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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 300

GROUND-WATER RESOURCES OF THE BRANDON MAP-AREA, MANITOBA

By
E. C. Halstead

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1959

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PREFACE

The Brandon area lies in a region of recurring droughts so that its continued development is dependent on adequate supplies of water. Ground water is the main source of future supplies, and to understand and utilize this resource fully, data must be gathered over a wide area. This comprehensive memoir presents a broader, more complete picture of the ground-water problems than the published Water Supply Papers, each of which covers a small part of the total area.

A brief outline of the bedrock and surficial geology provides background for discussion of the source, occurrence and movement of ground water and the recharge of aquifers. The principal aquifers are described together with their water-bearing possibilities, types of contained water, and the impurities. The report concludes with a discussion of methods of recovery and uses of ground water.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, June 27, 1957

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GROUND-WATER RESOURCES OF THE BRANDON MAP-AREA, MANITOBA

CHAPTER I

INTRODUCTION

This report summarizes all pertinent information on the nature and occurrence of ground water in the Brandon map-area. As the investigation proceeded preliminary reports covering blocks of sixteen to twenty-four townships were released so that the data would be available for use in connection with immediate problems. The object of this report is to present the results of the complete field investigation in a comprehensive account.

A critical need exists in this area for adequate and perennial supplies of water for towns and villages that wish to install municipal water-supply systems. Furthermore, the installation of rural hydro throughout southern Manitoba has improved the living conditions of the farmer by the introduction of home comforts and labour-saving devices that require a greater daily supply of water. It is essential, therefore, that farm wells penetrate water-bearing formations that receive sufficient recharge and retain in storage enough ground water to meet the added pumpage requirements.

The Brandon map-area lies in south-central Manitoba (*see* Figure 1). It extends from the International Boundary to latitude 50°00′ and from longitude 98°00′ to 100°00′, and covers an area of about 168 townships.

Previous Work

No extensive investigation of the ground-water resources in the Brandon map-area was made previously. W. A. Johnston (1934)[1] describes this area generally in his report on the ground-water supply of the Winnipeg map-area, which covers a large part of southern Manitoba. His publication also describes the Pleistocene geology.

The Mesozoic stratigraphy was described by R. T. D. Wickenden (1945). Deep well drilling in search of oil in southwestern Manitoba returned well cuttings from many localities and some of these were examined by L. B. Kerr (1949) who on the basis of her study compiled a report on the stratigraphy of Manitoba. W. M. Tovell (1951) reported on the geology of the Pembina-Dead Horse Creek area in 1951.

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[1] Dates in parentheses are those of publications listed in the Bibliography at the end of report.

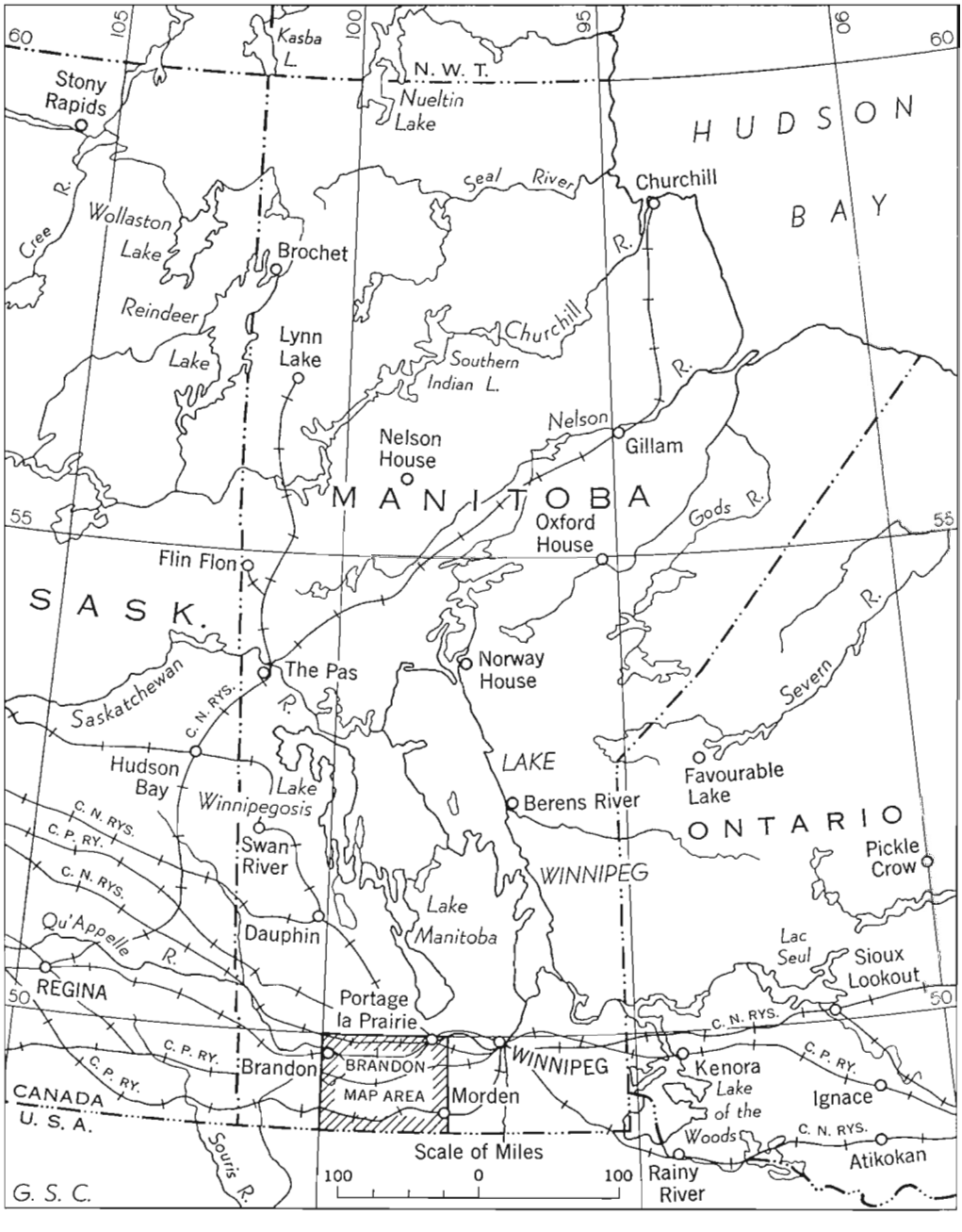

FIGURE 1. *Index map, showing location of Brandon map-area.*

Outline of Field Work

Ground-water investigations were carried on jointly and in cooperation with J. A. Elson who investigated and mapped the Pleistocene deposits. Field work on which this report is largely based was conducted by the writer during the field seasons of 1949, 1952 and 1953; ground-water data were collected by J. A. Elson during the field seasons of 1947 and 1948. The field investigation was concerned, mainly, with the determination of the position and areal extent of the water-bearing formations: the capacity of the formations to absorb, transmit and discharge water; and the chemical character of the ground water.

Well data were collected by interviews with well drillers, well owners and by direct measurement of accessible wells. More than 7,000 well records were thus collected and compiled. From the representative aquifers 100 water samples were collected. Elevations of the wells were determined by barometric readings at the well with a Paulin Aneroid barometer.

Acknowledgments

In compilation of this report, notes and geological maps prepared by J. A. Elson have been used and incorporated in its context. Complete cooperation of the personnel of the Mines Branch in Winnipeg resulted in prompt response to specific requests for data filed at their office. Water analyses were done by analysts of the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys, Ottawa.

In the field the writer was ably assisted in 1949 by K. A. Buckboro, in 1952 by G. R. Murphy, P. T. Maingot, G. D. Moody and J. J. Newman.

The writer wishes to thank the farmers and well owners in the area for their cooperation in supplying information about the wells and permitting access to their properties. Well logs furnished by well drillers, particularly Carman Well Drillers, Carman, Manitoba, and Coyle Drilling Co. of Winnipeg have been helpful in the interpretation of the geology and hydrology of the area.

GEOGRAPHY

Topography and Drainage

Manitoba escarpment trends northwest from Morden near the International Boundary and separates a lowland formerly occupied by glacial Lake Agassiz from an upland area or second prairie level on the west. The second prairie level in contrast with the lowland is a rolling country with considerable relief. About 50 miles north of the International Boundary the Assiniboine River crosses the escarpment in a broad saddle or gap. South of this a northeast-facing slope, known as Pembina Mountain, rises 300 to 500 feet above the lowland.

Tiger Hills are in a belt 5 to 10 miles wide south of the Assiniboine River and extend from the Manitoba escarpment to the Souris River. They represent a belt of end moraine and consist of a series of hills and closed depressions. Some of the depressions hold water throughout the year. A few of the highest hills southwest of Treherne have elevations of 1,650 feet above sea-level; those to the west near Souris River have elevations up to 1,575 feet. In most places the hills are lower and there are stretches of rolling country where the general elevation is 1,300 to 1,400 feet. Many are wooded chiefly with a growth of aspen, bur oak, poplar and birch.

Brandon Hills, a continuation of Tiger Hills, are separated from them by the deep, narrow valley of Souris River and by the area of comparatively low relief to the northwest of this river. Brandon Hills are best developed about 10 miles south of Brandon where the highest points have elevations of nearly 1,600 feet. Small ponds and lakes, such as Lake Clementi, occupy undrained basins in the hills.

The rolling plain that extends south from Tiger Hills to the International Boundary and southwest to Turtle Mountain is bounded near its north side by Pembina Valley. This valley has precipitous sides, a broad level bottom and contains long, narrow, remnant lakes, only a few feet deep, that have been dammed by deltas and fans built on the valley floor by tributary streams. Pembina Valley was formerly a drainage channel of glacial Lake Souris, but at present is occupied by Pembina River. Pembina River originates in Turtle Mountain, crosses a broad level belt northwest of Killarney en route to Pembina Valley through which it flows and leaves the Brandon map-area at the International Boundary in range 6. Crystal Creek, Long River and Badger Creek are tributary to Pembina River and flow north across the plain immediately north of the International Boundary. Much of the plain to the south of Pembina River is nearly level but hills, such as Pilot Mound and Nebogwawin Butte, rise 100 feet or more above the general level of the nearby surface. In the southwest corner of the area, Turtle Mountain rises some 500 feet above the surrounding country.

North of Tiger Hills a broad area is underlain by deltaic and fan-like deposits that are largely covered by sand dunes. Assiniboine River meanders across this area in a wide shallow valley. Annually this river reaches bank-full stage and has, at times, overflowed its banks to flood at Brandon and Portage la Prairie. Formerly, the Souris River followed the Pembina Valley, but a short tributary of the Assiniboine cut itself headward through the Tiger Hills to capture this drainage and the Souris River now joins the Assiniboine near Treesbank. Cypress River originates in the Tiger Hills and flows north to join the Assiniboine north of Holland, whereas Boyne River, also originating in Tiger Hills, flows eastward across the lowland to join Red River.

Climate

The climate is characterized by hot summers and cold winters typical of an interior continental region. The monthly average of daily maximum temperature for July is 80 degrees Fahrenheit; whereas, the monthly average of daily minimum temperature for January is 10 degrees below zero. These and other climatological data were taken from records of the Meteorological Division, Department of Transport, Canada (1954).

TABLE I

The Monthly and Annual Average of Daily Mean Temperatures, Degrees Fahrenheit, at Eight Stations in the Area

Station	Yrs. Obs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av. Year
Brandon	29	-3	1	16	38	51	60	65	62	53	40	21	6	34
Ninette	25	1	7	20	39	52	61	67	64	54	42	25	9	37
Ninga	11	-2	2	19	39	51	60	66	63	52	39	23	7	35
Portage	32	-2	1	16	37	51	62	68	64	55	42	22	7	35
Treesbank	53	-2	2	18	39	52	63	68	65	54	41	22	7	36
Treherne	40	1	5	18	38	52	61	66	63	54	41	24	8	36
Almasippi	22	-1	3	19	38	52	62	66	63	55	43	26	8	36
Morden	32	1	5	21	39	52	62	68	65	56	42	27	10	37

Rainfall is chiefly during the months of May, June, July and August, whereas the driest months are January and February. The percentage of total rainfall in light falls is smaller than elsewhere in the prairies but in heavy falls is from 5 to 10 per cent greater, so that the losses from evaporation are less and from run-off greater than elsewhere.

TABLE II

Average Annual and Monthly Precipitation in Inches at Eight Stations within the Area

Station	Yrs. Obs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av. Year
Brandon	29	0.73	0.58	0.76	0.99	1.62	2.77	2.37	2.18	1.52	0.83	0.79	0.59	15.73
Ninette	25	0.80	0.65	0.84	1.41	2.01	3.09	2.10	2.31	1.48	1.30	1.04	0.77	17.80
Ninga	11	0.82	0.80	1.01	1.72	1.70	1.76	2.10	2.25	1.56	0.58	1.04	1.11	16.45
Portage	32				1.23	1.80	2.96	2.54	2.13	2.26	1.03			
Treesbank	53	0.83	0.68	0.97	1.27	1.80	3.02	2.82	2.25	1.90	1.19	0.90	0.74	18.37
Treherne	40	0.81	0.58	0.86	1.51	2.15	3.31	2.66	1.88	1.87	1.25	0.97	0.78	18.63
Almasippi	22	0.93	0.75	1.10	1.33	2.18	2.87	2.82	2.05	2.28	1.12	0.93	1.01	19.37
Morden	32	0.72	0.67	0.95	1.25	1.92	3.10	2.44	1.76	1.84	1.16	0.89	0.84	17.54

In his study on the precipitation of the Prairie Provinces, Currie (1953) found that during the past 70 years a gradual decrease of precipitation had taken place over the prairies. Precipitation apparently reached a maximum during the 1870s and decreased sharply to a minimum during a severe drought period in the late 1880s and early 1890s. During the first decade of the present century precipitation recovered to a maximum and then decreased gradually but steadily to a minimum during the 1930s from which there has been no general recovery. Apart from the precipitation values, this latest decrease is exemplified by the steady lowering of the level of lakes scattered over the prairies and the increasing difficulties in providing adequate water supplies for livestock from shallow wells.

Cultural Development

The Census of 1951 recorded the total population of the area as 82,936. The two cities Brandon and Portage la Prairie together utilize 3,300,000 gallons of water daily from Assiniboine River. Carman obtains a municipal supply from Boyne River and has a daily consumption of 100,000 gallons, and Morden obtains water from Lake Minnewasta, a lake formed by the construction of an earth fill dam on Dead Horse Creek. Elsewhere the area is entirely dependent upon ground water. Only one village, Treherne, has a municipal water-supply system using ground water. Other villages with a population of 400 or more, namely, Cartwright, Crystal City, Glenboro, Manitou, McGregor, Pilot Mound and Wawanesa have private wells and upon consideration of the installation of a municipal water-distribution and sewage disposal system should estimate that an average of 50,000 to 60,000 gallons a day would be required to satisfactorily supply the demands.

The area is served by the following east-west highways, Trans-Canada and Provincial Highways Numbers 2 and 3. The main lines of both the Canadian National and Canadian Pacific Railways as well as branch lines serve all parts of the area.

The principal industry of the area is farming. The main crops are wheat, oats, barley, flax and hay. Dairy farming is also an important industry and supports creameries at Cartwright, Crystal City, Notre Dame de Lourdes and Somerset. In the lowland area east of the escarpment corn and peas are grown for canneries and some sunflowers are grown as commercial crops. Along the escarpment bentonite is strip-mined by the Pembina Mountain Clays Limited, and hauled to a plant at Morden.

CHAPTER II

GEOLOGY

Continental glaciers, upon entering this area, rode over a surface of sedimentary rocks largely composed of shales and during retreat covered this bedrock with glacial deposits. Later erosion exposed the bedrock in the river valleys, along the Manitoba escarpment and where the mantle of glacial deposits was thin. Modern road building has also exposed the bedrock in road-cuts and other excavations. The bedrock ranges in age from the Paleocene Turtle Mountain formation in the southwest corner to the Jurassic Amaranth formation in the northeast corner of the area (*see* Table of Formations).

The regional dip of the strata throughout the area is southeast at about 5 to 10 feet to the mile. Wickenden (1945) found that in the general vicinity of the Assiniboine River there is a reversal of dip between Treherne and St. Lupicin. The top beds of the Boyne are at least 25 feet lower in elevation near Treherne than the same beds near St. Lupicin. This may indicate a slight warping of the beds, with the high point in the vicinity of St. Lupicin.

Table of Formations

Era	Period or epoch	Formation or member	Thickness (feet)
Cenozoic	Pleistocene		
	Paleocene	Turtle Mountain	?
Mesozoic	Upper Cretaceous	Boissevain	100
		Riding Mountain	500
		Vermilion River Pembina Boyne Morden	450
		Favel Assiniboine Keld	170
		Ashville	100–200
	Lower Cretaceous	Swan River group	100
	Jurassic	Amaranth	190–220

Bedrock Geology

The Amaranth formation underlies the unconsolidated surface deposits in the northeast corner of the area near Portage la Prairie. Red shales, sandstones and white gypsum beds constitute this formation, which varies in thickness from 190 to 220 feet. The shales are sandy and a bed of sandstone forms the base. Kerr (1949) suggested that the Amaranth formation may be Triassic in age.

The Swan River group represents the oldest Cretaceous rocks in Manitoba and includes shales, sandstones and some low-rank coal. The total thickness is possibly less than 100 feet. The strata underlie the lake sediments throughout much of that part of Lake Agassiz basin within the area. The sandstones of the Swan River group carry water in many localities and in almost all wells the water is salty. However, in a few localities as at Neepawa and Deloraine the water from these sandstones is suitable for domestic use.

The Ashville formation lies under the glacial and lake deposits of silt and clay at the foot of the Manitoba escarpment. The beds are a dark grey, non-calcareous, somewhat fissile shale, and the formation is from 100 to 200 feet thick. Kerr (1949) concluded that probably the Manitoba equivalent of the Dakota formation is included in the Ashville formation. The Dakota formation is an excellent aquifer throughout North and South Dakota, northeastern Nebraska, western Minnesota and Iowa.

The Favel formation overlying the Ashville is a grey shale speckled with white calcareous material. Although these specks are regarded as fossil fragments by some investigators the possibility of their being calcite is being studied (Kerr, 1949, p. 25). Bands of limestone are found near the top of the formation and one such key bed of impure limestone marks the separation of the formation into two members, the Assiniboine and the Keld. The Favel formation is 170 feet thick in Commonwealth Manitou No. 2 well south of Manitou. No exposures were found south of Assiniboine River but exposures occur along that river in sec. 36, tp. 8, rge. 11, W. Prin. mer. and sec. 6, tp. 9, rge. 10, W. Prin. mer.

The Vermilion River formation overlies the Favel formation and includes three members, namely, Morden, Boyne, and Pembina. The total thickness in this area is about 450 feet, and includes various types of grey shale and a prominent series of bentonite beds at the base of the uppermost or Pembina member. Melanterite, hydrous ferrous sulphate, streaks the outcrops of this formation and is especially noticeable on the outcrops of the lower or Morden member.

Morden Member. Exposures near the town of Morden show a dark grey, non-calcareous shale with ellipsoidal concretions. Tovell (1951)

reported that the top of the Morden member is marked by the presence of interbedded fine sand or silt and shale. The fine sand and shale laminae are about one-eighth inch thick. The sand is almost pure quartz and is uncemented. The interbedded sand and shale forms a persistent zone along Pembina Valley that averages about 10 feet thick. The Morden member is about 180 feet thick. Beds of bentonite are thin or rare in this member.

Boyne Member. Several good sections of the Boyne member are exposed along the sides of the Pembina River. This middle member of the Vermilion River formation is about 150 feet thick. The lower 80 feet of this is a grey calcareous shale full of white specks and in appearance resembles the Favel formation. The top 70 feet consist of a buff weathering chalky or marly phase. This phase may be developed only under certain weathering conditions as there is evidence that it disappears to the west. Numerous thin beds of bentonite of the non-swelling type occur throughout the Boyne member.

Pembina Member. The uppermost or Pembina member is a dark grey or black, non-calcareous shale containing numerous bentonite bands in the lower part. Tovell (1951) noted two distinct phases characteristic of this member. At the base overlying the Boyne is a widespread well developed zone, roughly 15 feet thick, of thick bentonite beds interbedded with black shale. Overlying the basal bentonites are non-calcareous shales that are in part organic. Fish scales are common within the organic shales.

The Riding Mountain formation underlies the upland west of the Manitoba escarpment. The beds are exposed along the river and creek banks, in excavations and road-cuts. Where exposed this formation is either a slumped or a hard siliceous grey shale. Wickenden (1945) concluded that the hard type shale was a phase of Riding Mountain and called it Odanah. Tovell (1951) recognized two beds, the Odanah and Millwood, whereas Kerr (1949) noted that the contact between the two beds is not stratigraphic and further work has pointed to the probability that the two phases are complementary. The Riding Mountain formation is probably of the order of 1,100 feet thick but only the lower 400 feet or more are present in this area.

