water. They cite the results of seven water analyses for the subcrop area north of the Porcupine Hills. The analyses indicate a range of total dissolved solids of 1200 to 3600 mg/L of sodium bicarbonate, sulphate or chloride water, with less mineralized bicarbonate water occurring in the upper part of the formation.

No water wells are known to have tapped the Devonian and older carbonates near the boundary on this map sheet. It is expected, however, that water from these formations would be highly saline.

REFERENCES 63C

Little, J.; 1973; Groundwater Availability map series, Swan Lake area (63C); Manitoba Natural Resources, Water Resources.

Moran, S.R., and Whitaker, S.H.; 1969; Geology and groundwater resources of the Hudson Bay area (63C, D), Saskatchewan; Saskatchewan Research Council Map No. 8.

Rutulis, M.; 1981; Groundwater resources in the Swan River Planning District (a synopsis); Manitoba Department of Natural Resources, Water Resources Branch Report.

Rutulis, M.; in press; Hydrogeology of the Manitoba escarpment region; Manitoba Department of Natural Resources, Water Resources Branch.

MAPS 63E & 63F

63E Pasquia Hills, Saskatchewan 6

63F The Pas, Manitoba

The only detailed hydrogeological report close to the Manitoba-Saskatchewan boundary on these map sheets, is that of Pedersen (1973). The following summations are taken almost entirely from that report.

Glacial till is believed to be the main surficial material along the provincial boundary north to township 52. There are no drillholes to indicate the thickness of the drift or to evaluate aquifers in this area. The Swan River Formation underlies the drift and is in turn underlain by Devonian carbonates. Both of these formations can form good aquifers, but there is no data on the quantity or quality of water to be expected.

There is some testhole information near the boundary in townships 53 to 55 and additional information between the boundary and The Pas, further to the northeast. Alluvium, made up of clay, silt and sand, of the Saskatchewan River flood plain is the surficial material in this area. The alluvium overlies till, which rests on the eroded surface of the underlying Silurian dolomites. Karst features are present on the bedrock surface and within the Silurian dolomites. The karst sinkholes and solution channels have been infilled with quartz sands and clays of probable Cretaceous (Swan River Formation) age, and with dolomite rubble.

Alluvial sand, and Silurian dolomite, which includes Cretaceous sand infillings, form the main aquifers in this area. A test of one well in alluvial sand showed a transmissivity of 54 m^2/day, a hydraulic conductivity 1.5 X 10^{-4}m/sec., and a well specific capacity of 34 litres per metre of draw down indicating that a significant amount of water can be obtained from this aquifer, but water quality, and sulphate and chloride content may be high locally. Gas is present at some locations.

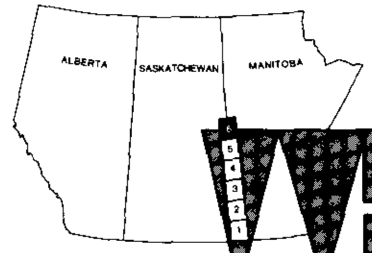
Silurian dolomite, in which fractures, joints, bedding planes, and solution cavities provide permeability, forms a major aquifer in this area. Pedersen (1973), states that water from this aquifer is generally of good quality (total dissolved solids less than 1000 mg/L) in the area north of the Saskatchewan River, and in other locations close to The Pas. The water, however, becomes more saline farther to the south, and reaches at least 14,000 mg/L dissolved solids at NW28-053-29W1. Water from a well in SE15-55-29W1 has a total dissolved solids content of 2121 mg/L, with a chloride content of 1045 mg/L. An aquifer test carried out in section 26-56-26W1 indicated an aquifer transmissivity of 7.7 X $10^{-2} m^2/sec$, indicating a high-yielding aquifer. Gas is present in several of the wells completed in dolomite.

The Ordovician Formations made up of dolomite and basal sand have not been tested in this area.

REFERENCES 63F

Manitoba Water Resources Branch, Planning Division, Groundwater availability Studies Report No. 9.

Pedersen, A.; 1973; Groundwater availability in The Pas area.



MAPS 63K & 63L

63K Cormorant Lake, Manitoba

63L Amisk Lake, Saskatchewan

7

The area adjacent to the provincial boundary is largely unsettled except for the immediate vicinity of Flin Flon. Groundwater information is scarce in this area, but there is some data along Highway 10 in Manitoba, some 30 km east of the boundary, and at Baker's Narrows on Lake Athapapuskow.

Drift cover is thin over most of the area, as evidenced by the many bedrock outcrops, but may locally exceed 30 metres. Subcropping and outcropping formations are Silurian dolomites at the south end of the profile and Ordovician dolomites with a thin basal sandstone to Township 64. Precambrian rocks of the Canadian Shield dominate the north end of the area.

<u>Sand and gravel</u> within the drift may form good local aquifers. <u>Ordovician and Silurian dolomites</u> may also form good aquifers where the rocks are suitably fractured or where karst features have developed. <u>Precambrian Shield</u> rocks however are largely impermeable, although some joints and fractures may yield small amounts of water. Well yields are expected to be variable, dependent on very local conditions. Water quality will probably be good within shallow aquifers because of very localized flow systems and rapid rates of infiltration.

REFERENCES 63K & 63L

Baillie, A.D.; 1952; Ordovician geology of Lake Winnipeg and adjacent areas, Manitoba; Province of Manitoba, Department of Mines and Natural Resources, Mines Branch, Publication 51-6.

Byers, A.R., Kirkland, S.J.T., and Pearson, W.J.; 1965; Geology and Mineral Deposits of the Flin Flon area, Saskatchewan; Province of Saskatchewan, Department of Mineral Resources Report No. 62.

Manitoba Mineral Resources Division; 1979; Geological Map of Manitoba, Map 79-2. Scale 1:1,000,000.