The basal or Millwood beds of the Riding Mountain formation are composed of soft somewhat waxy greenish grey shale. The thickness is variable and of the order of 65 feet in this area. These beds are not well exposed, slump readily, and are recognized mainly by the presence of slopes devoid of vegetation, whose surface shows mud-cracks and concretions.

Odanah beds are made up of hard, siliceous grey shale with a slight greenish cast when dry. Although massive in freshly exposed cuts, the shale within a short period of weathering breaks into fissile fragments. Soft

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bentonitic shale and thin beds of pure bentonite also occur especially near the base of the Odanah beds. Purple staining and purple stained concretions are characteristic of the weathered shale on slopes where Odanah beds outcrop.

On the flanks of Turtle Mountain the Boissevain formation overlies the Riding Mountain formation. Estimates based on the position of the top and bottom beds indicate a thickness of about 100 feet. It is a greenish grey sandstone that weathers yellow-rust. The rock of cemented lenses is quarried as a building stone.

On Turtle Mountain a series of beds, overlying the Boissevain formation, have been largely eroded and their total thickness is not known. These beds are included in the Turtle Mountain formation and consist of fine-grained, white or yellowish sand or sandstone, with fossil plant remains and bands of shale. Some of the beds are lignite-bearing.

Surficial Geology

Preglacial Topography and Pleistocene History

The preglacial topography in southwestern Manitoba was modified relatively little by glacial erosion. Perhaps as much as several tens of feet of bedrock were removed on highlands that received the full erosive force of the continental ice-sheets but the larger landforms such as the Manitoba escarpment, the ancestral Assiniboine Valley, and Turtle Mountain were eroded little except for a general smoothing effect. The bedrock surface contours shown in Figure 2 are based on the data available and the map should be interpreted as highly generalized.

The lowland areas of the present topography are in general underlain by preglacial valleys that were filled with glacial and glacio-fluvial sediments which completely obscure the preglacial valley form. The best developed preglacial valleys occur in the west part of the Brandon map-area: one trends south-southeast through townships 4, 3, 2, and 1, ranges 14 to 17 and in places is covered by more than 300 feet of drift; a second trends north through townships 2 to 10, ranges 17 and 18 and joins the ancestral Assiniboine Valley in township 10, range 16. The ancestral Assiniboine River drained a large part of central North America and flowed eastward across the Manitoba escarpment in a course slightly north of the present Assiniboine River (Figure 2). A preglacial river system with a shallow valley drained townships 1 to 9, ranges 10 to 14, northward into ancestral Assiniboine River. The lower part of the Pembina Valley, townships 3 to 1, ranges 6 to 10, is an exhumed preglacial gully.

At least two different ice-sheets overrode the bedrock in Pleistocene time, although evidence of this has not been found within the Brandon map-area. The last ice-sheet that covered the area flowed southeastward and

as it thinned and retreated, probably about 12,000 years ago, it divided into two lobes that coalesced along the Manitoba escarpment north of Pembina Mountain. The lobe east of the escarpment flowed south and persisted longer than the lobe west of it. Township 1, range 6, was the first area uncovered by the retreating ice, followed successively by the townships south of the end moraine built up in the area of Tiger Hills and Darlingford.

During the retreat of the ice west of the Manitoba escarpment, meltwater flowed southward across the Tiger Hills through several channels; numerous small eskers were deposited in ranges 8 to 14; and a series of low, discontinuous lobate ridges in places crossed by small eskers were deposited in ranges 13 to 19 south of the Souris-Pembina Valley.

During retreat of the western lobe, the lobe east of the Manitoba escarpment, from which a sublobe extended westward up the Assiniboine Valley, remained stationary along Pembina Mountain and the Tiger Hills. Meltwater from the wasting of this lobe flowed southward across the Tiger Hills into the Souris-Pembina Valley through several channels. Small glacial lakes formed south and southeast of Greenway, south of Cypress River village and Glenboro, southwest of Wawanesa and southwest and west of Brandon Hills. When the ice margin retreated farther the last three lakes coalesced to form the Brandon glacial lake which drained into or merged with glacial Lake Agassiz that had formed east of Manitoba escarpment as the eastern lobe retreated. At this time the Assiniboine River flowed eastward into Lake Agassiz basin east of Brandon and deposited there in the form of a delta the material eroded from the Assiniboine and Qu'Appelle valleys to the west. This delta extends from Brandon eastward to Portage la Prairie. As Lake Agassiz receded and was finally drained by erosion of its southern outlet, much of the sand on the surface of the Assiniboine delta was blown into dunes. Readvancing ice caused Lake Agassiz to partly fill once more, thus flooding and depositing lake sediments and alluvium in the Assiniboine Valley and other tributary gullies. Final recession of the ice-sheet opened outlets for the draining of Lake Agassiz which probably occurred more than 5,000 years ago. Since the draining of Lake Agassiz, alluvium has been deposited more or less continuously in alluvial fans and flood plains within the lake basin as well as along stream courses.

Surficial Deposits

In general, glacial deposits form the surface of the Brandon map-area at altitudes higher than 1,300 feet, whereas glacial lake deposits cover the surface below that altitude. Thus, glacial deposits are found in the northwest corner of the map-area, and in the south half of the area west of the Manitoba escarpment which trends southeast from township 7, range 8, to township 1, range 5.

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Glacial Deposits

Till. Till comprises the greater part of the glacial deposits in the map-area and occurs as both ground and end moraine. Till is a mixture of rock particles of all sizes that has resulted from the grinding action of the ice on the bedrock and other debris over which the glacier has ridden. Till is deposited in two ways, as ablation till and as lodgment till. In the first case, debris is thrust upward to a position near the margin of the glacier and as the glacier melts the finer debris is transported by meltwater and the remaining debris is gradually lowered to the ground as the melting continues. Little till of this type has been recognized in the Brandon map-area. In the lodgment type of deposition, comminuted debris at or near the base of the glacier is plastered on to the ground as a combined result of the forward motion and basal melting of the glacier. The fine debris is not carried off by meltwater, hence the lodgment till is dense and composed of particles of rock varying from clay size to large boulders. Irregular pockets and lenses of gravel, sand, silt or mixtures of these may occur in the till. Till is sandy or silty where the glacier has overriden sandstone or sand but over a large part of the area of glacial deposits in the Brandon map-area the till has a high proportion of clay as the glacier overrode shales of the Riding Mountain formation.

In the Tiger Hills east of range 17 and on Pembina Mountain the till is composed dominantly of comminuted shale (Riding Mountain formation) which has not been transported very far. In the southwestern part of the map-area, a layer of sandy till from 10 to 40 feet thick generally overlies sandy clayey till probably 40 to 80 feet thick. These two tills either grade into each other in a vertical distance of 1 foot to 3 feet, or are separated by a layer of boulders.

The tills described above form the ground moraine shown on the map. In the western part of the map-area and in township 1, ranges 6 and 7, a series of discontinuous parallel ridges 3 to 30 feet high and 500 feet to 1.5 miles long were formed parallel to the retreating glacier margin. These parallel ridges, mapped as washboard moraines, are composed of sandy till with numerous inclusions of silt and sand as irregular masses. Streamlined ridges such as Pilot Mound consist of bedrock overlain by a thin mantle of ground moraine.

Silty till of both lodgment and ablation origin occurs in the Darlingford-Tiger Hills end moraine. In contrast to ground moraine, which forms a plain, end moraine has the form of a ridge, in this case with a local relief from 6 to 75 feet. Knobs and undrained depressions characterize end moraine. Irregular bodies of silt, sand and gravel are common in end moraine which is dominantly sandy till in townships 6 to 9, ranges 18 and 19.

Ice-contact Stratified Drift. Ice-contact stratified drift occurs as kames, pitted outwash and eskers. The kames are irregular bodies of poorly sorted sand and gravel that probably accumulated as outwash cones or small deltas on the ice; after the ice melted these deposits remained as mounds. Topography characteristic of kame areas is displayed in townships 3 and 7, ranges 10 to 13. The sand and gravel of the pitted outwash occur as plains that slope away from end moraines and are marked with kettles 10 to 50 feet deep and 50 to 500 feet in diameter. An excellent example of such a pitted outwash plain occurs in the southwest corner of township 6, range 16. Eskers, representing deposits formed in subglacial tunnels, are not merely deposits on the surface of ground moraine but extend downward into it, commonly 6 feet or more. Eskers in the Brandon map-area are comparatively small and form ridges 3 to 30 feet high, 100 to 500 feet wide and from a few hundred feet to 3 miles long. Most of the eskers east of range 13 contain a high proportion of shale gravel whereas in the west of range 14 the eskers contain gravel in which Palæozoic and Precambrian rock types are abundant.

Outwash. Outwash comprises gravel, sand and silt that were washed out of the debris at the glacier margin by meltwater. It may be as much as 15 feet thick close to its former source adjacent to end moraine and thins to a feather edge away from the source. In the Brandon map-area outwash occurs as broad plains overlying ground moraine and as a thin mantle on terraces in Pembina Valley.

Lake Deposits

Beach Deposits. Beach deposits are composed of well sorted sand and gravel in ridges that range from 2 to 15 feet thick, from 100 to 500 feet wide and from a few hundred feet to many miles long with minor gaps. Beach ridges are concentrated along the eastern slopes of Pembina Mountain and also occur farther east and north in the Lake Agassiz basin and 3 miles northeast of Rounthwaite in the western part of the map-area. The largest beach ridge in the area, the Campbell strand line, at an altitude of about 1,040 feet near Morden is 10 to 15 feet thick and extends with minor gaps from township 1, range 5 to township 7, range 8.

Lake Bottom Deposits. Medium- to coarse-grained lake-bottom sediments, which were probably deposited in water less than 100 feet deep, occur on the east slope of Pembina Mountain, north of Tiger Hills, southwest and west of Wawanesa, and south, north and northeast of Brandon. Fine-grained lake sediments deposited in deeper water, perhaps as much as 400 feet deep, occur west and southwest of Portage la Prairie. In town-

ships 5 to 11, ranges 5 and 6, deep-water lake sediments are overlapped by deltaic sediments. Deep-water sediments also occur under the Assiniboine delta as far west as range 14.

Lake bottom deposits range in thickness from 6 to 150 feet, and in general thicken eastward in Lake Agassiz basin where they are underlain by lenticular deposits of sand and gravel.

The boulders present in the deep-water clays were probably dropped from floating ice derived from the glacier that formed the north boundary of glacial Lake Agassiz.

Deltaic Deposits. The Assiniboine delta comprises the greater part of the lake deposits in the Brandon map-area. The Assiniboine delta extends eastward from an apex at Brandon and is bounded on the northeast by deep-water lake basin deposits, on the south by the northern slope of both the Tiger Hills and Pembina Mountain and extends eastward into townships 5 and 6, ranges 5 to 7. Gravel, sand, silt and clay comprising the topset beds of the delta are, in general, west of the 1,100-foot contour, whereas the deeper water foreset and bottomset beds of predominantly silt and clay are east of the 1,100-foot contour. The topset beds are well sorted and coarser near the apex of the delta. Deposits of gravel and coarse sand in townships 9 and 10, range 18 and township 10, range 19 represent the apex of the delta and are as much as 25 feet thick. As a result of the shifting of the river channel during delta deposition thin lenses of silt and clay are found interbedded with extensive deposits of sand and silt. The topset and foreset beds of the Assiniboine delta together range in thickness from 20 to at least 150 feet.

The delta contains a very high proportion of porous, permeable, medium-grained sand west of the 1,100-foot contour. Areas of silt also occur on the surface of the delta west of this contour and may be underlain by sand or contain lenses of sand. East of the 1,100-foot contour the silt and clay of the bottomset beds contain minor beds of sand and fine sand. Large tracts of medium-grained sand on the surface of the delta have been blown into dunes.

Alluvium

Valley Fills. The alluvium in Pembina Valley consists of several beds of gravelly silt each as much as 6 inches thick. The accumulation of these beds thickens downstream from Snowflake, to a thickness of 50 to 60 feet near the International Boundary and now forms paired terraces 20 to 75 feet above the valley floor.

The alluvial fill in the Assiniboine Valley forms paired terraces that have an altitude of about 1,050 feet. It extends downstream from township 8, range 14, to township 9, range 9 and comprises a unit of alternating silt and clay beds 1 inch to 6 inches thick. At the west end the alluvial fill is less than 2 feet thick whereas at the east end alluvial fill may be as much as 50 feet thick.

The deposits on the floor of the Assiniboine Valley are mainly sandy, silty alluvium with minor lenses of gravel, clay and muck. The sandy, silty alluvium, mainly a flood plain deposit, ranges in thickness from 6 to more than 20 feet. In Pembina Valley upstream from La Rivière the valley floor deposits are predominantly the alluvial fans of small tributaries of Pembina River. The fans are as much as 30 feet thick near the valley walls and consist of poorly sorted shale, gravel and sand.

Alluvial Fans. Alluvial fans are common along the east side of Pembina Mountain. They are predominantly clay with lenses of sand and gravel near their apex. Most of the fans are thin, less than 6 feet thick and several cover beach ridges.

The alluvial fan of the Assiniboine River, mainly in townships 11 and 12, ranges 5 to 7, includes sand deposits, silt built up as natural levees bordering river channels, and backswamp deposits of clay beyond the levees.

The alluvial fan built by Cypress River south of the village of Cypress River is composed of poorly sorted shale, gravel, sand and silt. Much of the fan comprises 6 to 10 feet of clayey silty sand overlying 2 or 3 feet of well sorted shale pebbles, gravel and sand. Several channels 20 to 40 feet wide and up to 10 feet deep cross the fan and are now filled with sand and gravel.

CHAPTER III

GROUND WATER

Source

Ground water is that water which occurs beneath the land surface from whence a supply is recovered from springs or wells that flow or are pumped. The water is derived essentially from direct penetration into the ground of rain or snow melt, or downward and lateral percolation of surface water from lakes, ponds and streams. The water in most shallow wells is that which fell on the surface nearby but water in the deeper wells may have migrated miles through water-bearing formations.

That the total amount of precipitation would be sufficient to supply ground water demands is shown by the fact that an inch of water falling on one square mile amounts to about 14,520,000 gallons*. The annual average amount of precipitation in southern Manitoba is 18 inches, therefore, each year some 261,360,000 gallons of water falls on each square mile. Of this, part runs off directly into streams, sloughs and lakes; a part evaporates or is transpired by plants, and the remainder seeps below the land surface to recharge ground water. Unlike other mineral resources, ground water is renewable and geographic and geological factors limit its replenishment.

Occurrence and Movement

The receptacles and conduits for water beneath the land surface are the interstices, voids or pore spaces within the rock materials. The volume of these pore spaces, expressed as porosity, depends upon the arrangement, shape and degree of sorting of the particles comprising the rock and whether or not it is consolidated. Therefore, the maximum pore space can be expected as long as there is uniform shape and packing in each occurrence whether gravel or clay. However, such conditions are seldom found in actual existence and the degree of sorting is such that smaller particles fill or partly fill the spaces between the larger particles and thereby the porosity is lessened. If the pore spaces are all minute and not interconnected, water will be withheld or retarded in its movement but if the pore spaces are large and interconnected, as in sand and gravel, water is transmitted freely and the rock is said to be permeable. Under natural conditions not all the water will drain out of the rock material into a well because capillary forces will prevent drainage by gravity and also water will be held by molecular attraction. This

* "Gallons" in this report refers to imperial gallons.

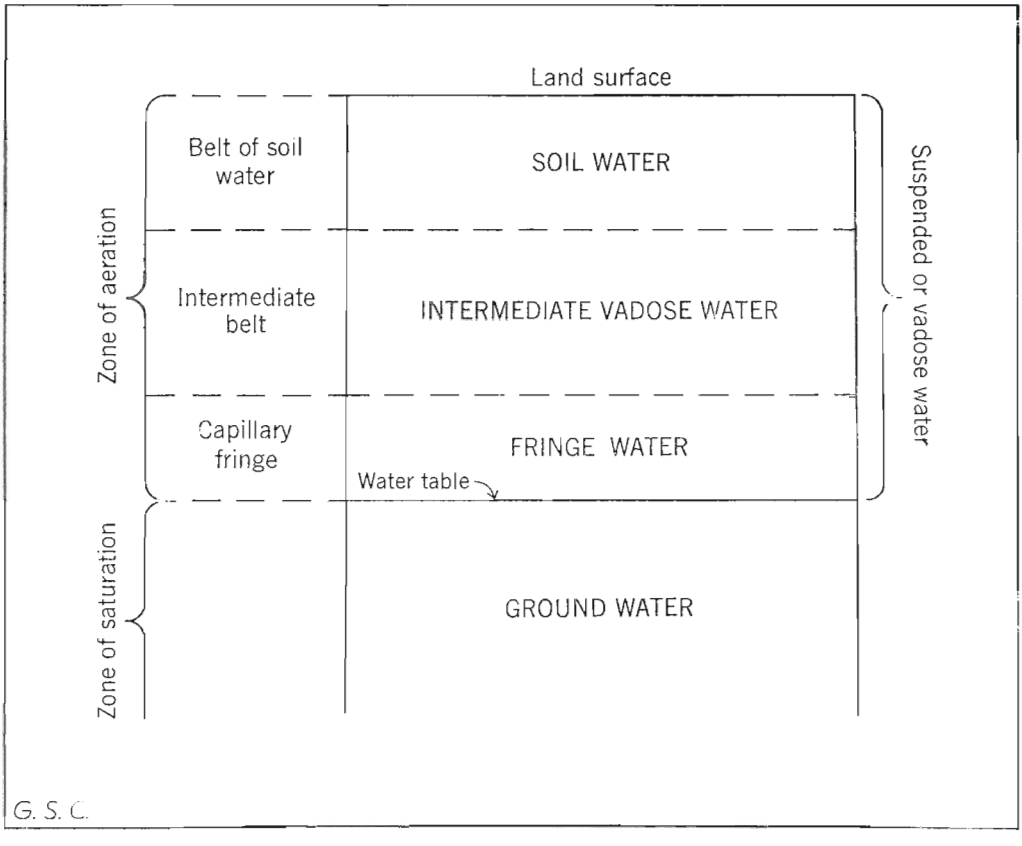

FIGURE 3. *Divisions of subsurface water, modified after Meinzer.*

latter force becomes more significant with decreasing size of pore because of the increased surface area of solid material to which water can adhere. In general, the smaller the interstices or pore spaces the lower will be the permeability and hence the yield. Clay and silt commonly have higher porosities than sand or gravel but yield considerable less water.

All the pore spaces are filled with water in the zone of saturation, and in the development of ground water by means of wells it is necessary that this zone be penetrated. A zone of aeration in which the water is either suspended or percolating downward separates the ground surface and the zone of saturation (Figure 3). The soil zone directly beneath the surface of the ground supports vegetation. Water is retained in this zone largely by molecular attraction but is returned to the atmosphere by transpiration of the plants and direct evaporation. Beneath the soil zone is a zone in which

water is percolating downward. The upper part of this intermediate zone is dry but more moisture is present as greater depths are penetrated or as the zone of saturation is approached. Above the zone of saturation and at the base of the zone of aeration is a fringe of capillary water. Thus, in digging a well through permeable materials a soil zone is penetrated followed by an intermediate zone in which water is percolating downward and the increased moisture with depth is evidence of nearing the third zone, the zone of saturation. Within the zone of saturation water moves laterally under the influence of gravity and enters the well freely as gravity ground water. Under such conditions water will rise in the well to a level at which the hydrostatic pressure equals the atmospheric pressure. This level is the water-table and corresponds to that of the top of the zone of saturation of the water-bearing formation in which the well was dug. The water-table, an irregular surface below which all the rocks are saturated, is not stationary but fluctuates up and down seasonally and annually with variations in precipitation, withdrawal from wells, temperatures and other related factors. The water-table is influenced by, but does not exactly reproduce, the configuration of the land surface.

If the formation in which the well was dug yields water in sufficient quantity to be of consequence as a source of supply, it is a water-bearing formation or an aquifer. The term aquifer is used to designate individual water-bearing beds that are local in extent and from a few inches to a few feet thick, as well as those thick series of beds of varying permeability in which the water migrates freely from bed to bed. Aquifers overlain by permeable beds have a water-table dependent on the characteristics of the particular aquifer and wells that obtain water from such a source are termed water-table wells. On the other hand, in some areas deeper wells encounter water in completely saturated beds under an impermeable layer. This water is confined water under sufficient pressure to rise in a well to a level above the bottom of the impermeable layer. These wells are called artesian wells whether or not the water flows at the land surface. The level to which the artesian water will rise under its full head in an artesian well is called the piezometric surface.

Water-bearing materials generally occur in layers of differing permeability and, therefore, a perfectly homogeneous aquifer is rare. Many beds are not continuous but thin laterally or are replaced by materials of a different permeability. Thus local impermeable beds of limited extent may occur in the zone of aeration and a body of ground water may be perched on such a local layer with unsaturated permeable materials between this local body of ground water and the underlying main or regional water-table. The upper surface of such a perched body of ground water is called a perched water-table.

On the basis of field tests, a rate of movement of ground water as much as 420 feet a day has been reported by Meinzer (1942). However, it is generally accepted that the rate of movement in a recognized water-bearing formation is not greater than 5 feet a day and not less than 5 feet a year.

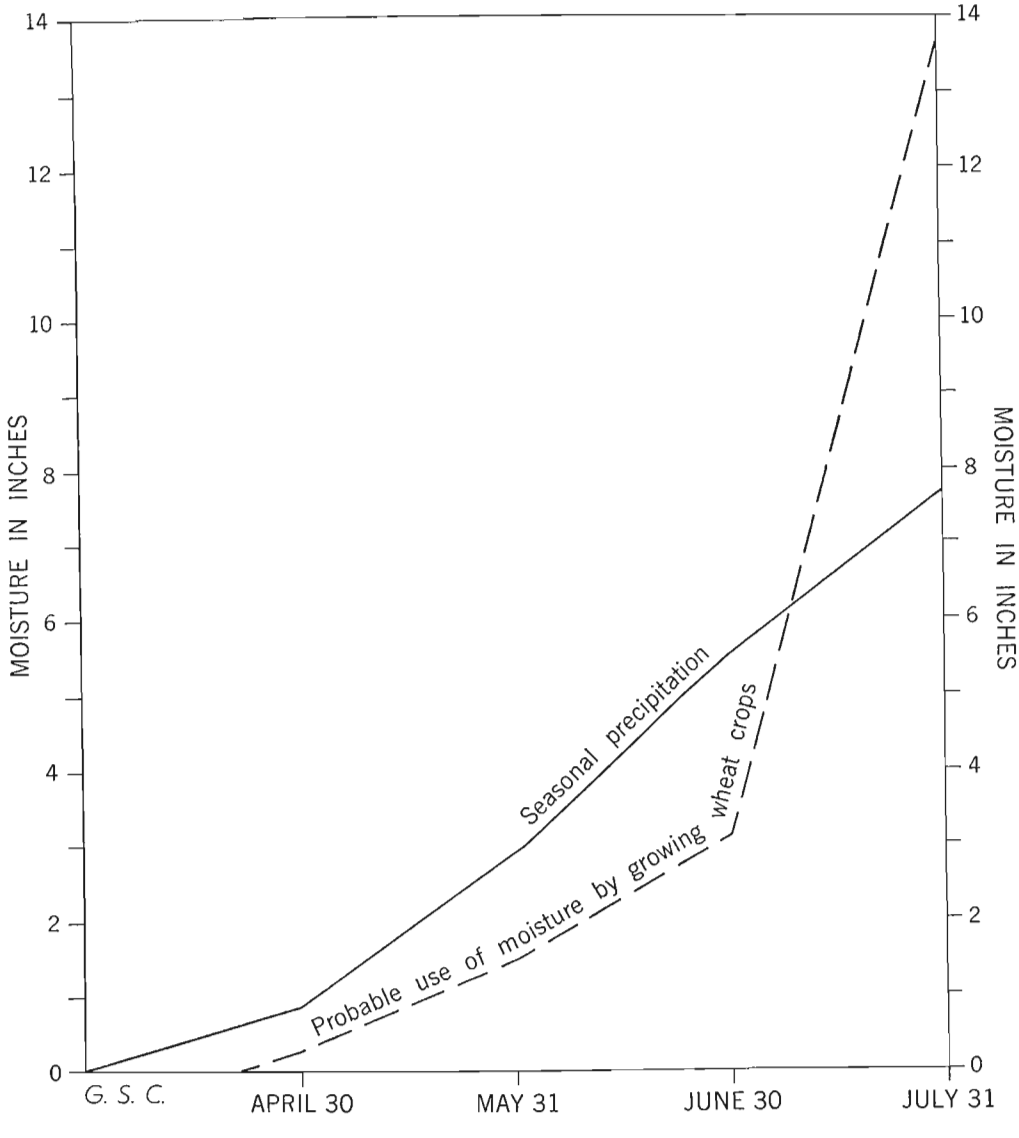

FIGURE 4. *Water requirements of wheat crops. (After Searle Grain Company crop report No. 1, June 30, 1954.)*

Recharge and Discharge

Ground water recharge is the replenishment of the water in the aquifers or underground reservoirs. The source of the recharge is chiefly rain or snow melt and the proportion of water that seeps into the ground-water reservoir is dependent on the intake facilities of the surficial deposits and the bedrock.

Precipitation that occurs as a light rain may all be absorbed by the soil but a continuous rain during which water falls about as fast as it can seep into the soil is the most effective. When the soil-water deficiency has been satisfied and the rain continues then water will be available for ground water recharge. A heavy downpour of short duration may only partly replenish the soil demands for much of such rainfall would be lost in run-off over the surface. Little or no recharge may also be due to the demands of vegetation as well as to the paucity of the rain. Rainfall during the growing season, April, May, June and July of the crop year, is seldom sufficient to meet the water requirements of grain crops. This is illustrated in Figure 4, based on the results of extensive research on water requirements of crops at the Dominion Experimental Farm, Swift Current, Saskatchewan. The average growing season deficiency amounts to about 6 inches by the end of July, but this amount can be partly or wholly conserved from autumn rainfall by modern tillage practices. Recharge to the ground-water reservoirs occurs in the autumn or early spring, during years of average precipitation. The proportion of this precipitation that will reach the aquifer depends upon the intensity and the quantity of the rainfall, the amount and the type of vegetation, the slope of the land surface, the permeability of the soil and the underlying materials and the areal extent of the intake area. Aquifers that are overlain by permeable beds of considerable areal extent are favourably situated for recharge. Aquifers overlain by impermeable beds generally receive water that has travelled some distance laterally from intake areas that in many cases are limited in extent.

Natural discharge of ground water occurs where the water-table intersects the land surface and the water issues as a spring. Springs may also issue at the contact of a permeable rock on an impermeable rock or from fissures and faults in the bedrock. Ground water is also discharged in quantities of major importance by transpiration of plants and evaporation from the soil where the water-table is close to the surface of the ground. Withdrawal of water from wells is an artificial discharge that, under favourable conditions, will be compensated for without serious depletion of the reservoir supply.

Principal Aquifers and Their Water-bearing Possibilities

Till

Till that accumulated by lodgment and that is mapped as ground moraine, is known locally by drillers and others familiar with it as "hardpan". Till has a high proportion of clay and those pore spaces present are minute thus holding water by molecular attraction against free movement by gravity. However, some water does pass through till, especially if the till has a blocky structure due to parting planes that probably resulted from reduction of pressure by removal of the overlying ice. At shallow depth water migrates along these planes more readily than through pore spaces, therefore, wells dug to a maximum depth of 20 feet in such till may yield a supply sufficient for domestic needs.

Small lenses or lenticular bodies of sand and gravel that occur locally in till are probably isolated as shown in the sketch of Figure 5. Such lenses below the water-table, however, are an important source of ground water,

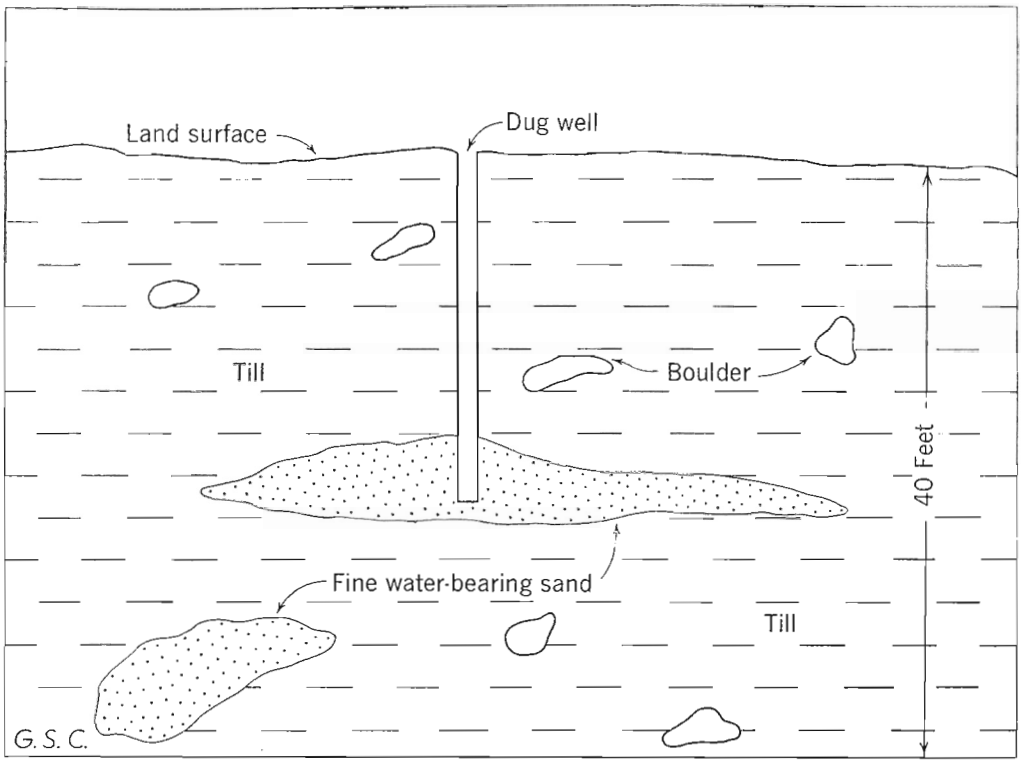

FIGURE 5. *Well tapping ground water stored in a lens of fine sand in relatively impervious till.*

which may be obtained at many localities by digging inexpensive wells. Irregular bodies of silt, sand and gravel are common in the Tiger Hills-Darlingford end moraine and are an important source of ground water in that area. In the Tiger Hills east of range 17 and on Pembina Mountain the till is composed dominantly of shale pebbles and is slightly permeable allowing precipitation to percolate through it into the fractured bedrock below.

Wells tapping till are commonly inexpensive to dig for many are less than 25 feet deep and 3 feet in diameter. They are lined with wooden cribbing and fitted with hand pumps. The yield from such wells rarely exceeds 150 gallons a day and the yield of almost all wells that do not intercept a lens of sand or gravel is negligible. As till, in places, does supply sufficient water it is advisable to investigate its water possibilities by test boring with an auger to depths of from 20 to 30 feet before undertaking the drilling of a well to bedrock in search of water below till.

The water supply for most municipal and farm needs in the Brandon area is obtained from wells that tap lenses of sand and gravel in the glacial till. The volume of water recovered annually from such aquifers depends largely upon their thickness, extent and whether they are interconnected. Therefore, some lenses may not yield water sufficient for farm use whereas other thicker, interconnected lenses may yield enough water to supply a population of several hundred. The rate at which some aquifers are unwatered suggests that practically all the water is from storage and replenishment is limited probably owing to the fact that the lenses are completely enclosed in impervious till. Aquifers that receive limited replenishment in till formerly met the water requirements on many farms but the installation of electrical pumps and modern plumbing has overtaxed the supply.

Till, although commonly a weak aquifer with very poor capacities for the intake, transfer and storage of water, may yield sufficient water to wells for general household uses when annual precipitation is normal.

Grain size distribution and hydrologic properties of representative till samples collected in the Brandon map-area are shown in Table III.

Sand and Gravel Aquifers

By far the most productive aquifers in the Brandon map-area are the accumulations of sand and gravel mapped as ice-contact stratified drift and outwash. Mixed sand and gravel has a porosity of as much as 15 per cent, whereas the porosity of clean and uniform sand or gravel ranges from 25 to 45 per cent. Ice-contact stratified drift is generally poorly sorted and consequently has a low porosity and good permeability. Beach deposits, on the other hand, are composed of well sorted sand and gravel and are both porous

TABLE III

Grain-size Distribution and Hydrologic Properties of Typical Sediments in the Brandon Map-Area

	Material	Location (W. Prin.)	Size of grain (per cent by weight): Coarse fraction 2mm.	Sand 2mm.-1/16mm.	Silt 1/16mm.-1/256mm.	Clay 1/256mm.	Porosity	Permeability	Water yield
1	Till, silty clay	NE 13-1-17	1.4	14.6	52.2	31.8	Medium	Impermeable	Nil
2	Till, sandy clayey	NW 35-1-17	8.7	33.0	27.1	31.2	Low	Impermeable	Nil
3	Till, clayey sandy	NE 29-4-17	4.9	31.0	42.3	21.8	Low to medium	Impermeable	Nil
4	Till, clayey sandy	NE 17-6-9	4.5	35.6	42.8	17.1	Low	Impermeable	Nil
5	Till, sandy	N/2 25-5-7	5.1	32.6	47.9	14.6	Low	Almost impermeable	Nil
6	Till, sandy	NW 35-1-17	3.4	36.4	46.2	12.0	Low	Almost impermeable	Slight yield
7	Till, sandy	SE 6-4-19	5.7	34.9	43.5	15.0	Low to medium	Almost impermeable	Nil
8	Till, sandy, silty	SE 34-2-12	7.9	35.9	52.7	3.5	Medium	Slightly permeable	Low yield
9	Till, very silty	NE 23-1-6	2.5	17.6	70.9	9.0	Medium	Slightly permeable	Moderate to low
10	Lake silt	NW 15-7-17	trace	4.0	70.0	26.0	Medium to high	Permeable	Moderate to low
11	Lake sand (deltaic)	NE 33-7-16	0.9	98.8	0.3		Medium to high	Very permeable	High yield
12	Beach ridge	SE 2-7-8	84	14	2		Medium to high	Very permeable	High
13	Esker gravel	NW 23-2-8	60.5	38.0	1.5		Medium to low	Very permeable	High
14	Alluvial fill	SW 4-2-7	52.2	47.5	0.3		Low to medium	Permeable	Moderate yield
15	Typical lake clay	No laboratory analysis	nil	2	13	85	Medium to high	Impermeable	Nil

Porosity: high 40-65%, medium 30-40%, low 15-30%. This property determines the amount of water the material can contain.
Permeability: this property determines the amount of water a material will yield; in general, permeability increases roughly with the average grain size and degree of sorting.
In specimens 11 to 14, clay-sized particles are included with silt.

and permeable. These permeable materials are recharged directly by downward percolation of rain and snow melt. Where such aquifers are thin even a moderate supply of water cannot be expected but the thickness and areal extent of many such aquifers are sufficient to confirm their potential as excellent sources of ground water. In the moderate- to coarse-grained material, driven wells are used, in other materials water is obtained from shallow dug wells either with wooden or cement cribbing. As the water-table is near the surface, wells that penetrate such deposits are classed as water-table wells.

Coarse outwash more than 5 feet thick forms a satisfactory aquifer and the water obtained is generally low in mineral content. Ice-contact stratified drift deposited in the form of eskers are aquifers worth prospecting as a source of ground-water supply. The sand and gravel of these ridges at places extend down into the till for short distances and in North Dakota all of some bodies of stratified material of this origin occur below the surface of the ground in areas apparently representing gaps in the continuity of eskers.

Sand and gravel in deltas, beaches, bars and spits along Pembina escarpment and the western edge of glacial Lake Agassiz are important aquifers and a probable source of water to be used for irrigation. Sand and gravel, probably a beach deposit now buried by alluvium underlying the town of Miami, provide a ground-water reservoir large enough to supply sufficient water for municipal uses.

In the north part of the Brandon map-area deltaic sand and gravel and younger wind-blown sand cover several townships. This provides an extensive area of permeable surface deposits over which run-off is at a minimum. The conditions of deposition of the gravel and sand varied within short distances to give layers of very fine sand, silt or clay interbedded with sand and gravel. Aquifers in this formation yield water to dug wells less than 20 feet deep. However, in driven wells it may be necessary to drive the point to depths of 100 feet or more before penetrating a layer of sand and gravel that is free of fine sands and silts. Along the west side of the sand area, east of Brandon, and also in and near Glenboro, the sands are coarser than elsewhere and in such deposits sandpoints are placed less than 20 feet deep.

Three drilled wells 70, 73 and 96 feet deep supply the daily water requirements of 400,000 gallons at Shilo Military Camp, Shilo, Manitoba. The wells penetrate deltaic sands and each is fitted with 9-inch-diameter well screens 13 feet in length. The water-table as of March 1945, was 44 feet below the surface and during pumping at a rate of 200 gallons a minute, the well 96 feet deep, showed a drawdown of 6.5 feet in 12 minutes after which the water-table became stable. A well at Carberry Airport, Carberry, Manitoba, penetrated 63 feet of sand (*see* log, p. 60) and the yield was 105 gallons a minute.

Aquifers Within and Underlying Lake Agassiz Sediments

East of Pembina escarpment a supply of ground water sufficient in most cases for domestic uses is obtained from wells dug 15 to 20 feet deep that penetrate a silt unit overlying the denser clays deposited in the basin of glacial Lake Agassiz. The results of drilling completed during a recent study of the ground-water resources of the Neche area, North Dakota (Paulson, 1951) indicated an upper silt unit ranging in thickness from 20 to 35 feet. The water-table in the silt unit is within 15 feet of the land surface but this fluctuates depending upon the amount of seasonal rainfall. Water is transmitted through the silt very slowly under natural conditions. These deposits are not a potential source of water supply for municipal or other purposes requiring water in greater amounts than is needed for modest domestic uses.

The clays deposited in the basin of glacial Lake Agassiz are dense, homogeneous throughout and impermeable (Table III, No. 15). A well at Rosenfeld, Manitoba, penetrated 143 feet of surficial deposits, a large part of which is clay. Beneath the clay, glacio-aqueous deposits overlying till are aquifers of varying importance. In those areas where supplies from the surface silt unit have failed test holes are drilled in search of more productive aquifers at greater depths. Several wells in the area including most of townships 5 to 10, ranges 5 and 6, reach aquifers at depths of from 75 to 272 feet (*see* logs, pp. 49 to 64). In most cases the water is under sufficient pressure to rise above the level of the confining beds and in some wells static levels reach a point 15 feet below the surface of the ground. Intake areas for these aquifers are limited to narrow outcrops along the margin of glacial Lake Agassiz. Salts and other impurities accumulate in such water en route from the intake to the well.

Aquifers in Preglacial Valleys

The principal change caused by glaciation was the filling of preglacial valleys with glacial and glacio-fluvial sediments. Preglacial valleys (Figure 2) are favourable areas to drill for ground water when a considerable supply is required. The water encountered may be under sufficient pressure to rise to the surface and flow or the static level of the water in the well may be a few feet below the ground surface. Wells drilled to glacio-fluvial deposits in a buried preglacial channel are found in township 1, ranges 14 and 15. Those flowing artesian wells drilled in township 11, ranges 18 and 19, probably encounter gravels lining a bedrock channel tributary to the ancestral Assiniboine River.

Aquifers in the Riding Mountain Formation

The Upper Cretaceous shales of the Riding Mountain formation are the principal aquifers in an area that extends west from the escarpment to

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a line from Cartwright through Pelican Lake to Wawanesa and north from the International Boundary to highway 2. Glacial till overlies the shales and the till deposits vary in thickness from less than 5 feet to as much as 100 feet depending upon the configuration of the bedrock surface. Where the overburden is thin dug wells are common; elsewhere wells are drilled.

The Riding Mountain formation in southern Manitoba was estimated by Wickenden (1945) to be 1,000 feet thick and Tovell (1951) estimated a minimum thickness of 200 feet of Odanah beds and 65 feet maximum of Millwood beds in the Pembina Valley-Dead Horse Creek area. The Odanah beds of hard, siliceous, grey shale have a low permeability and, although apparently massive, joints and fractures transmit water. At depth aquifers appear to be confined to fracture zones but near the surface the shale is broken into fissile fragments. Water percolating through the permeable thin covering of till enters the bedrock and moves laterally through the joints and fractures. Ground waters from the Riding Mountain formation contain little of the sulphates expected from the soluble gypsum in the till, and this indicates that either these waters were recharged from intake areas where overburden is thin or the sulphates were reduced by a base exchange reaction after the water entered the fractured bedrock.

The yield from aquifers in the Riding Mountain formation may average 0 to 40 gallons a minute but rarely would the yield be in excess of 5 to 10 gallons a minute. Dug wells penetrating the Riding Mountain formation at shallow depths are better producers than deep wells. A deep well yielding 10 gallons a minute may be only 100 feet distant from a well of the same depth yielding only a gallon or so a minute. This is due to the fact that aquifers in the bedrock are not extensive and the water is stored in and moves along joint and fracture planes.

Soft bentonitic shales at the base of the Riding Mountain formation are important sources of ground water in the Pembina Valley area. One well drilled 46 feet deep and another 83 feet deep in sections 1 and 3, respectively, township 1, range 6, enter aquifers in these beds that yield soft water and probably two wells drilled 125 and 130 feet deep in section 34, township 1, range 8, also tap aquifers in bentonitic shale. In an area extending north from Ninga to Souris River, bedrock lies beneath 100 feet or more of impervious glacial till. Sufficient water is not available in the till, hence, wells must be drilled to depths of from 150 to 410 feet to reach water-bearing zones in bedrock. The water is commonly too salty for domestic uses but some wells yield good quality water (*see* Analyses, p. 36).

Hard, siliceous phases of the Riding Mountain formation are massive, and resistant to erosion and thus form bedrock cores for hills, promontories and drumlins. When drilling for ground water from bedrock the best sites,

therefore, are in depressions on the surface for these generally indicate the underlying bedrock is weaker than that on high ground and hence likely to be fractured and water bearing.

Aquifers in Boissevain Sandstone

Boissevain sandstone overlies the Riding Mountain formation and is exposed on the flanks of Turtle Mountain. The rock is a poorly cemented yellow to rusty coloured sandstone that is porous. Only a few wells receive their water supply from Boissevain sandstone and this and the small areal extent of the beds presently limit their importance as an aquifer.

Aquifers in Turtle Mountain Formation

Turtle Mountain formation overlying the Boissevain sandstone is a series of shale, sandstone and lignite beds. These sediments are not known to contain aquifers of major importance in the map-area but the equivalent Fort Union formation in North Dakota and Montana contains important aquifers. The outcrops of the Turtle Mountain beds form, however, an excellent intake area for aquifers in the underlying formations.

Other Bedrock Aquifers

Although the Riding Mountain formation underlies the greater part of this area and at places is 1,000 feet thick, older formations may be prospected for water especially in the eastern part. The Vermilion River, Favel and Ashville formations underlie the overburden in a belt parallel with the escarpment and the Swan River group underlies the sediments in Lake Agassiz basin. Elsewhere these formations are at depths of roughly 1,000 feet and drilling costs are high. The Ashville formation is the equivalent of the Dakota sandstone in which artesian aquifers occur throughout the central plains region of the United States. No recent records are available of any test drilling to the Ashville formation in search of water in the Brandon area. The Ashville formation, however, was encountered at a depth of 1,595 feet in the Deloraine well, drilled during the years 1888 to 1892. This well is 1,943 feet deep and bedrock was encountered under 94 feet of overburden. An upper water zone occurs in the Riding Mountain shale at a depth of 150 feet from the land surface and a flow of salty water was obtained at 1,800 feet, from the contact of beds of the Ashville formation and those of the Swan River group.

A well drilled for water by the town of Morden in 1890 reached a depth of 601 feet. Fifteen feet of overburden were penetrated before reaching the Vermilion River formation and at a depth of 324 feet salty water was encountered in the Ashville formation. A deep well drilled at Rathwell in 1913 reached the top of the Swan River group at 427 feet below the land surface.

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Quality of Water

Information about the chemical character of the ground water is based on analyses of one hundred samples collected during the period of the field work. From this data the suitability of the ground water for industrial use, for irrigation, and for domestic use may be predicted. The data do not show the sanitary conditions of the water.

The analyses (*see* p. 36) indicate great variation in the chemical composition of the ground water. This variability in the type and quantity of dissolved solids is to be expected in water moving through aquifers of different composition, structure and geological history as is the case in the Brandon map-area. In general, however, it may be said that the ground water of the entire area is essentially hard although sodium bicarbonate characterizes that water from bedrock aquifers. Nitrates, which point to contamination, are normally present in negligible amounts in the water of deep wells but water from shallow wells shows concentrations of as much as 800 parts per million. The source of local concentrations of nitrates usually can be traced to organic matter from refuse from stables, sewage or other waste.

Ground waters are generally of uniform quality from year to year although changes in rate of draft from wells may bring about changes in quality of the water recovered. This quality change with rate of draft is experienced on many farms where formerly several head of stock were watered daily and at present water is required for domestic use only. An explanation of this feature is that the reservoir of water remaining in the well under conditions of limited usage causes the water to move slowly through the aquifer and thereby to absorb and to dissolve more constituents than formerly when the flow was fast to refill the well. As a result the water becomes bitter and salty. The improvement of the quality of the water in such wells can be effected by pumping more water daily or emptying the reservoir of water accumulated after periods of increased recharge especially from soakage of spring rains and snow melt.

Calcium (Ca) and Magnesium (Mg)

In most ground waters hardness is due almost entirely to salts of the alkaline earths, calcium and magnesium. These constituents are also active agents in the formation of almost all the scale in steam boilers and in other vessels in which water is heated or evaporated.

Carbonate hardness is due to calcium and magnesium bicarbonates. These are largely removed by boiling the water; consequently this condition by some is called temporary hardness. Noncarbonate hardness is due to calcium and magnesium sulphates or chlorides; as these cannot be removed by boiling, they result in what is sometimes referred to as permanent hardness. With

reference to the effects on soap, there is no difference between carbonate and noncarbonate hardness. In general, noncarbonate hardness forms a harder scale in steam boilers.

Most of the ground water in southern Manitoba is hard; of the samples analysed the hardness ranges from 45.9 to 2,469.5 parts per million. Water with a hardness of less than 50 parts per million is generally rated as soft water and treatment for the removal of hardness is not necessary under ordinary circumstances. Hardness between 50 and 150 parts per million does not seriously interfere with the use of the water for most purposes, but as hardness within this range slightly increases the consumption of soap the use of the softening process is profitable for laundries or other industries using large quantities of soap. Hardness above 150 parts per million is noticeable by anyone, and in areas where the hardness is above 300 parts per million many soften the water for household use or install cisterns to store soft rain water.

The alkaline earths, calcium and magnesium, are found in appreciable amounts in the ground water of the Brandon map-area. Their presence is due to the action of percolating water charged with carbon dioxide on limestone, dolomite, gypsum and silicate minerals of the overburden.

Hard water has long been considered a cause of poor health. However, the amount of calcium in hard waters is much less than the daily nutritional requirements, as the human body needs about 0.7 to 1.0 gram of calcium a day, most of which is secured from food supply (American Manual, 1950). Magnesium is not known to produce toxic effects but a permissible maximum concentration of 125 parts per million is suggested; higher concentrations of magnesium salts are a laxative.

Sodium (Na) and Potassium (K)

Sodium salts make up a considerable part of the dissolved constituents in the ground water in southern Manitoba and their source is the sodium and potassium-bearing minerals that are common in the surficial deposits and underlying marine beds.

The ratio of alkali bases, sodium and potassium, to alkaline bases, calcium and magnesium, is of particular significance in waters used for irrigation as this ratio determines the maintenance of the permeability of soils to the irrigation water. This ratio is commonly expressed as per cent sodium, and the maximum permissible for irrigation purposes is about 60 per cent.

Iron (Fe) and Manganese (Mn)

Fourteen of the ninety-six chemical elements compose 99 per cent of the earth's crust. Iron is preceded by only three, namely, aluminum, silica, and oxygen. Therefore, it is not surprising to find iron collected in ground water from oxidized zones of overburden en route to the zone of saturation.

Iron, even in small amounts, raises problems and the limit of iron plus manganese should not exceed 0.3 part per million in any process waters. Iron present in ground water as ferrous bicarbonate with a concentration of more than 1 part per million ferrous iron in solution, normally develops a reddish turbidity, and in many cases this is a colloidal product formed by the oxidation of the iron to ferric oxide. If this oxidation occurs while the water is being used it will cause staining of fabrics and porcelain, discoloration of dyes, textiles and paper, and corrosion of materials.

Iron contributes to the hardness of ground water that has a high sulphate content. Such waters are common in the shallow aquifers of the overburden in southern Manitoba. Rust particles from piping, well casings and pumps contribute to the iron content. The quantitative determination of iron in ground water should be made in the field immediately after the sample is collected to avoid precipitation of iron by oxidation. The iron content of the waters was not determined in the samples collected although in many cases its presence is indicated by turbidity of the sample.

Manganese occurs less commonly than iron, but where present the effects on water are the same as those of iron.

Manganous compounds are oxidized and precipitated as brown to black oxides or hydrated oxide. The Odanah shale of the Riding Mountain formation and some concretions in it are purple stained by manganese oxides.

Carbonate (CO_3) and Bicarbonate (HCO_3)

The carbonate and bicarbonate in ground water result from the solution of carbonate rocks, as limestone, through the action of carbon dioxide dissolved in the water. Bicarbonates render the insoluble carbonates of calcium and magnesium soluble and boiling reverses this process causing a scale to coat the inside of pots, kettles, and steam pipes.

Sulphates (SO_4)

Sulphates are dissolved in large quantities from gypsum, a hydrous calcium sulphate, that is widespread in the surficial deposits of this area. Another source is the oxidation of metallic sulphides such as pyrite and, hence, it is not uncommon to find iron compounds in sulphate water. Sulphates are the chief constituents of water from aquifers within the surficial deposits but where present in less than 250 parts per million these constituents have

little effect except to increase the cost of softening hard water. Sulphate salts of sodium and magnesium exceeding 250 parts per million in water give a bitter taste and produce a laxative effect.

Chloride (CL) and Fluoride (F)

Chloride is a constituent of all ground waters and is derived from chloride-bearing rocks and deposits of the salts sodium or potassium chloride that were formed by the gradual evaporation or drying up of bodies of salt water. Aquifers at depth in the marine Cretaceous shales, and hence a source of chloride, yield water containing abundant sodium chloride.

A limit of 250 parts per million of chloride will not be noticeable to the taste but greater amounts will render the water salty in taste and unsuitable for domestic uses. Chloride concentrations as high as 2,226.1 parts per million are recorded in the analyses on page 36. Chlorides, especially when combined with calcium and magnesium, markedly increase the corrosiveness of the water and cause permanent hardness.

Fluorides in ground water originate from contact with rocks containing fluorine-bearing minerals. These include cryolite in igneous rocks, and fluorite in sedimentary rocks. Fluorine occurs in some volcanic gases, and in southern Manitoba, such gases probably were present during the deposition of bentonite beds of the Upper Cretaceous formations. Materials originating from these formations in this area compose the greater part of the glacial deposits through which ground water percolates to the zones of saturation.

Only in recent years has fluoride and tooth decay been connected. The teeth of children during their calcification or formation become mottled if the quantity of fluorine in the water increases above 1.5 parts per million. The incidence of tooth decay is reported, by some, as being less when small amounts of fluorine are present in the water supply than when there is none. It is now a practice in some cities to add sodium fluoride to public water supplies to compensate for deficiencies of this constituent.

Tests for fluoride were made on 32 samples and the amount present ranged from nil to 2.0 parts per million. Only one sample contained 2.0 parts per million and two samples 1.2; all others were less than one. The concentration of fluoride in the ground water of southern Manitoba is probably within the safe limits for healthy teeth.

Nitrates (NO_3)

All common nitrates, nitrites and nitrogen-containing compounds are soluble and do not occur to any extent in rocks or salts exposed to ground water. Most nitrates present in ground water are added from vegetable or animal matter. The decomposition of vegetable or animal waste may cause oxidation of nitrogen compounds to nitrates or their reduction to ammonia.

Large quantities of nitrates usually indicate heavy pollution by organic materials and oxidation. High concentrations of nitrates are more indicative of recent pollution; therefore high nitrate or nitrite concentration in a water should be carefully investigated for sources of pollution. Nitrate content, unless nitrite is determined, normally includes nitrite as this is oxidized to nitrate before testing. Nitrates are responsible for the development of cyanosis or methemoglobinemia (blue babies); therefore water with a nitrate concentration greater than 44 parts per million should not be used in the preparation of food for infants.

Silica

Silica is dissolved in small quantities from almost all rocks. It has a detrimental effect in some industrial uses, particularly in high-pressure boiler operation. Silica in waters so used leads to the formation of very hard silicate scales and acts as a cementing agent for the softer, carbonate scales.

TABLE IV

Silica Content of the Principal Aquifers

Aquifer	Silica content of water ppm.
Surface sands	20 to 22
Aquifers in till	18 to 23
Gravel below Lake Agassiz sediments	15 to 19
Turtle Mountain formation	30 to 39
Boissevain sandstone	24 to 30
Riding Mountain formation, shallow aquifers	20 to 31
Riding Mountain formation, aquifers at depth	33 to 38

Types of Water in the Brandon Map-Area

The chemical characteristics of representative types of ground water in this area are shown graphically in Figure 6. The height of the divisions of each column corresponds to the quantity of the different constituents present expressed in terms of equivalents per million rather than in parts per million. One equivalent per million corresponds to 20 parts per million of calcium, 12 of magnesium, 23 of sodium, 39 of potassium, 61 of bicarbonate, 48 of sulphate, 35 of chloride, 62 of nitrate or 50 of hardness as calcium carbonate. Only the basic and acidic constituents that are in chemical equilibrium with one another are represented in the diagrams; silica and iron, which are generally considered to be in water in the colloidal state as oxides, are not included. Potassium, which is usually present in relatively small quantities as compared with sodium, is included in the pattern for sodium, and nitrate which is also usually present in relatively small quantities especially in the deeper waters is included in the pattern for chloride.

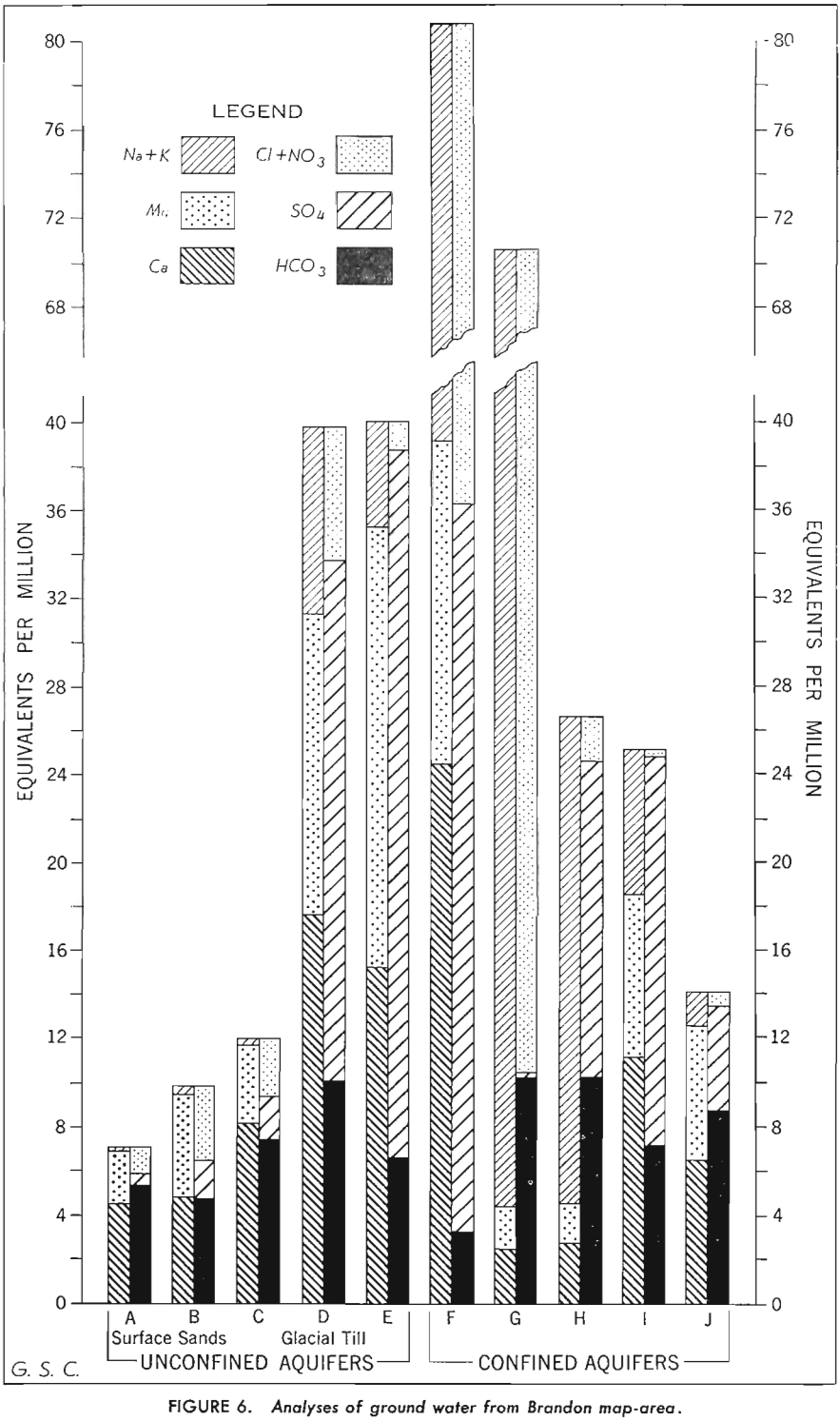

FIGURE 6. *Analyses of ground water from Brandon map-area.*

The ground waters in this area differ greatly in the amount and the relative proportions of the different mineral constituents. However, almost all can be referred to the types shown in Figure 6, as representative of the major aquifers.

A and B represent water from wind-blown sands, well-sorted sands and coarse silt of deltaic, fan-like and lake deposits, in which it is common practice to obtain water by means of driven wells. The water is generally hard; calcium, magnesium and bicarbonate predominate. Such water contains less mineral constituents than other ground water in the area, and they supply such centres as Carberry, Glenboro, Lavenham, Melbourne, Sidney and Stockton.

A large number of wells penetrate glacial deposits in which ground water is available in outwash sand and gravel, ice-contact stratified drift and ground and end moraine. C represents the quality of water from an aquifer in end moraine at Darlingford. Surface sands are well sorted whereas outwash gravel within end moraine is commonly partly cemented by carbonate, hence, the source of plentiful calcium, magnesium and bicarbonate to make these waters particularly hard.

D and E represent the quality of water in dug wells penetrating ground moraine at Dunrea and Nesbitt, respectively. The water is very hard due to the solution of calcium and magnesium especially from the upper weathered part of the till where the feldspars and other rock materials are in part decomposed. The sulphates come from readily soluble flat platy crystals of gypsum in the till.

The quality of water in aquifers beneath glacial Lake Agassiz sediments is shown in F. This water in its downward percolation through the unconsolidated silts and clays has dissolved all those constituents characteristic of the water in shallow aquifers and in addition sodium and chloride. It is therefore a hard, salty water.

Aquifers in the Riding Mountain shale yield water of the character shown in G and H. H represents the chemical character of ground water that has percolated through 5 to 50 feet of glacial deposits to enter bedrock, thence to wells that range in depth from 15 to 150 feet. This type of water is common in much of the southern part of the area and is characterized by a high bicarbonate content and generally a much lower content of calcium and magnesium resulting in a water without noncarbonate hardness. These waters, however, contain a concentration of the alkalis, sodium and potassium, that in most cases is greater than 100 parts per million and may exceed 1,000 parts per million. Water with high percentages of sodium does not qualify for irrigation uses.

G represents the water in a well drilled through 100 feet of overburden and 250 feet of shale to reach an aquifer at 350 feet in NE.¼ sec. 32, tp. 3, rge. 19. This sample illustrates the change the water undergoes in percolating to greater depths. All the constituents have become concentrated with the exception of the sulphates which are negligible. A possible explanation of this change is that the water has percolated into the Riding Mountain aquifer from an intake area on Turtle Mountain about 10 miles south of the well. This water picked up methane gas from the disseminated carbonaceous material of the coal seams characteristic of the Turtle Mountain formation at this locality. The water then percolated through the Boissevain sandstone and into the Riding Mountain formation and during this migration the methane gas reduced the sulphates to hydrogen sulphide gas and oxygen that combined with the iron to precipitate it upon standing. Many wells pump murky water that is probably due to excess methane gas escaping when the water reaches the surface of the ground where the containing pressure is lessened. Also a drilled well in NE.¼ sec. 33, tp. 3, rge. 20, 180 feet deep yields hard, salty water with some natural gas. Most ground waters in the deeper aquifers are low in sulphate. However, this is not always so as is shown by the analysis of a sample of water from a well drilled 410 feet deep in NW.¼ sec. 20, tp. 3, rge. 18 in which the sulphate content is greater than that of the chloride.

Boissevain sandstone and Turtle Mountain formation aquifers cover only a small part of the Brandon map-area in the southwest corner. The types of water from these formations are shown in I and J, respectively. The Boissevain sandstone yields water that has calcium as the predominate basic constituent and sulphate as the predominate acidic constituent. The Turtle Mountain formation yields essentially a calcium-bicarbonate water. Some of this water may have a slight brownish colour due to the contact of the water with carbonaceous material present in this formation.

Temperature of Ground Water

In general, the average temperatures of water taken from wells that are 25 to 100 feet deep, will be that of the mean annual atmospheric temperature of the locality. Below 100 feet the temperatures increase roughly one degree Fahrenheit for each 100 feet in depth.

During the course of the investigation the temperature of the water from about 100 wells was observed. These recorded temperatures ranged from 39 to 45 degrees Fahrenheit. Ground-water temperatures remain fairly constant throughout the year.

TABLE V

Analyses of Water from Wells in Brandon Map-Area

Alkalinity=carbonate hardness Total hardness—alkalinity=noncarbonate hardness WPM—West Principal meridian

Location WPM ¼	Sec.	Tp.	Rge.	Dis-solved solids	Ca	Mg	Na + K	HCO_3	SO_4	Cl	NO_3	Alkalinity as $CaCO_3$	Total Hard-ness	Remarks
					parts per million									
Aquifer—sand and gravel below Lake Agassiz sediments														
NE	7	5	5	3455.0	306.9	180.6	617.0	360.6	995.0	907.2	255.0	295.6	1509.4	Bored well 24″ diameter, 192′ deep; water in gravel at 190′. Considerable turbidity from precipitated iron.
NW	10	10	5	5716.6	567.0	172.7	1131.0	165.4	2069.0	1665.6	13.0	135.6	2126.4	Bored well 14″ diameter for 80′ then drilled a 3″ diameter hole for 100′.
SE	23	6	6	5829.7	596.6	177.4	1132.0	79.5	1625.8	2226.1	17.0	65.2	2219.7	Drilled well 5″ casing, 272′ deep; aquifer of fine sand at 215′-272′, odour of H_2S.
NE	12	10	6	1681.6	213.4	149.6	153.5	651.0	609.8	113.5	105.0	533.6	1148.7	Drilled well 135′ 6″ casing; considerable turbidity due to precipitated iron.
NW	34	10	6	1797.6	136.4	88.7	354.1	463.1	529.2	435.0	7.5	379.6	705.6	Bored well 24″ diameter, 119′ deep; water in gravel at 115′-119′.
Aquifer—Boissevain sandstone														
NW	1	2	18	1122.0	173.4	65.5	115.5	317.2	475.2	3.2	8.8	860.0	702.0	Drilled well 6″ diameter, 120′ deep.
Aquifer—Turtle Mountain formation														
SE	25	1	19	850.0	154.0	56.4	50.0	634.9	242.9	nil	7.0	520.0	615.9	Dug well 14′ deep; water flows 6″ above the ground surface.
NW	17	2	19	1156.0	102.0	90.0	25.0	427.0	202.5	31.5	49.6	350.0	625.5	Bored well 40′ deep, 24″ diameter.
Aquifer—Riding Mountain shale at depths of 250 to 400 feet														
SE	5	2	12	3945.3	42.9	15.9	1516.0	770.6	5.0	1962.0	0.0	631.6	172.4	Drilled well 290′ deep; depth to bedrock 105′.
NW	20	3	18	2380.0	54.0	17.3	351.0	615.0	612.8	244.4	7.0	544.0	206.8	Drilled well 2″ diameter, 410′ deep; depth to bedrock 120′.
SE	36	3	18	1474.0	77.0	21.0	511.2	639.0	331.1	41.1	3.4	544.0	278.4	Drilled well 300′ deep.
NE	32	3	19	4162.0	51.4	23.2	1510.0	625.4	9.9	2188.0	2.0	512.6	223.6	Drilled well 2″ diameter, 350′ deep; depth to bedrock 100′.

Aquifer—Riding Mountain formation (upper fractured zones in shale), wells less than 150 feet deep														
SW	30	3	8	384.7	75.1	18.6	19.3	196.7	40.7	47.8	64.0	161.2	264.2	Dug well 36′ deep at residence of G.N. Sutherland. Manitou, Man.
SW	21	5	8	938.7	109.1	49.0	156.2	608.5	262.1	11.6	24.0	498.8	474.2	Dug well at Altamont, 17′ deep; 8′ to bedrock.
SW	31	2	10	3973.7	140.8	37.5	1324.0	605.6	7.4	2118.0	20.0	496.4	505.5	Drilled well 128′ deep.
NW	31	5	10	1075.5	169.0	49.2	102.8	374.5	134.2	152.0	252.0	307.0	624.0	Bored well, 18″ diameter, 60′ deep; 10′ to bedrock.
NE	1	8	10	502.2	97.3	30.3	44.9	397.2	99.6	9.4	2.4	325.6	367.5	Flowing well at Treherne, approx. 105′ deep.
NW	23	4	11	1270.2	13.6	2.9	441.0	714.9	422.2	5.5	6.0	586.0	45.9	Drilled well 96′ deep.
NW	33	1	12	2624.0	26.6	9.5	1008.0	763.7	220.6	948.0	5.3	626.0	105.4	Drilled well 112′ deep.
SE	25	2	12	1051.0	87.8	26.5	239.2	419.7	430.4	36.6	4.0	344.0	328.0	Well drilled 85′ deep at the residence of N. E. Gorrell. Crystal City.
SE	25	2	12	1807.5	18.8	4.6	672.0	746.6	311.2	404.4	4.5	612.0	65.8	Well drilled 82′ at the residence of J. E. Montgomery, Crystal City.
SE	7	4	12	2525.4	79.7	41.9	742.0	616.3	1321.0	11.4	0.0	505.2	371.1	Bored well 41′ deep, 39′ to bedrock; water with considerable iron.
SE	36	1	13	1906.3	36.6	14.5	644.0	734.4	582.7	216.0	13.5	602.0	151.0	Drilled well 90′ deep.
NE	6	2	13	4724.4	110.9	51.4	1456.0	737.9	2392.6	330.0	0.0	604.0	488.0	Well at residence of A. L. Fulford, Mather, Man. 61′ deep; bedrock at 28′.
SW	19	3	14		122.2	124.0	?	266.0	201.2	218.9	0.2	218.0	462.1	Well at general store, Neelin, dug 22′ deep.
NE	20	5	15	1096.9	179.0	80.0	74.0	424.6	240.6	153.0	132.9	348.0	775.8	Well at cafe in Belmont, bored 50′ deep.
Aquifer—Surficial deposit, till in ground and end moraine and the associated stratified deposits														
NE	8	3	6	4169.1	301.6	417.1	439.8	951.6	2166.1	164.6	184.0	180.0	2469.5	Dug well 20′ deep at Thornhill Co-Op store.
NE	8	3	7	662.9	163.2	41.1	11.7	460.4	93.8	92.2	14.0	377.4	576.6	Darlingford community well on Railway Ave.; dug 43′ deep.
NE	19	5	9	1802.6	342.7	64.1	152.4	279.6	305.7	516.2	256.0	229.2	1119.3	Well dug 17′ deep at residence of G. Vielfaure, Somerset.
NW	20	1	14		224.7	61.6	?	673.4	698.4	63.4	4.4	552.0	814.1	Drilled well 140′ deep; water enters at 138′ through sand below till.
NW	6	2	14		292.8	92.0	?	666.1	637.0	172.5	426.2	546.0	1675.3	Cartwright community well dug 27′ deep.
SE	24	2	16	1856.3	186.0	200.0	131.9	496.5	787.3	156.5	150.6	407.0	1287.1	Well at C.P.R. station Holmfield dug 22′ deep.
NE	2	3	17	1590.9	160.0	199.9	126.2	745.4	642.8	77.5	66.5	611.0	1221.8	Well at C.P.R. station Killarney dug 39′ deep.
NE	20	5	17	2402.5	351.8	165.2	218.0	611.2	1133.4	199.9	33.2	501.0	1557.5	Community well at Dunrea; bored 63′ deep.
SW	21	5	18	1859.0	277.0	168.0	42.0	427.8	1106.0	37.2	17.8	380.0	1237.7	Well bored 55′ deep at Margaret.
NW	28	8	18	680.0	91.1	71.5	34.8	366.2	106.6	63.8	23.0	354.2	521.5	Dug well 41′ deep.
SW	36	11	19	2560.4	405.0	115.4	270.0	507.5	1291.0	229.0	0.0	416.0	1485.4	Dug well 54′ deep.

TABLE V

***Analyses of Water from Wells in Brandon Map-Area**—Conc.*

Alkalinity=carbonate hardness Total hardness—alkalinity=noncarbonate hardness WPM—West Principal meridian

Location WPM ¼	Sec.	Tp.	Rge.	Dis-solved solids	parts per million Ca	Mg	Na + K	HCO_3	SO_4	Cl	NO_3	Alkalinity as $CaCO_3$	Total Hard-ness	Remarks
Aquifer—surface sands (windblown and deltaic) and outwash deltaic gravel, sand and coarse silt														
SW	22	8	6	567.2	85.4	24.5	75.4	302.6	100.4	32.2	80.0	248.0	314.0	Dug well 12′ deep at residence of J. C. Beaulieu, Haywood.
SW	15	10	9	503.8	87.4	41.4	29.6	337.7	87.6	14.8	64.0	276.8	388.5	Well at skating rink, Rossendale, dug 14′ deep.
NE	35	9	10	398.9	90.3	29.9	3.4	323.5	28.8	17.2	48.0	265.2	348.6	Community well dug 24′ deep at Lavenham.
SW	33	10	13	278.4	62.1	19.0	4.9	259.6	12.8	2.2	32.0	212.8	233.1	Sandpoint at Melbourne, 40′ deep at filling station on No. 1 highway.
NE	10	7	14	830.0	109.0	64.4	10.9	295.4	79.1	121.0	7.0	286.0	536.9	Sandpoint 28′ deep at home of W. H. Carrothers, Glenboro.
NE	30	10	14	584.0	106.6	34.5	26.7	295.2	60.1	23.4	19.4	290.0	408.0	Sandpoint 40′ deep at the Nelson Hotel, Carberry.
NW	21	7	15	463.0	97.0	27.3	13.2	255.0	66.7	4.4	19.4	221.0	354.3	Sandpoint 22′ deep at the residence of T. Brown, Stockton.

CHAPTER IV

RECOVERY AND USE OF GROUND WATER

Types of Wells and Well Construction

In determining the site and method of construction of a well the general principles of recovery of ground water as related to the local geological and topographical features, and records of nearby wells are most useful. Convenience and possible sources of pollution may also influence the location. Where the anticipated cost of the well is great, test holes to determine the character and yield of the rocks prevent failures. Records should be kept of the materials encountered during the digging or drilling, as well as data obtained during pumping tests. Such records are invaluable for reference in the development of the aquifer, in the selection of a well screen, if one is to be used, and in future repairs to or deepening of the well.

Dug Wells

A dug well, as the name implies, is one excavated by digging, usually with hand tools. Dug wells are common because they are inexpensive and also initial attempts to get a supply of water are directed to the unconsolidated surface deposits. Dug wells are most successful in areas where there is a shallow water-table in unconsolidated materials that do not cave readily. Most dug wells are less than 50 feet deep and the diameters vary from 2 feet to as much as 6 feet. The larger diameter is advantageous where water is obtained from a poor water-bearing formation because a larger infiltration area and storage capacity are available.

The cribbing may be made of wood, cement, brick or tile. Inadequate cribbing and covering allows for pollution and the use of board tops is discouraged. It is recommended that the wells have concrete brick or tile cribbing with a concrete covering in which there is a manhole with a tightly fitting cover, to allow access for repairs to the pump or well.

The advantages of a dug well are that it may be installed by unskilled labour, with hand tools, and therefore is less expensive to construct than drilled wells; it exposes a relatively large area of a water-bearing formation and thereby may obtain from poor aquifers yields sufficient for minimum domestic and farm needs; it provides a relatively large reservoir space per foot of depth from which water may be pumped heavily for short periods and the supply replenished between pumping. In southern Manitoba the chemical quality of water obtained from a dug well is apt to be as good as or better than that obtained from deeper drilled wells at a given site.

The disadvantages of a dug well are that it can be excavated cheaply only in unconsolidated deposits where the water-table is within 40 feet of the land surface (where the water-table is deeper construction costs are comparatively high); it requires careful construction and location with respect to possible sources of sanitary wastes to prevent pollution; in periods of drought the water-table may decline below the bottom of the well, especially inasmuch as dug wells may be difficult to extend far below the water-table.

Where the surface deposits include a thick impervious till and existing drilled well data in the vicinity indicate that the chance of obtaining satisfactory supplies from the underlying bedrock is poor, one or more dug wells may possibly supply the minimum needs. A dug well is advantageous where thin deposits of sand mantle thick impervious tills. In this instance the well should be of moderate diameter and should be excavated several feet into the underlying till so that the full thickness of the sand deposit will be utilized to maintain drawdown at a minimum and to provide additional reservoir space. In almost all aquifers of coarse sand and gravel, the water-table is close to the surface and under such conditions a series of large-diameter dug wells supply industrial and municipal plants.

Driven, Bored, and Drilled Wells

Drilled and driven wells are similar in that both types are deep in comparison to their diameters. Drilled wells are excavated with power tools in all kinds of rock whereas driven wells are forced by percussions into sandy deposits generally by means of hand tools.

The driven well is perhaps the easiest and least expensive type of well to install where conditions are favourable. The well is constructed by driving a pointed screen called a drive point, well point or sandpoint that is attached to a length of pipe into the ground to the water-bearing formation. The pipe, 1½ to 4 inches in diameter, is added in sections as the point is driven deeper. Driven wells may be installed in unconsolidated formations that contain layers permeable enough to yield sufficient water to small diameter screens. In some such deposits, however, large cobbles or boulders obstruct driving the point. Deposits of sand or fine gravel are particularly favourable for coarse gravel obstructs driving and fine sand does not as a rule yield enough water or that produced may not be clear. Well points are made with screens of various meshes, and the yield of the well is improved by installing the appropriate size of mesh. If the pumping level is 25 feet or less below the surface shallow well pumps coupled directly to the top of the well pipe are satisfactory. If the pumping level is below 25 feet a deep well pump must be used.

Driven wells are extensively used to obtain domestic and farm supplies in the sand-plain area covering most of the northwest quarter of the Brandon map-area. They are not successful in bedrock, till, alluvial or lacustrine clay and silt. The yield of driven wells depends principally upon the permeability of the aquifer and on the diameter and length of screen used. As a rule, clean, water-bearing sand about 10 feet thick will yield about 100 gallons a minute. Where small diameter screens are used in a fine-grained aquifer, the full length of the screen should be driven below the lowest pumping level, as determined from test pumping, to allow for excessive drawdown in the immediate vicinity of the well. Under favourable conditions an extensive aquifer will yield to a number of driven wells enough water for moderate industrial or commercial needs.

Bored wells are constructed by means of a power-driven auger that bores a hole of the desired diameter, 12 to 30 inches, through the surface deposits and into the broken fractured upper part of the bedrock. As the walls of such wells will cave or slump they are reinforced with wooden or preferably tile cribbing. Like dug wells, bored wells are subject to pollution and, therefore, in both types the same precautions are desirable. Bored wells are not as expensive as drilled wells and are convenient where shallow water-tables are lacking in the thin overburden so that the upper zones of the bedrock must be penetrated for a supply of ground water.

Drilled wells are the best type for obtaining water from bedrock and from boulder clay (till) and coarse gravel. Drilled wells are constructed by two principal methods of drilling, the cable-tool method also known as the percussion or churn-drill method and the hydraulic-rotary method. Each method is appropriate under certain conditions. In the Brandon map-area the percussion method is the most widely used. This method involves the excavation of a hole by the percussion and cutting action of a chisel-edged drilling bit attached to the bottom end of a heavy drill stem which is alternately raised and dropped. The formation through which the hole is being drilled is thus broken into small fragments that become in part pulverized and mixed into a sludge. At intervals this sludge is removed from the hole with either a bailer or a sand pump. In hard rock the hole usually is drilled without casing but in unconsolidated materials well casing is repeatedly driven down so that only a few feet of open drill-hole extend below the bottom of the casing. Where a screen is used it generally is of smaller diameter than the well casing and is lowered within the casing to the desired depth. The casing is then pulled back to a point just above the top of the screen, or a screen having an open bottom is bailed down so as to extend below the end of the casing, after which the bottom of the hole below the screen is cemented.

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The rotary method involves rotating suitable tools that cut, chip and abrade the rock into small particles. Drilling mud, a thin sludge of clay or especially prepared materials, is pumped down the hollow rotating drill rod out through the drill bit attached to the lower end of the drill rod and back to the land surface through the annular space between the drill rod and the walls of the hole. As the mud returns to the land surface it not only carries along the cuttings of the bit but seals the formations that have been penetrated thus decreasing caving of the hole. Well casing and a screen are lowered and set into place after the well has been drilled to the required depth and the well is surged or otherwise treated to remove the clay seal from the walls of the hole through the aquifer and opposite the screen.

In aquifers of fine sand a gravel-walled or gravel-packed well is constructed after first drilling a hole by either the cable tool or hydraulic-rotary method. Although several methods of construction are possible, they are all designed to produce an envelope of graded or uniform sized gravel between the well screen and the fine sand. This permits the use of larger screen openings than otherwise would be possible without admitting excessive sand and consequently the recovery of more water from the aquifer.

In post-drilling development of wells methods of treatment commonly used to improve the yield include surging, overpumping, back-washing and treatment with acid or other chemicals. With the exception of the chemical treatment all methods are designed primarily to wash the fine sand, silt and clay from the water-bearing formation immediately surrounding the well screen, or if the aquifer be rock from the joints and bedding planes or other water-bearing openings within the rock immediately surrounding the hole. This facilitates the entry of water into the well and thereby increases the yield per foot of drawdown.

Surging is probably the best method of developing a well under average conditions encountered in sand and gravel aquifers of southern Manitoba. The method utilizes a tight fitting plunger that is moved up and down inside the well casings from a point 10 to 20 feet below the static level of the water or at intervals below the static water level through the entire depth of the well. The suction created causes the water to surge back and forth into and out of the well, thereby loosening the finer particles in the formation and carrying them into the well where they are removed either by bailing or by pumping. The well is alternately surged and bailed until a few or no fine particles are recovered.

If quicksand is encountered when drilling a well it is advisable to force the casing through it to the underlying stratum provided the quicksand is

not too thick to do this. Where the layer is 5 feet or less thick this can be done by maintaining a head of water in the casing. This head of water helps to stabilize the quicksand as the casing is forced through it.

Uses of Ground Water

Domestic

Standards by which to ascertain the suitability of waters for human consumption have been established by the United States Public Health Service. Table VI based on these standards gives the maximum allowable in parts per million of certain constituents in water.

TABLE VI

Recommended Limits for Specific Constituents

Constituents	Limit ppm.
Fluoride	1.5
Iron and manganese together	0.3
Magnesium	125.0
Chloride	250.0
Sulphate	250.0
Nitrate	44.0
Total solids, desirable	500.0
Total solids, permitted	1,000.0

Farm and private wells for domestic purposes are required to yield less than 100 gallons a day. The principal requirements are that the water has a pleasing appearance and is free from objectionable tastes and odours. The ground water of almost all the wells examined, although fulfilling these requirements, is hard.

Industrial

Up to the present a relatively small quantity of ground water is used industrially in creameries at Cartwright, Crystal City, Glenboro, Notre Dame de Lourdes and Somerset. Industries at Brandon, Portage la Prairie and Morden use water from municipal systems, the source of which is the Assiniboine River at Brandon and Portage la Prairie, and Lake Minnewasta at Morden.

Irrigation practices are not widespread chiefly because the crop is principally grain and modern dry farming methods are effective in the conservation of soil moisture. In future, however, irrigation practices may be employed for the corn and pea crops at Morden. A sufficient supply of ground water for such irrigation probably is present in surface sands along and east of Pembina escarpment.

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Stock

The quality of the ground water is generally suitable for stock. The salty water of some wells in bedrock is beneficial to cattle and in many instances no salt in the form of salt-licks is necessary. Where supplies of ground water are not abundant dugouts are built to collect and store surface run-off, which throughout the year is used to water the stock.

As it is useful, when digging or drilling a well, to make an estimate of the daily consumption requirements of water both for domestic and stock uses, the following table is included.

TABLE VII

Estimate of Average Daily Water Requirements

Unit	Gallons per day
Each member of the family	30 gallons
Each dairy cow	30 "
Each beef cow	10 "
Each horse	10 "
Each hog	2.5 "
Each sheep	2.5 "
Each 100 chickens	5.0 "

Therefore, a well supplying water to a family of five, and also watering five hundred chickens and ten head of dairy cattle, should be capable of supplying 475 gallons a day. A minimum for fire protection is in the order of 5 gallons per minute at 30 pounds pressure.

Municipal Systems

The village of Treherne, with a population of about 600, has installed a municipal water system supplied by ground water. The well taps an artesian aquifer at a depth of 105 feet and, on the basis of results of test pumping, yields 4,500 gallons an hour. The water (*see* Analyses, p. 36) is used directly without softening, filtration or chlorination.

Brandon, with a population of 22,000, takes its water from Assiniboine River. The water is subjected to the following purification processes, filtration, lime-soda softening, chlorination and fluoridation. The daily consumption is 2,300,000 gallons.

Portage la Prairie takes its water from Assiniboine River and after sand filtration and chlorination distributes 1 million gallons daily to the 8,500 population.

At Carman, population 1,900, water is pumped from Boyne River to supply a daily requirement of 100,000 gallons.

Morden pumps water from Lake Minnewasta, which is 1½ miles west from the town. After filtration and chlorination the water is distributed to 200 domestic, 26 commercial and 5 industrial users. The daily consumption is 80,000 gallons.

SUMMARY OF THE GROUND-WATER CONDITIONS

All potable ground water originates essentially from precipitation that falls on the area. A layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 gallons. As the average annual precipitation in the form of rain or snow in the Brandon map-area is about 18 inches, each year some 261,360,000 gallons of water falls on each square mile. If roughly 10 per cent of this amount percolates downward to the ground-water aquifers then approximately 26 million gallons of water per square mile is available for recharge.

Those areas underlain by porous sand and gravel are best suited for infiltration. All water, other than that lost to evaporation, replenishment of the soil moisture and plant growth, will reach the ground-water reservoirs. Where till underlies the surface an estimate of 10 per cent recharge may be in excess of what actually occurs. Seasonal recharge in the shale occurs by the water percolating along bedding, lamination planes and vertical joints.

By far the greatest use of ground water in the area is for farm supplies. On the Assiniboine delta and in some areas of outwash, driven wells are used, and there a supply of ground water sufficient for domestic and farm needs is available and the cost of well construction is low. Wells in till furnish only relatively small supplies for domestic use and many are inadequate for even these small demands. In areas of till wells obtain their water from small bodies of sand and gravel within the till which may be isolated from one another. From such deposits minimum domestic and farm needs may be met by constructing one or more large diameter wells.

Aquifers in shale generally occur at depths of from 20 to 30 feet below the top of the shale, and are reached by bored or drilled wells. Such aquifers do not appear to be extensive in any one horizontal layer but are localized to systems of abundant fractures in hard resistant beds. Most drilled wells in shale do not yield much more than 10 gallons a minute for relatively long periods of time. A system of wells properly spaced so as to produce the minimum of interference with one another might yield considerable water, for individual wells under proper conditions would produce from 7,000 to 14,000 gallons a day.

Most of the ground water of the area is of suitable quality for the required uses. The main objection is the hardness, which ranges from 45.9 to 2,469.5 parts per million in those samples analysed. The predominant salts are

sulphates of calcium and magnesium picked up as the water percolates through till containing minute gypsum crystals. The water of the deeper aquifers carries more salts than ground water from shallow sources, but despite this, it is on the average soft due to the predominance of sodium bicarbonate.

Municipal supplies for the villages in the area would require an average of 50,000 to 60,000 gallons each a day to satisfactorily supply the demands. Five or more wells drilled in a group to aquifers in the bedrock may supply this amount. Probably water in such quantities would not be available from unconsolidated surface deposits except in areas of extensive outwash.

Wells are failures owing to either formation conditions or the type of well and construction. What appears to be a poor aquifer may become an excellent producer with proper development by surging or gravel packing. Gravel treatment, of course, is effective only in wells drilled to unconsolidated aquifers. During periods of less than normal rainfall wells may fail owing to the lowering of the water-table. Deepening such a well will be effective if the bottom of the well is not below the base of the aquifer. A well constructed and developed during autumn when the water-table is low is not so likely to fail as one constructed and developed when the aquifers are fully recharged and the water-table is high.

Much more information than that available is required before all the details of ground water resources of the area are understood. A large-scale development of ground water in the area should be preceded by test drilling, pumping tests and a critical examination of all factors involved. The favourable constant temperature of the water of about 42 degrees Fahrenheit, combined with its generally good quality, makes the water suitable for a wide range of uses. This is especially true of ground water available in the areas of outwash.

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APPENDIX I

Logs of Wells and Test Holes in the Brandon Map-Area

Material	Thickness (feet)	Depth (feet)
SW.¼ Sec. 11, Tp. 6, Rge. 5		
Clay, bluish grey	70	70
Till	48	118
Gravel, medium to coarse, and sand	2	120
SW.¼ Sec. 1, Tp. 7, Rge. 5		
Sand	6	6
Clay, bluish grey	104	110
Hardpan (till)	10	120
Clay	40	160
Sand	.....	160
NE.¼ Sec. 25, Tp. 8, Rge. 5		
Clay, light brown	35	35
Clay, blue	93	128
Gravel and sand	2	130
SW.¼ Sec. 23, Tp. 9, Rge. 5		
Clay, light brown	35	35
Clay, blue	65	100
Hardpan	45	145
Sand, very fine, some water	25	170
Hardpan	5	175
Gravel and sand	5	180
SW.¼ Sec. 19, Tp. 10, Rge. 5		
Clay, blue	105	105
Till, hardpan	9	114
Sand, fine, some water	1	115
Till	35	150
Gravel, coarse, water-bearing	2	152
NE.¼ Sec. 30, Tp. 10, Rge. 5		
Clay, brown	55	55
Clay, blue	45	100
Hardpan	15	115
Hardpan and boulders	15	130
Hardpan, some gravel and broken shale	30	160

Material	Thickness (feet)	Depth (feet)
NE.¼ Sec. 14, Tp. 5, Rge. 6		
Rosebank Airport Test Hole No. 1		
Black loam	3	3
Clay, yellow	27	30
Clay, blue	103	133
Gravel and coarse sand	1	134
Clay with streaks of sand or gravel	3	137
Clay, blue	22	159
Sand, coarse, water-bearing	3	162
Clay, silty	30	192
Sand, fine	10	202
Clay	9	211
Note: Yield of 2 gallons per minute.		
NE.¼ Sec. 14, Tp. 5, Rge. 6		
Rosebank Airport Test Hole No. 2		
Clay, grey	25	25
Clay, dark brown	13	38
Clay, blue	86	124
Till (hardpan)	5	129
Sand, coarse and gravel, water-bearing	1	130
Hardpan	10	140
Note: Yield of 18 gallons per minute.		
NW.¼ Sec. 36, Tp. 5, Rge. 6		
Sand	4	4
Clay	86	90
Sand, fine and water (quicksand)	10	100
Clay	21	121
Gravel	10	131
Clay	69	200
Shale	22	222
SE.¼ Sec. 23, Tp. 6, Rge. 6		
Clay	108	108
Hardpan	107	215
Sand, fine and water	57	272
NW.¼ Sec. 30, Tp. 8, Rge. 6		
Top soil	5	5
Clay	95	100
Sand	14	114
Clay	15	129
Clay and boulders	1	130

Material	Thickness (feet)	Depth (feet)
NW.¼ Sec. 7, Tp. 11, Rge. 6		
Portage la Prairie Airport Test Hole, NE. Corner of the NW.¼ Sec. 7		
Clay	123	123
Sand, gravel and boulders	5	128
Clay	7	135
Shale	10	145
NW.¼ Sec. 7, Tp. 11, Rge. 6		
Portage la Prairie Airport Test Hole; 1,735 feet from west boundary and 704 feet south of north boundary of NW.¼ Sec. 7		
Clay	135	135
Clay and shale	10	145
Gravel, clay and little water	5	150
Clay	10	160
NW.¼ Sec. 5, Tp. 11, Rge. 6		
Portage la Prairie Airport Test Hole		
Top soil	1	1
Sand, dry yellow	2	3
Clay, yellow	12	15
Clay, blue	95	110
Clay, light blue	20	130
Sand and gravel	4	134
Clay, white sandy	7	141
Note: Water in sand and gravel at 130 feet; yield 21 gallons per minute.		
SW.¼ Sec. 23, Tp. 2, Rge. 7		
Clay, yellow	25	25
Clay, blue and boulders	3	28
Till (hardpan)	56	84
Clay, blue	19	103
Shale	.....	103
SE.¼ Sec. 13, Tp. 9, Rge. 9		
Till	35	35
Sand	55	90
Clay	15	105
NE.¼ Sec. 17, Tp. 9, Rge. 9		
Clay, sandy	10	10
Sand	15	25
Clay	29	54
Sand, fine and water (quicksand)	2	56
Clay	2	58

Material	Thickness (feet)	Depth (feet)
NE.¼ Sec. 6, Tp. 2, Rge. 13		
Clay, yellow	28	28
Shale	33	61
SW.¼ Sec. 6, Tp. 4, Rge. 14		
Till	86	86
Shale, soft	10	96
Shale, hard (Odanah)	6	102
NW.¼ Sec. 20, Tp. 10, Rge. 14 Carberry Airport Well		
Sand, yellow	9	9
Sand, yellow, dry	8	17
Sand, yellow with streaks of clay	11	28
Sand, grey	33	61
Sand, fine, grey	2	63
NW.¼ Sec. 32, Tp. 11, Rge. 14 Petrel Airport Test Hole No. 1		
Clay	5	5
Sand, fine	10	15
Sand and clay	4	19
Sand	17	36
Sand, coarse, brown	8	44
Sand, coarse with fine sand in lenses	56	100
Sand, fine, silty	15	115
NW.¼ Sec. 20, Tp. 1, Rge. 15		
Clay, yellow	12	12
Till	27	39
Sand, black	1	40
NW.¼ Sec. 7, Tp. 11, Rge. 16 Douglas Airport Test Hole No. 1		
Clay	4	4
Sand, coarse	12	16
Sand and clay	16	32
Sand	9	41
Sand with streaks of blue clay	57	98
SW.¼ Sec. 7, Tp. 11, Rge. 16 Douglas Airport Test Hole No. 2		
Clay	3	3
Sand, coarse	5	8
Clay, sandy	12	20
Sand, coarse	20	40
Sand and clay	5	45

Note: Yield of well 5 gallons per minute.

Material	Thickness (feet)	Depth (feet)
SW.¼ Sec. 7, Tp. 11, Rge. 16		
Douglas Airport Test Hole No. 3		
Clay, sandy	7	7
Sand, coarse	7	14
Sand and clay	7	21
Sand and gravel	16	37
Shale	1	38
Note: Yield of well 8 gallons per minute.		
SW.¼ Sec. 35, Tp. 10, Rge. 18		
Chater Airport Test Hole No. 1; 1,750 feet north of the SW. corner at west boundary of the airport		
Clay, yellow, sandy	8	8
Clay, blue, sandy	8	16
Sand, fine	1	17
Clay, blue	8	25
SW.¼ Sec. 35, Tp. 10, Rge. 18		
Chater Airport Test Hole No. 5; 300 feet south of No. 1 test hole		
Clay, yellow	9	9
Sand, coarse with gravel and boulders	3	12
Clay and boulders	2	14
Note: Yield of well 27 gallons per minute.		
NW.¼ Sec. 17, Tp. 7, Rge. 19		
Clay, yellow	30	30
Clay, blue	55	85
Till (hardpan)	20	105
Sand, fine, water-bearing	15	120
Till	5	125
Gravel	5	130
NW.¼ Sec. 12, Tp. 2, Rge. 17		
Clay, yellow	10	10
Clay, yellow and boulders	30	40
Clay, blue	15	55
Clay, blue and boulders	10	65
Clay, blue	10	75
Sand	35	110
Sand, fine (quicksand)	25	135
Gravel	5	140
Shale	75	215

APPENDIX II

Records of Wells and Test Holes in the Brandon Map-Area

	Section	Town-ship	Range	Type of Well[1]	Depth (in feet)	Elevation (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Aquifer	Quality of Water	Use[2]	Greatest number stock watered	Remarks
NW.	6	1	5	Dug	12	1331	10	3	Shale	Hard	D.S.	20	
NW.	13	1	5	Dug	15	989	12		Sand	Hard	S.		
NW.	18	1	5	Dug	26	1436	11	25	Shale	Hard	D.S.	30	
NE.	22	1	5	Dug	12	1019	8		Sand	Hard	D.S.		Water in beach bars of former Lake Agassiz
SE.	27	1	5	Dug	12	1009	8		Sand	Hard	D.S.	15	Water in beach bars of former Lake Agassiz
SE.	34	1	5	Dug	12	1023	7		Sand	Hard	D.S.	30	Water in beach bars of former Lake Agassiz
SE.	3	2	5	Dug	8	1013	3		Sand	Hard	D.S.		Water in beach bars of former Lake Agassiz
SW.	7	2	5	Dug	32	1175	26		Drift	Hard	D.S.	35	
NW.	21	2	5	Dug	11	1033	9		Sand	Hard	D.S.	10	
SW.	36	2	5	Dug	12	951	9		Sand	Hard	D.S.	20	
SE.	20	3	5	Dug	20	964	16		Sand	Hard	D.S.	20	
NE.	5	4	5	Dug	41	950	22		Drift	Hard	D.S.		Also drilled at 120 feet, no supply
NW.	11	4	5	Drl.	90	907	70		Sand	Hard	D.S.	25	
NE.	24	4	5	Dug	100	891	45		Sand	Hard	D.S.	20	
SW.	28	4	5	Dug	100	911	70		Sand	Hard	D.S.	15	
SW.	34	4	5	Drl.	185	908	16		Sand	Hard	D.S.	25	
NE.	4	5	5	Drl.	165	916	30		Sand	Hard	D.S.	80	
NE.	7	5	5	Brd.	192	919	28		Gravel	Hard	D.S.		*See* chemical analyses
SE.	23	5	5	Drl.	120	890	50		Gravel	Hard	D.S.	50	
SW.	4	6	5	Drl.	168	903	15		Gravel	Salty	S.	50	
SW.	11	6	5	Drl.	120	881	15		Gravel	Hard	S.	50	*See* log
SW.	1	7	5	Brd.	160	878	20		Sand	Hard	D.S.	100	*See* log
SE.	8	7	5	Drl.	120	913	30		Gravel	Hard	D.S.	100	
NW.	31	7	5	Dug	14	922	8		Sand	Hard	D.S.	45	
NE.	3	8	5	Dug	13	873	4		Sand	Hard	D.S.		
SE.	13	8	5	Brd.	140	859	50		Gravel	Hard	D.S.	35	
SE.	25	8	5	Drl.	123	838	23		Gravel	Hard	D.S.		*See* log
SE.	2	9	5	Drl.	212	843	64		Gravel	Hard	D.S.	80	
SW.	23	9	5	Drl.	180	812	30		Gravel	Hard	D.S.	40	*See* log
NW.	10	10	5	Brd.	180	831	26		Gravel	Hard	S.		*See* chemical analyses
SW.	19	10	5	Drl.	152	829	30		Gravel	Hard	D.S.	40	*See* log
NW.	23	10	5	Drl.	175	834	25		Gravel	Salty	S.	25	
NE.	30	10	5	Drl.	160	824	22		Drift	Hard	D.S.	70	*See* log
SW.	2	11	5	Dug	16	822	12		Sand	Hard	D.S.	35	
SW.	9	11	5	Dvn.	13	821			Sand	Hard	D.S.		Water-table within 10 feet of surface
SW.	12	11	5	Dvn.	14	817			Sand	Hard	D.S.		
NW.	11	1	6	Dug	25	1472	10	10	Shale	Hard	D.S.	40	
SE.	21	1	6	Dug	24	1504	20	10	Shale	Hard	D.S.	40	
SE.	9	2	6	Dug	13	1400	8	13		Hard	D.S.	20	Water at contact of drift and bedrock
SE.	24	2	6	Dug	15	1165	12		Gravel	Hard	D.S.	25	
NE.	31	2	6	Brd.	33	1366	15		Drift	Hard	D.S.	15	
NE.	8	3	6	Dug	20	1311	5		Drift	Hard	D.		*See* chemical analyses; well at Thornhill store

NE.	24	3	6	Dug	12	993	8		Sand	Hard	D.S.		Three shallow wells on farm
SE.	4	4	6	Dug	20	1068	18		Drift	Hard	D.S.	60	
SW.	29	4	6	Dug	25	1072	17		Drift	Hard	D.S.	30	
NE.	35	4	6	Dug	22	956	15		Drift	Hard	D.S.	20	
SW.	8	5	6	Dug	24	1004	19		Sand	Hard	D.S.		Well at Monarch Lumber Co., Miami, Manitoba
NE.	14	5	6	Drl.	211	940				Hard			*See* log. Yield 2 gallons a minute
NE.	14	5	6	Drl.	140	940	28		Gravel	Hard	D.		*See* log. Yield 18 gallons a minute
NW.	23	5	6	Drl.	160	939	40		Sand	Hard	D.S.	65	
SE.	29	5	6	Drl.	117	962	15		Sand	Hard	D.S.	35	
NW.	36	5	6	Drl.	220	925	26	200	Gravel	Salty	S.		*See* log
SW.	8	6	6	Dug	18	977	15		Drift	Hard	D.S.	20	
SE.	15	6	6	Drl.	160	959	12		Gravel	Hard	S.		Water in gravel at 150 feet
SE.	19	6	6	Dug	12	983	8		Sand	Hard	D.S.	60	
SE.	23	6	6	Drl.	272	938	40		Sand	Hard	S.		*See* log; *See* chemical analyses
SE.	35	6	6	Drl.	200	935	29			Salty	S.	50	
NE.	3	7	6	Dug	12	946	8		Sand	Hard	D.S.	25	
SW.	27	7	6	Dug	10	961	7		Sand	Hard	D.S.	35	
SE.	5	8	6	Dug	12	952	9		Sand	Hard	D.S.	40	
NW.	30	8	6	Drl.	130	975	50		Sand	Hard	D.S.	40	*See* log; water in sand at 100 feet
NW.	2	9	6	Dug	9	949	8		Sand	Hard	D.S.	40	
SW.	8	9	6	Dug	17	964	15		Sand	Hard	S.	50	
SW.	23	9	6	Dug	11	941	8		Sand	Hard	D.S.	30	
NE.	12	10	6	Drl.	135	855			Gravel	Hard	S.	20	*See* chemical analyses
NW.	26	10	6	Drl.	109	849	79		Gravel	Salty	S.	35	
NW.	34	10	6	Brd.	115	853	49		Gravel	Hard	D.S.	100	*See* chemical analyses. Water in gravel at 114 feet
NW.	5	11	6	Drl.	141	920			Drift				*See* log of test holes Portage la Prairie airport
SW.	1	1	7	Brd.	90	1539	40	50	Shale	Hard	D.S.	25	
NW.	16	1	7	Brd.	32	1544	15		Sand	Hard	D.S.	20	
SE.	25	1	7	Brd.	67	1504	13	30	Shale	Hard	D.S.	25	
SW.	23	2	7	Drl.	104	1489	24	103	Shale?	Hard	S.	40	*See* log
NW.	8	3	7	Dug	43	1588	29		Drift	Hard	M.		*See* chemical analyses; well at Darlingford
NE.	20	3	7	Dug	19	1553	7	14	Shale	Hard	D.S.	30	
NW.	20	4	7	Dug	27	1572	20	27		Hard	D.S.		Water at contact of drift and bedrock
NE.	31	4	7	Dug	14	1490	10	6	Shale	Hard	D.S.		
NE.	8	5	7	Dug	25	1406	15	12	Shale	Hard	D.S.	30	
SW.	26	5	7	Dug	26	1054	23		Drift	Hard	D.S.	16	Temperature of water 43° F.
NW.	30	5	7	Dug	60	1427	35		Drift	Hard	D.S.	25	
SW.	34	5	7	Dug	29	1110	22		Drift	Hard	D.S.	50	
NE.	16	6	7	Dug	20	1012	10		Drift	Hard	D.S.	15	
SW.	3	7	7	Dug	11	992	9		Sand	Hard	D.S.	18	
SE.	13	7	7	Dug	10	981	6		Sand	Hard	D.S.	24	
NW.	23	7	7	Dug	12	1001	7		Sand	Hard	D.S.	30	
NE.	34	7	7	Dug	14	1008	8		Sand	Hard	D.S.	30	
NE.	32	8	7	Dug	10	1018	8		Sand	Hard	D.S.	30	
NW.	22	9	7	Dug	12	1014	8		Sand	Hard	D.		Five shallow wells on farm
NE.	32	9	7	Dug	11	980	7		Sand	Hard	S.		Also a driven well 10 feet deep on farm
SW.	1	10	7	Dug	11	962	9		Sand	Hard	D.S.	40	
SW.	28	10	7	Dug	14	945	10		Sand	Hard	D.S.	55	
SW.	32	10	7	Drl.	145	964	18		Drift	Salty	S.		Also a well drilled 165 feet deep
NW.	34	10	7	Dug	12	934	8		Sand	Hard	D.S.	75	
NE.	1	1	8	Brd.	45	1582	15	15	Shale	Hard	D.S.	40	

[1]Type of well—Drl.—drilled well
Brd.—bored well
Dvn.—driven well or sandpoint

[2]Use—D.—domestic use
S.—stock use
M.—municipal use

APPENDIX II—*Con.*

Records of Wells and Test Holes in the Brandon Map-Area—*Con.*

	Section	Town-ship	Range	Type of Well[1]	Depth (in feet)	Elevation (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Aquifer	Quality of Water	Use[2]	Greatest number stock watered	Remarks
SW.	7	1	8	Brd.	24	1553	9	14	Shale	Soft	D.S.	40	
SW.	14	1	8	Brd.	30	1387	28	3	Shale	Hard	D.S.	30	
SE.	4	2	8	Dug	61	1572	25	15	Shale	Hard	D.S.	30	
NW.	10	2	8	Dug	32	1578	12	3	Shale	Hard	D.S.	30	
NW.	22	2	8	Brd.	89	1562	15	50	Shale	Soft	D.S.	40	
NW.	35	2	8	Drl.	85	1583	20	12	Shale	Hard	D.S.	100	
SE.	16	3	8	Dug	34	1624	20	16	Shale	Hard	D.		Well for stock 34 feet deep
NE.	27	3	8	Brd.	30	1595	20	12	Shale	Hard	D.S.		Well for stock 27 feet deep
SE.	30	3	8	Brd.	36	1612	24		Shale	Hard	D.		Well at residence of G. Sutherland, Manitou
SE.	3	4	8	Dug	19	1624	10	6	Shale	Soft	D.S.	20	
SE.	15	4	8	Brd.	70	1630	15	6	Shale	Hard	S.	30	House well is 26 feet deep
SE.	26	4	8	Dug	41	1611	10	11	Shale	Hard	D.S.	15	
NE.	30	4	8	Dug	22	1637	10	4	Shale	Soft	D.S.	60	
SE.	7	5	8	Brd.	25	1644	13	15	Shale	Hard	D.S.	50	
SW.	21	5	8	Dug	17	1590		8	Shale	Hard	M.		*See* chemical analyses; well at Altamont
NE.	27	5	8	Dug	34	1500	18	15	Shale	Hard	D.S.	30	
SE.	5	6	8	Dug	28	1529	17	20	Shale	Hard	D.S.	23	
NE.	19	6	8	Dug	28	1512	23		Drift	Hard	D.S.	15	
NE.	31	6	8	Dug	14	1498	11		Gravel	Hard	D.S.	15	
NW.	13	7	8	Dug	12	1046	9		Sand	Hard	D.S.		
SW.	18	7	8	Dug	22	1434	16	16	Shale	Hard	D.S.	45	
SE.	25	7	8	Dug	11	1043	6		Sand	Hard	D.S.		
SE.	32	7	8	Drl.	108	1064	6		Drift	Hard	D.S.	33	Well was a flowing artesian when first drilled
SW.	17	8	8	Dug	35	1051	22		Drift	Salty	S.	10	
NW.	22	8	8	Dug	16	1050	11		Sand	Hard	D.S.	40	
NW.	32	8	8	Brd.	20	1050	15		Drift	Hard	D.S.	25	
SE.	2	9	8	Dug	14	1027	8		Sand	Hard	D.S.	68	
NE.	31	9	8	Dug	11	995	9		Sand	Hard	D.S.	15	
NE.	2	10	8	Dug	12	976	9		Sand	Hard	D.S.	40	
NW.	32	10	8	Drl.	150	958	40		Drift	Salty	S.		
SE.	11	11	8	Dug	12	950	8		Sand	Hard	D.S.	50	
NE.	17	11	8	Dug	14	926	7		Sand	Hard	D.S.	50	
NW.	30	11	8	Dug	18	925	7		Drift	Hard	D.S.	15	
NE.	36	11	8	Brd.	68	856	14		Drift	Hard	D.S.		
SW.	5	12	8	Drl.	50	882	20		Drift	Hard	S.	10	
NE.	6	1	9	Dug	35	1545	25		Gravel	Hard	D.S.	15	
SW.	29	1	9	Brd.	20	1546	15	20	Drift	Hard	D.S.		
NE.	12	2	9	Dug	13	1579	8	6	Shale	Soft	D.S.	24	
NW.	22	2	9	Dug	35	1543	20	33	Shale	Hard	D.S.	20	
SE.	6	3	9	Drl.	187	1564	12		Shale	Soft	D.S.	60	
SE.	13	3	9	Brd.	64	1593	17	35	Shale	Hard	D.S.	25	
NE.	29	3	9	Dug	21	1558	8	8	Shale	Hard	D.S.		
NW.	16	4	9	Brd.	45	1553	10	15	Shale	Hard	D.		Also a stock well 60 feet deep

NW.	32	4	9	Dug	51	1563	35	28	Shale	Hard	D.		Also a stock well 52 feet deep
SE.	16	5	9	Dug	32	1646	17	6	Shale	Hard	D.S.	35	
SW.	18	5	9	Dug	22	1537	16		Sand	Hard	S.	27	
NE.	19	5	9	Dug	17	1562	5		Drift	Hard	D.		*See* chemical analyses; well at Somerset
NW.	24	5	9	Dug	50	1612	30	8	Shale	Hard	D.S.	20	
NW.	16	6	9	Dug	46	1595	40	15	Shale	Hard	D.S.	12	
SW.	30	6	9	Dug	50	1565	20	10	Shale	Hard	D.S.	30	
SE.	3	7	9	Dug	18	1548	15	3	Shale	Hard	D.S.	35	
NW.	25	7	9	Drl.	65	1277	20		Shale	Hard	S.	25	
SW.	32	7	9	Dug	38	1380	15	20	Shale	Hard	D.S.	25	
SE.	4	8	9	Dug	14	1229	6	10	Shale	Hard	D.S.		
SE.	20	8	9	Drl.	30	1122	25		Drift	Hard	D.		Yield approximately 40 gallons an hour
NW.	24	8	9	Dug	39	1104	24		Drift	Hard	S.	30	
NE.	34	8	9	Dug	28	1089	13		Drift	Hard	S.	15	
SE.	13	9	9	Drl.	105	1049	65		Sand	Hard			*See* log
NE.	17	9	9	Dug	58	1043	55		Drift	Hard	D.S.	50	*See* log
SE.	32	9	9	Dug	19	1108	17		Sand	Hard	D.S.		
SE.	8	10	9	Dug	51	1101	41		Sand	Hard	D.S.	48	Water in sand at 48 feet
NE.	25	10	9	Dug	12	963	9		Drift	Hard	D.S.	10	
NE.	13	11	9	Dug	17	931	13		Drift	Hard	D.S.	40	
SE.	21	11	9	Dug	10	951	6		Sand	Hard	D.S.	37	
NE.	31	11	9	Dug	18	939	11		Sand	Hard	D.S.	20	
SW.	11	12	9	Drl.	120	897	60		Drift	Hard	D.S.		
NE.	13	1	10	Drl.	175	1566	20		Shale	Hard	D.S.		Water at 91 and 175 feet
SW.	19	1	10	Brd.	95	1597	35		Shale	Hard	S.	100	
NW.	22	1	10	Brd.	90	1613	40	10	Shale	Hard	D.S.	70	
SW.	2	2	10	Brd.	50	1579	18	10	Shale	Hard	S.	40	Also a well 45 feet deep
SW.	7	2	10	Brd.	48	1574	18	13	Shale	Hard	D.S.		
SW.	31	2	10	Drl.	128	1543	20		Shale	Hard	D.S.	20	*See* chemical analyses
SE.	34	2	10	Drl.	100	1558	20		Drift	Hard	D.		
NW.	5	3	10	Drl.	200	1562	27	20	Shale	Soft	D.S.		
SE.	27	3	10	Brd.	57	1564	12	8	Shale	Hard	D.S.		
SW.	36	4	10	Brd.	35	1573	15		Shale	Hard	D.S.		The water has a high concentration of nitrates
SW.	15	5	10	Brd.	54	1566	37		Shale	Hard	D.S.		
SW.	20	5	10	Dug	30	1572	24	10	Shale	Hard	D.S.		
NW.	31	5	10	Brd.	60	1590	35	10	Shale	Hard	D.S.		*See* chemical analyses
SE.	4	6	10	Brd.	42	1529	20	18	Shale	Hard	S.		
SE.	15	6	10	Dug	22	1516	16	22		Hard	D.S.		The water has a high concentration of nitrates
NE.	22	6	10	Dug	34	1546	24	24	Shale	Hard	S.		Well 34 feet deep for domestic supply
SE.	17	7	10	Dug	25	1476	13	15	Shale	Hard	D.S.	20	
SW.	30	7	10	Dug	36	1348	31	35	Shale	Hard	D.S.	30	
NE.	1	8	10	Drl.	105				Shale	Hard	M.		Flowing artesian well at Treherne. *See* analyses
NW.	3	8	10	Dug	34	1230	17		Drift	Hard	D.S.	15	
NW.	18	8	10	Dug	28	1231	23		Drift	Hard	D.S.	20	
SW.	25	8	10	Dug	36	1166	27		Drift	Hard	S.		
NE.	32	8	10	Dug	38	1221	33		Drift	Hard	D.S.		
SW.	11	9	10	Dug	57	1157	15		Drift	Hard	D.S.	40	
SE.	22	9	10	Drl.	130	1053	90		Drift	Salty	S.		
NE.	35	9	10	Dug	24	1154	22		Sand	Hard	D.S.	10	*See* chemical analyses
SW.	12	10	10	Dug	36	1137	31		Drift	Hard	D.S.	35	
NE.	36	10	10	Dug	11	999	8		Sand	Hard	D.S.	15	
SE.	17	11	10	Dug	11	989	7		Sand	Hard	S.		

[1]Type of well—Drl.—drilled well
Brd.—bored well
Dvn.—driven well or sandpoint

[2]Use—D.—domestic use
S.—stock use
M.—municipal use

APPENDIX II—*Con.*

Records of Wells and Test Holes in the Brandon Map-Area—*Con.*

	Section	Town-ship	Range	Type of Well[1]	Depth (in feet)	Elevation (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Aquifer	Quality of Water	Use[2]	Greatest number stock watered	Remarks
NW.	23	11	10	Drl.	150	972	15		Drift	Hard	S.	100	
NW.	2	1	11	Brd.	42	1563	20	24	Shale	Hard	D.S.		
SW.	18	1	11	Drl.	270	1516	15	150	Shale	Hard	D.S.		Also 2 wells drilled 208 and 318 feet deep
SE.	31	1	11	Brd.	72	1544	37	8	Shale	Hard	D.		Stock well drilled 90 feet deep
NW.	7	2	11	Brd.	48	1523	16		Shale	Hard	D.S.	40	
SW.	20	2	11	Brd.	43	1514	15	26	Shale	Hard			Well was bored in 1951
SE.	4	3	11	Brd.	20	1537	11	8	Shale	Hard	D.S.		Two wells 20 feet deep on farm
NW.	13	3	11	Brd.	45	1550	13		Shale	Hard	D.S.		Water has a high nitrate concentration
SE.	12	4	11	Brd.	88	1531	14	48	Shale	Hard	D.S.		Also a bored well 72 feet deep
NW.	23	4	11	Drl.	96	1497	40		Shale	Soft	D.S.		*See* chemical analyses
SW.	28	4	11	Drl.	100	1516	25	30	Shale	Soft	D.S.		
SW.	31	5	11	Dug	63	1437	58	30	Shale	Hard	D.S.		
NE.	13	6	11	Dug	64	1554	48		Shale	Hard	D.S.	15	
NW.	17	6	11	Drl.	75	1466	55	20	Shale	Hard	D.		Well at convent at Bruxelles
NW.	34	6	11	Dug	25	1404	13	20	Shale	Hard	D.S.	15	
NE.	2	7	11	Dug	35	1352	19		Drift	Hard	D.		Well for stock bored 65 feet deep
NE.	7	7	11	Dug	34	1259	24	10	Shale	Hard	D.S.	15	
NW.	10	7	11	Dug	40	1305	38	23	Shale	Hard	D.		Stock well 32 feet deep
NE.	23	7	11	Dug	18	1268	14	10	Shale	Hard	D.S.	40	
SW.	2	8	11	Dug	25	1231	20		Sand	Hard	D.S.		
NW.	9	8	11	Dug	20	1215	13		Sand	Hard	D.S.	25	
NW.	22	8	11	Dug	34	1219	32		Sand	Hard	D.S.	40	
NE.	30	9	11	Dvn.	30	1212			Sand	Hard	D.S.	45	
NW.	4	10	11	Dvn.	30	1180			Sand	Hard	D.S.	30	
SW.	7	10	11	Dvn.	25	1213			Sand	Soft	D.S.	35	
NW.	12	10	11	Dug	45	1225	30		Sand	Hard	D.S.	25	
SW.	21	10	11	Dug	35	1199	31		Drift	Hard	D.S.	20	
SW.	35	10	11	Dug	90	1187	87		Sand	Hard	D.S.	25	
SE.	4	11	11	Brd.	44	1146	36		Drift	Hard	D.		
NW.	14	11	11	Dug	8	1015	2		Sand	Hard	D.S.		
SE.	31	11	11	Dug	18	1009	6		Sand	Hard	D.S.		
NE.	1	12	11	Dug	12	961	3		Drift	Hard	D.		
NE.	5	12	11	Drl.	63	982	12		Drift	Hard	D.S.		
SW.	10	12	11	Dug	29	977	6		Drift	Hard	D.S.		
NE.	21	1	12	Brd.	30	1539	12	18	Shale	Hard	D.S.		
NW.	33	1	12	Drl.	112	1519	30		Shale	Soft	D.S.		*See* chemical analyses
SE.	5	2	12	Drl.	290	1523		105	Shale	Hard	S.		*See* chemical analyses
SE.	20	2	12	Brd.	35	1487	15	11	Shale	Hard	D.		Well at school, Clearwater
SE.	25	2	12	Drl.	82	1511	20		Shale	Soft	D.		*See* chemical analyses. Well at Crystal City
SE.	25	2	12	Drl.	85	1505	17		Shale	Hard	D.		*See* chemical analyses. Well at Crystal City
SE.	32	2	12	Brd.	42	1509	17	41	Shale	Hard	D.S.		
NE.	10	3	12	Drl.	45	1527	40			Hard	D.		Stock well 45 feet deep
NW.	19	3	12	Brd.	24	1477	20		Sand	Hard	S.		Also a driven well 22 feet deep

SE.	7	4	12	Brd.	41	1473	11	39	Shale	Hard	D.S.		*See* chemical analyses
NW.	26	4	12	Brd.	93	1490	45		Shale	Hard	S.	20	
SE.	30	4	12	Brd.	65	1443	25		Shale	Hard	D.S.	50	
SW.	2	5	12	Drl.	68	1498	24		Shale	Hard	D.		Well at hotel in Mariapolis
SE.	21	5	12	Dug	21	1443	11		Drift	Hard	D.S.		
SE.	12	6	12	Dug	35	1475	18	15	Shale	Hard	D.S.	20	
NW.	25	6	12	Brd.	70	1413	40	13	Shale	Hard	S.	20	
SE.	5	7	12	Dug	39	1262	15	30	Shale	Hard	D.S.	30	
SW.	15	7	12	Dug	22	1242	17	15	Shale	Hard	D.S.		
SW.	28	7	12	Dug	36	1245	33		Sand	Hard	D.S.	25	
NE.	36	7	12	Drl.	135		45	50	Shale	Hard	D.S.	35	
NE.	26	9	12	Dvn.	40	1214			Sand	Hard	D.S.	40	
SW.	8	10	12	Dvn.	35	1216			Sand	Hard	D.S.	150	
SE.	13	10	12	Dvn.	70	1229			Sand	Hard	D.S.	30	
SW.	22	10	12	Dvn.	60	1229			Sand	Hard	D.S.		
NE.	31	10	12	Dvn.	50	1247			Sand	Hard	D.S.	80	
SW.	11	11	12	Dug	40	1140	24		Drift	Hard	D.S.	30	
SE.	24	11	12	Dug	45	1088	40		Drift	Hard	D.S.	30	
NE.	1	1	13	Brd.	65	1608	12	10	Shale	Soft	D.S.		
NW.	9	1	13	Drl.	140	1549	20	20	Shale	Soft	D.S.	30	
SW.	20	1	13	Dug	28	1539	16	27	Shale	Hard	D.S.		
SE.	36	1	13	Drl.	90	1547	40		Shale	Hard	D.S.		*See* chemical analyses
NE.	6	2	13	Drl.	61	1532	10	28	Shale	Hard	D.		*See* chemical analyses; *See* log
NE.	22	2	13	Drl.	80	1518	18	22	Shale	Soft	D.		Yields not more than 15 to 20 gallons a day
SW.	2	3	13	Drl.	285	1498	57		Shale	Hard	D.S.		
NE.	20	3	13	Dvn.	20	1485			Sand	Hard	D.S.		
SW.	33	3	13	Dvn.	18	1501			Sand	Hard	D.S.		Driven well at Glenora
SE.	10	4	13	Dug	28	1451	13		Drift	Hard	D.S.		Water in a lens of gravel at 27 feet
SE.	21	4	13	Brd.	20	1441	10		Gravel	Hard	D.S.		
SE.	35	4	13	Dug	40	1427	20	40		Hard	D.S.	30	
NE.	2	5	13	Brd.	22	1410	18	20	Shale	Hard	D.		Well at store at Greenway
NE.	1	6	13	Dug	38	1371	34	20	Shale	Hard	D.S.	20	
SW.	10	6	13	Dug	40	1326	33	20	Shale	Hard	D.S.		
SW.	18	6	13	Brd.	61	1319	22		Shale	Hard	S.		
SE.	30	6	13	Dug	30	1240	27		Gravel	Hard	D.S.		
SW.	3	7	13	Dug	15	1238	8		Drift	Hard	S.	35	
NW.	8	7	13	Dvn.	40	1245			Sand	Hard	D.S.		Fitted with a 60 gauze screen
NW.	11	7	13	Dvn.	28	1231			Sand	Hard	D.S.		Fitted with a 80 gauze screen
SE.	35	7	13	Dvn.	13	1184			Sand	Hard	D.S.		
SW.	27	9	13	Dvn.	40	1223			Sand	Hard	D.S.	50	
NE.	5	10	13	Dvn.	60	1253			Sand	Soft	D.S.	75	
SE.	14	10	13	Dvn.	70	1245			Sand	Hard	D.S.	60	Fitted with a 90 gauze screen
SW.	33	10	13	Dvn.	40	1250			Sand	Hard	D.		*See* chemical analyses
SE.	26	11	13	Dvn.	106				Sand	Hard	D.S.		
NW.	30	11	13	Dvn.	83				Sand	Hard	D.S.		
SE.	1	12	13	Dug	40		30		Drift	Hard	D.S.	25	
NE.	2	1	14	Brd.	79	1541	13	75	Shale	Soft	D.S.	56	
SE.	6	1	14	Drl.	226	1530	19		Drift	Hard	D.S.		Water in gravel at 226 feet
SE.	7	1	14	Drl.	206	1522	6		Drift	Salty	S.	50	
SE.	17	1	14	Drl.	317	1516	5		Drift	Hard	D.S.	30	
SE.	18	1	14	Drl.	179	1541	6		Sand	Hard	D.S.	200	
NW.	20	1	14	Drl.	140	1517	6		Drift	Hard	D.S.		*See* chemical analyses

[1]Type of well—Drl.—drilled well
Brd.—bored well
Dvn.—driven well or sandpoint

[2]Use—D.—domestic use
S.—stock use
M.—municipal use

APPENDIX II—*Con.*

Records of Wells and Test Holes in the Brandon Map-Area—*Con.*

	Section	Township	Range	Type of Well[1]	Depth (in feet)	Elevation (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Aquifer	Quality of Water	Use[2]	Greatest number stock watered	Remarks
SW.	1	2	14	Brd.	30	1522	5	20	Shale	Soft	D.S.		
NW.	6	2	14	Dug	27	1531	21		Gravel	Hard	M.		*See* chemical analyses; well at Cartwright
NW.	14	2	14	Brd.	67	1551	19	67		Hard	D.S.	50	Water at contact of drift and bedrock
NE.	18	2	14	Drl.	128	1528	18		Drift	Hard	D.S.	100	
SW.	25	2	14	Brd.	50	1543	35	40	Shale	Hard	D.S.	50	
SE.	3	3	14	Drl.	175	1515	50	55	Shale	Soft	D.S.	45	
SE.	15	3	14	Drl.	190	1499	50	100	Shale	Soft	D.S.	100	
SW.	19	3	14	Dug	22	1378	12	12	Shale	Hard	D.		*See* chemical analyses; well at Neelin store
NE.	32	3	14	Dug	37	1495	21		Drift	Hard	D.		Temperature of water 44° F.
SW.	6	4	14	Drl.	201	1532	37	86	Shale	Salty	D.S.	150	*See* log
NW.	15	4	14	Drl.	120	1454	20	100	Shale	Salty	D.S.	100	
SW.	30	4	14	Dug	27	1468	9	10	Shale	Soft	D.S.	20	
SE.	5	5	14	Brd.	61	1421	10	60	Shale	Soft	S.	50	
NE.	12	5	14	Dug	28	1410	9	13	Shale	Hard	D.S.	50	
NE.	24	5	14	Brd.	45	1423	30	40	Shale	Hard	D.S.	40	
SE.	32	5	14	Brd.	60	1407	24		Drift	Hard	D.S.	20	
SE.	3	6	14	Dug	45	1417	23	20	Shale	Hard	D.S.	40	
SE.	19	6	14	Brd.	57	1282	9	10	Shale	Hard	S.	40	
NW.	30	6	14	Dug	24	1243	21		Drift	Hard	D.S.	100	
NE.	33	6	14	Dvn.	30	1240			Sand	Hard	D.S.	100	
NE.	7	7	14	Dvn.	21	1222			Sand	Hard	D.S.	100	
NE	10	7	14	Dvn.	28	1230			Sand	Hard	D.		*See* chemical analyses; well at Glenboro
SW.	36	7	14	Dvn.	32	1208			Sand	Hard	D.S.	50	
NW.	36	8	14	Dvn.	27				Sand	Hard	D.S.		
SE.	31	9	14	Dvn.	20				Sand	Hard	D.S.		
NE.	12	10	14	Dvn.	40				Sand	Hard	D.S.		
NW.	20	10	14	Dvn.	35	1250			Sand	Hard	D.		Well at Carberry air station: 100,000 gals/day
NW.	20	10	14	Drl.	64	1250			Sand	Hard			*See* log; yield 105 gals/min; Carberry air station
NE.	30	10	14	Dvn.	40				Sand	Hard	D.		*See* chemical analyses; well at Carberry hotel
NW.	18	11	14	Dvn.	40				Sand	Hard	D.S.		
SW.	27	11	14	Dvn.	50				Sand	Hard	D.S.		
NW.	32	11	14	Drl.	115	1255	25		Sand	Hard	D.		*See* log. Well at airdrome
NE.	3	12	14	Dvn.	48				Sand	Hard	D.S.		
SE.	2	1	15	Dug	25	1552	9		Drift	Hard	D.S.	20	
SW.	13	1	15	Drl.	240	1546	20		Drift	Salty	D.S.		Water in sand at 240 feet
NW.	20	1	15	Drl.	40	1563			Drift	Soft	D.S.		Well flows at rate of 120 gallons an hour. *See* log
SE.	24	1	15	Drl.	135	1538	6		Drift	Hard	D.S.		
SW.	29	1	15	Drl.	60	1573			Drift	Hard	D.S.	60	
SE.	36	1	15	Brd.	69	1538	17		Drift	Hard	D.S.	100	Water in sand at 51 and 69 feet
SW.	16	2	15	Dug	42	1544	35		Drift	Hard	D.S.	60	Water in gravel at 40 feet
SW.	25	2	15	Brd.	60	1529	30		Drift	Hard	D.S.	50	
NW.	2	3	15	Brd.	36	1526	15		Drift	Hard	D.		
NW.	9	3	15	Dug	24	1529	9		Drift	Hard	D.S.	50	

SW.	26	3	15	Dug	40	1523	32	40		Soft	D.S.	12	
SW.	34	3	15	Brd.	80	1513	30	60	Shale	Hard	D.S	50	
NW.	1	4	15	Brd.	110	1544	40	70	Shale	Hard	D.S.	30	
NE.	14	4	15	Dug	39	1480	3		Drift	Hard	S.	20	Too salty for domestic use
NE.	27	4	15	Brd.	56	1494	27		Drift	Hard	D.S.	50	
NE.	36	4	15	Dug	24	1477	16	18	Shale	Hard	S.	35	
NE.	3	5	15	Brd.	62	1474	20	20	Shale	Hard	D.S.	45	
NW.	15	5	15	Dug	54	1480	19		Shale	Hard	S.	20	
NE.	20	5	15	Brd.	50	1528			Drift	Hard	D.		*See* chemical analyses
NW.	30	5	15	Dug	35	1489	15		Drift	Hard	D.S.	30	
NE.	9	6	15	Brd.	65	1370	15	20	Shale	Hard	D.S.	100	
SE.	28	6	15	Dug	18	1278	12	6	Shale	Soft	D.S.	40	
NW.	2	7	15	Dvn.	20	1227			Sand	Hard	D.S.	30	
SW.	5	7	15	Brd.	70	1267	8	4	Shale	Hard	S.	35	
NE.	14	7	15	Dvn.	18	1211			Sand	Hard	D.S.	100	
NW.	17	7	15	Dvn.	42	1217	34		Sand	Hard	D.S.	20	
SE.	35	7	15	Dvn.	40	1164	22		Sand	Hard	D.		Also a well dug 35 feet deep
NE.	14	10	15	Dvn.	25	1247			Sand	Hard	D.S.		
SW.	36	10	15	Dvn.	28	1267			Sand	Hard	D.S.	20	
NE.	9	11	15	Dvn.	25				Sand	Hard	D.S.		
SW.	19	11	15	Dvn.	25	1275			Sand	Hard	D.S.		
NW.	33	11	15	Dvn.	25				Sand	Hard	D.S.		
SW.	12	12	15	Dvn.	27				Sand	Hard	D.S.		
NW.	5	1	16	Brd.	48	1796	27		Drift	Hard	D.S.	10	Water in lens of gravel at 40 feet
SW.	10	1	16	Drl.	62	1733			Gravel	Hard	D.S.		Flows at rate of 540 gallons an hour. Temperature 42° F.
SE.	20	1	16	Drl.	90	1722			Gravel	Hard	D.S.		Flows at rate of 600 gallons an hour
NW.	24	1	16	Dug	33	1628	22		Drift	Hard	D.S.	40	
NE.	33	1	16	Dug	30	1656	22		Gravel	Soft	D.S.	50	
NE.	9	2	16	Dug	54	1610	47		Gravel	Hard	D.S.	10	
NW.	20	2	16	Dug	42	1606	37		Drift	Hard	D.S.	25	
SE.	24	2	16	Dug	22	1552	14		Drift	Hard	D.		*See* chemical analyses; well at Holmfield
SW.	14	3	16	Dug	18	1541	4		Drift	Hard	D.S.	35	
NW.	18	3	16	Dug	19	1564	9		Drift	Hard	D.S.	50	
NE.	21	3	16	Dug	35	1537	18		Drift	Hard	S.	40	
NW.	1	4	16	Dug	31	1507	10		Drift	Hard	S.	25	
NW.	16	4	16	Brd.	33	1514	3		Drift	Soft	D.S.	10	
SE.	31	4	16	Drl.	70	1522	40	60	Shale	Hard	D.S.	30	
SE.	35	4	16	Dug	18	1536	6	18		Hard	D.S.	75	Water at the contact of drift and bedrock
NE.	2	5	16	Brd.	22	1556	15		Drift	Hard	D.S.	30	
NW.	20	5	16	Dug	18	1489	5		Gravel	Hard	D.		Yields 850 gallons a day for sanatorium
NW.	22	5	16	Dug	21	1515	16		Drift	Soft	D.S.	12	
NW.	12	6	16	Brd.	30	1433	9	30		Hard	S.	40	Water at the contact of drift and bedrock
NE.	16	6	16	Brd.	47	1456	38	37	Shale	Hard	D.S.	50	
NW.	24	6	16	Brd.	33	1384	15	15	Shale	Hard	S.	30	
SE.	32	6	16	Brd.	61	1399	20	23	Shale	Hard	S.	40	
SE.	3	7	16	Brd.	51	1348	15	20	Shale	Hard	S.	60	
SE.	14	7	16	Dvn.	51	1238	45		Sand	Hard	D.S.	25	
SE.	16	7	16	Drl.	78	1262	14		Shale	Hard	D.S.	45	
SE.	30	7	16	Dug	24	1231	20		Drift	Hard	D.S.	50	
SW.	19	8	16	Dug	14	1133	6		Sand	Hard	D.		
NW.	32	8	16	Dvn.	21	1165	18		Sand	Hard	D.S.		

[1]Type of well—Drl.—drilled well
Brd.—bored well
Dvn.—driven well or sandpoint

[2]Use—D.—domestic use
S.—stock use
M.—municipal use

APPENDIX II—*Con.*

Records of Wells and Test Holes in the Brandon Map-Area—*Con.*

	Section	Town-ship	Range	Type of Well[1]	Depth (in feet)	Elevation (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Aquifer	Quality of Water	Use[2]	Greatest number stock watered	Remarks
NW.	35	10	16	Dvn.	16	1246			Sand	Hard	D.S.		
NW.	7	11	16	Drl.	98	1255			Sand	Hard			*See* logs of test holes at Douglas airport
NE.	30	11	16	Dvn.	32				Sand	Hard	D.S.		
SW.	5	12	16	Dvn.	18				Sand	Hard	D.S.		
SW.	7	1	17	Brd.	48	1860	13		Drift	Hard	D.S.	100	
NE.	21	1	17	Dug	54	1814	5		Drift	Hard	D.S.	70	
NE.	25	1	17	Dug	45	1747	33		Drift	Hard	D.S.	40	
SE.	9	2	17	Drl	100	1757	15		Drift	Hard	S.	50	
NE.	14	2	17	Drl.	272	1676	22	90	Shale	Soft	S.	90	
NW.	17	2	17	Drl.	92	1728			Sandstone	Hard	S.	50	Flowing artesian well
NE.	26	2	17	Dug	44	1627	32		Drift	Hard	D.S.	50	Lens of gravel at 44 feet
NW.	31	2	17	Brd.	54	1658	28		Drift	Hard	D.S.	50	
NE.	2	3	17	Dug	39	1622	28		Drift	Hard	D.		*See* chemical analyses; temperature of water 46° F.
NE.	10	3	17	Dug	36	1614	33		Drift	Soft	D.S.	20	
SE.	1	4	17	Dug	40	1580	34	30	Shale	Hard	D.S.	70	
NW.	13	4	17	Drl.	200	1552	20	60	Shale	Hard	S.	35	Also a drilled well 158 feet deep
NW.	26	4	17	Brd.	51	1538	15		Drift	Hard	D.S.	50	
SE.	33	4	17	Brd.	90	1519	70		Drift	Hard	D.S.		Water in a lens of gravel at 90 feet
SW.	9	5	17	Drl.	108	1516	13	72	Shale	Hard	S.	40	
SE.	13	5	17	Brd.	50	1495	22	20	Shale	Hard	D.S.	15	
NE.	20	5	17	Brd.	63	1501	6		Drift	Hard	D.S.		Temperature of water 44° F.
NE.	33	5	17	Dug	18	1349	8	3	Shale	Hard	S.	65	
NE.	8	6	17	Dug	42	1498	16		Drift	Hard	D.S.		
NW.	14	6	17	Dug	34	1490	27		Drift	Hard	D.S.	25	
NW.	18	6	17	Drl.	200	1477	14	90	Shale	Salty	D.S.	100	
NE.	29	6	17	Dug	21	1435	12		Sand	Hard	D.S.	15	
SW.	1	7	17	Drl.	80	1294	15	40	Shale	Hard	D.S.	15	
NW.	5	7	17	Drl.	103	1334	21		Shale	Hard	S.	25	
NW.	14	7	17	Drl.	90	1285	41	45	Shale	Hard	S.	40	
SW.	33	7	17	Brd.	48	1298	33		Drift	Hard	S.	40	
SW.	1	8	17	Dug	38	1232	16		Drift	Hard	S.	70	
NE.	7	8	17	Drl.	104	1286	9		Drift	Hard	D.S.	40	Water at 102 feet in gravel
SW.	14	8	17	Dug	21	1237	5		Drift	Hard	S.	40	
NW.	28	8	17	Dug	27	1202	9		Drift	Hard	D.S.	12	
NW.	16	9	17	Dug	22	1181	18		Gravel	Hard	D.S.	100	
NW.	20	10	17	Dvn.	30	1233	15		Sand	Hard	D.S.	65	
NW.	24	10	17	Dvn.	10	1215	6		Sand	Hard	D.S.	100	
SW.	34	10	17	Dvn.	19	1229	12		Sand	Hard	D.S.	100	
NE.	6	11	17	Dug	65		50		Drift	Hard	D.S.	20	
SE.	20	11	17	Brd.	78		25		Drift	Hard	S.		
SW.	34	11	17	Dug	36	1330	30		Sand	Hard	D.S.	90	
NE.	10	12	17	Brd.	40	1358	25		Drift	Hard	S.		Also a well dug 20 feet deep
NW.	7	1	18	Brd.	72	1996	6		Drift	Hard	D.		

NW.	16	1	18	Brd.	40	1916	18	31	Shale	Soft	D.S.	60	
NW.	25	1	18	Dug	23	1839	9		Drift	Hard	D.S.	30	
NW.	1	2	18	Drl.	120	1821	20	90	Sandstone	Hard	D.S.	20	*See* chemical analyses
SW.	8	2	18	Dug	42	1804	25		Drift	Hard	D.S.	40	
NW.	18	2	18	Drl.	100	1783	21	90	Sandstone	Soft	D.		
NW.	32	2	18	Dug	24	1735	15		Drift	Hard	D.S.	50	
NW.	1	3	18	Dug	25	1641	16		Drift	Hard	S.	30	
NW.	14	3	18	Dug	22	1636	15		Drift	Hard	S.	40	
NE.	18	3	18	Brd.	52	1668	22		Drift	Hard	D.		Also a well 33 feet deep
NW.	20	3	18	Drl.	410	1651	30	120	Shale	Hard	D.S.	100	*See* chemical analyses
NE.	31	3	18	Drl.	380	1662	30	120	Shale	Soft	D.S.	60	
SE.	36	3	18	Drl.	300	1641	20		Shale	Hard	D.S.	60	*See* chemical analyses
SE.	4	4	18	Drl.	268	1652	20	90	Shale	Salty	S.	50	
NW.	9	4	18	Drl.	209	1640	12	100	Shale	Soft	D.S.	30	
NW.	26	4	18	Brd.	125	1593	90	90	Shale	Hard	S.	15	
SE.	29	4	18	Drl.	175	1595	12	70	Shale	Hard	D.S.	25	
SW.	6	5	18	Drl.	180	1631	30	60	Shale	Soft	D.		
NW.	9	5	18	Drl.	300	1563	20	90	Shale	Soft	D.S.	20	
SW.	21	5	18	Brd.	55	1549	40		Drift	Hard	D.		*See* chemical analyses; well at Margaret
NW.	26	5	18	Brd.	85	1547	75		Drift	Hard	D.S.	5	
NE.	30	5	18	Drl.	180	1533	22	30	Shale	Hard	D.		
NW.	14	6	18	Brd.	60	1621	49		Drift	Hard	D.S.	30	
NE.	30	6	18	Drl.	275	1515	30	100	Shale	Salty	D.S.	30	
NE.	7	7	18	Dug	32	1462	11		Drift	Hard	D.S.	15	
NW.	14	7	18	Dug	21	1388	13		Drift	Hard	D.S.	15	
NE.	28	7	18	Dug	37	1410	23		Drift	Hard	D.		Well at Nesbitt
NE.	9	8	18	Dug	35	1462	32		Drift	Hard	D.S.	60	
SE.	14	8	18	Drl.	75	1342	30		Drift	Hard	D.S.	50	
NW.	28	8	18	Dug	41	1410	13		Drift	Hard	D.		*See* chemical analyses
SW.	19	9	18	Dug	17	1266	12		Drift	Hard	D.S.	70	
NE.	29	9	18	Drl.	45	1259	25		Drift	Hard	D.S.	60	
NE.	5	10	18	Dug	12	1272	7		Sand	Hard	D.S.		
SW.	18	10	18	Drl.	48	1274	45		Sand	Hard	D.S.	20	
SE.	25	10	18	Dug	18	1240	12		Drift	Hard	D.S.	15	
SE.	32	10	18	Dug	20	1291	17		Drift	Hard	D.S.		
SW.	35	10	18	Drl.	14	1235			Sand	Hard	M.		Well at Chater airport; *see* logs of test holes
SE.	3	11	18	Drl.	94	1302	25		Gravel	Hard	D.S.		Also a drilled well 110 feet deep
NE.	6	11	18	Drl.	75	1320	50		Gravel	Hard	D.S.		
SW.	13	11	18	Drl.	75	1306	15		Sand	Hard	D.S.		Also a drilled well 80 feet deep
NW.	20	11	18	Brd.	40	1359			Sand	Hard	D.S.		Flowing artesian well
SW.	30	11	18	Brd.	65	1395	20		Drift	Hard	D.S.		
SE.	35	11	18	Brd.	42	1376	20		Drift	Hard	D.S.		
NE.	3	12	18	Drl.	50	1466	25		Drift	Hard	D.S.		
SW.	9	12	18	Brd.	73	1488	23		Drift	Hard	D.S.		
SW.	21	1	19	Brd.	42	2155	6		Drift	Hard	D.		
SE.	25	1	19	Dug	14	1923			Sand	Hard	D.S.		Flowing artesian well: *see* chemical analyses
NW.	1	2	19	Brd.	125	1863	45	96		Hard	D.S.	100	Water in the Turtle Mountain formation
SE.	7	2	19	Brd.	40	1925	21		Drift	Hard	D.S.	40	
NW.	17	2	19	Brd.	40	1821	20	20	Shale	Hard	D.S.		*See* chemical analyses
SE.	35	2	19	Dug	47	1800	30		Drift	Hard	D.S.	20	
SW.	10	3	19	Dug	50	1753	25		Drift	Soft	D.S.	50	
SE.	11	3	19	Brd.	70	1723	50	60	Sandstone	Hard	S.	60	

[1]Type of well—Drl.—drilled well
Brd.—bored well
Dvn.—driven well or sandpoint

[2]Use—D.—domestic use
S.—stock use
M.—municipal use

APPENDIX II—*Conc.*

Records of Wells and Test Holes in the Brandon Map-Area—*Conc.*

	Section	Town-ship	Range	Type of Well[1]	Depth (in feet)	Elevation (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Aquifer	Quality of Water	Use[2]	Greatest number stock watered	Remarks
NW.	16	3	19	Brd.	45	1669	20		Drift	Hard	D.S.	30	
NW.	24	3	19	Drl.	299	1644	10	80	Shale	Soft	D.S.	50	
NE.	32	3	19	Drl.	350	1634	25	100	Shale	Hard	D.S.	40	*See* chemical analyses
SE.	8	4	19	Drl.	280	1639	30	100	Shale	Salty	D.S.	30	
NE.	13	4	19	Drl.	175	1640	40	100	Shale	Hard	D.S.	35	
SE.	21	4	19	Drl.	195	1666	32	80	Shale	Hard	D.S.	50	
NW.	33	4	19	Drl.	190	1605	25	90	Shale	Hard	S.	50	
NE.	12	5	19	Drl.	140	1590	30	80	Shale	Hard	D.S.	40	
SW.	16	5	19	Drl.	190	1608	20	60	Shale	Hard	D.S.	50	
SE.	35	5	19	Drl.	175	1647	15	80	Shale	Hard	D.S.	35	
SW.	4	6	19	Drl.	212	1543	25	90	Shale	Hard	D.S.	50	
NE.	10	6	19	Dug	33	1461	27	33	Shale	Hard	D.S.	40	
SE.	25	6	19	Dug	30	1530	23		Drift	Hard	D.S.	35	
NW.	10	7	19	Brd.	100	1569	30		Drift	Hard	D.S.		
SE.	23	7	19	Dug	23	1466	12		Drift	Hard	D.		Also a stock well 45 feet deep
SE.	16	8	19	Dug	26	1516	22		Drift	Hard	D.		
NW.	26	8	19	Brd.	80	1482	30		Drift	Hard	D.S.	100	
SW.	34	8	19	Dug	40	1407			Drift	Hard	D.S.		Flowing artesian well
NE.	33	9	19	Drl.	100	1318	30		Drift	Hard	S.		
NE.	9	10	19	Dug	22	1313	18		Drift	Hard	D.S.		Three shallow dug wells on farm
NW.	12	10	19	Dug	16	1348	8		Drift	Hard	D.S.	75	
SE.	2	11	19	Drl.	46	1331	21		Drift	Hard	D.S.	65	
SE.	10	11	19	Drl.	58	1350	15			Hard	D.S.		Water in a layer of boulders at 50 feet
NW.	23	11	19	Dug	37	1366			Sand	Hard	D.S.		Flowing artesian well; *see* log
NW.	24	11	19	Dug	47	1368			Sand	Hard	D.S.		Flowing artesian well
SW.	36	11	19	Drl.	54	1438	30		Drift	Hard	D.S.		*See* chemical analyses
SE.	1	12	19	Drl.	140				Sand				Test hole drilled by California Standard Co.; encountered a flow of fresh water in sand at 72 feet: rate of flow 93 gallons a minute; hole plugged

[1]Type of well—Drl.—drilled well
Brd.—bored well
Dvn.—driven well or sandpoint

[2]Use—D.—domestic use
S.—stock use
M.—municipal use

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