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A HYDROGEOLOGICAL REPORT OF THE HOBBEMA INDIAN RESERVE, ALBERTA CANADA

by: E. G. Le Breton

February 1970

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A HYDROGEOLOGICAL REPORT OF THE HOBBEMA INDIAN RESERVE, ALBERTA, CANADA

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by

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Research Council of Alberta
Edmonton, Alberta

February 1970

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A HYDROGEOLOGICAL REPORT OF THE HOBBEMA INDIAN RESERVE, ALBERTA, CANADA

ABSTRACT

The Hobbema Reserve covers an area of about 115 square miles. The area lies within the Battle River drainage basin and the river itself forms part of the boundaries of the reserve.

The bedrock formations underlying the area and relevant to this report are the Horseshoe Canyon, Whitemud and Battle Formations of the Edmonton Group, and the Paskapoo Formation. The upper part of the Edmonton Group in the area is divisible into sandstone, shale and coal beds, and the Paskapoo comprises a series of shale, carbonaceous shale, coal, siltstone and sandstone beds. The sandstone beds of the Edmonton Group, ranging up to 40 feet thick, are the main source of groundwater supply with well yields possibly as high as 100 imperial gallons per minute. Well yields from coal seams and siltstone beds in the Paskapoo are estimated to be commonly less than 5 imperial gallons per minute.

Unconsolidated surficial deposits cover the bedrock. These deposits include preglacial(?) gravel 20 feet thick capping the bedrock for 15 square miles in the southeast part of the reserve. These gravels do yield water, but the capacity of water wells completed within them is unknown. Deposits of till occur above the gravel, with till and surficial sands being observed across much of the reserve. A major buried valley of the preglacial Red Deer River cuts across the area from the southwest to northeast.

The water is chemically mainly of the sodium bicarbonate type, with total dissolved solids commonly ranging from 700 to 1,000 parts per million. In the north

part of the area, sodium chloride, though commonly a minor constituent is frequently present in significant proportions up to 40 per cent of the total ions. Groundwater supplies are commonly soft and suitable for human consumption.

INTRODUCTION

The purpose of this report is to evaluate groundwater yield and quality in the area of the Hobbema Reserve with a view to future groundwater exploration for light industrial water supplies.

Study of the geology and groundwater development near Hobbema has been based almost entirely on water-well drillers' records supplied to the Canada Department of Indian Affairs. In the interpretation of the geology frequent use was made of the report by Allan and Sanderson (1945). It was also supplemented, in the latest stages of the work, by examination of structure test-hole data supplied by the Alberta Oil and Gas Conservation Board, to verify the accuracy of the interpretation.

Acknowledgments

The author is indebted to Mr. J. Grainge, Regional Engineer, Public Health Engineering Division, Department of National Health and Welfare, Edmonton, Alberta, for his interest in and concern over problems associated with groundwater development near Hobbema, for his direct assistance in obtaining chemical analyses of groundwaters, and for inspiring this study to be carried out. Mr. H. McBride, formerly supervisor of construction at the Hobbema Reserve, aided in the location of well records and Mr. M. Mattern, Assistant Superintendent, Hobbema Reserve, continued serious interest in groundwater development following Mr. McBride's transfer to Calgary. The general high quality of water-well records made possible a detailed and moderately accurate study of the bedrock and surficial geology and of groundwater

occurrence and availability.

Those responsible for such high quality work are the drillers who have worked in the area, especially Warnke Bros. and the late Mr. George Henderson; also Elk Point Drilling Co., Edmonton, who supplied electric logs, Forrester Drilling, Red Deer, who supplied sample cuttings, and R. Flinn, Lacombe. R. Green and M. A. Carrigy supplied information on the geology of the area and to the northwest of the reserve.

GEOGRAPHY

Location and extent of the area

The Hobbema area lies between parallels of latitude 52°42' and 52°56' north and meridians of longitude 113°13' and 113°38' west. On the basis of the Alberta land survey system it falls within townships 43 to 45, ranges 23 to 25, west of the fourth meridian, and covers about 115 square miles. The location of the reserve, approximately 50 miles south of Edmonton (a city of 400,000), 10 miles south of the city of Wetaskiwin (population 6,000) and 11 miles north of Ponoka (population 4,500), is quite suitable for commercial development. The Hobbema Reserve is shared by the Sampson, Ermineskin, Bull and Montana peoples, each with land areas of about 50, 40, 12, and 12 square miles, respectively.

Topography and drainage

The area can be divided into two distinct parts. That part to the northwest of the village of Hobbema falls within the Bear Hills, which rise to a height of 2,850 feet, 200 feet above the surrounding land surface. The bedrock strata of the hills are capped by about 40 feet of sandstone overlain by about 10 feet of glacial drift. The greater part of the study area, mainly southeast of the village of Hobbema, is between elevations of 2,550 to 2,650 feet above sea level.

The Battle River is the only important stream and follows an irregular course in the area. It approaches from Ponoka in the south, cuts east through the settlement or forms the south boundary, turns north to form part of the east boundary of the reserve, and then east away from the area.

Climate

The climate of the area is humid continental, cool summer, no dry season, based on Köppen's classification (Canada. Department of Mines and Technical Surveys, 1957). The temperature ranges between extremes of 99°F (37.2°C) in the summer and -53°F (-29.4°C) in the winter, and the average annual precipitation is about 18.3 inches. Most of the precipitation falls as rain during the months of April to September, the remainder falling mainly as snow in the months from October to March.

GEOLOGY

General statement

A brief study of the geology is very important to the understanding of the present groundwater situation and in considering future development of groundwater resources. In the Bear Hills part of the area, groundwater is obtained from siltstones, sandstones, and coal seams associated with the lower and upper Ardley coal zones overlying the Battle Formation, whereas elsewhere in the reserve, due to the absence of the Ardley zones, groundwater is developed mainly from sandstone and siltstone beds below the Battle Formation.

Bedrock geology

The near-surface bedrock formations of relevance to this report are the Horseshoe Canyon, Whitemud and Battle Formations of the Edmonton Group and the Paskapoo Formation of late Cretaceous and Tertiary age. The areal distribution of these formations is shown in figure 1.

A table of formations (Table 1) is included to compare the previous subdivision of the Paskapoo and the Edmonton rock units with that proposed by M. A. Carrigy and by E. J. W. Irish. The subcrop of the Battle Formation top has been drawn (Fig. 1) combining the structure contour information on figure 1 with the bedrock surface data (Fig. 3). The Paskapoo Formation subcrops to the west of this marker bed and the Edmonton Group subcrops to the east.

Edmonton Group

"The composition of the strata in this formation varies greatly, both laterally and vertically. The Edmonton Formation in this map-area consists of fine-grained sandstones, highly calcareous sandstones, sandy shales, bentonitic sandstone and shales, bentonite, ironstone bands, carbonaceous shales and coal. Bentonite is the prevailing constituent throughout the whole series of beds." (p. 24). "The whole formation is composed of a few rock types occurring repeatedly as relatively thin strata. Poorly sorted sandstones and siltstones, cemented for the greater part with bentonitic clay, make up the bulk of the rocks of the formation. The common association is interfingering beds of whitish, relatively coarse sandstone and grey, fine-grained silt, each with from 8 to 35 per cent of colloidal clay which acts as a binder." (Allan and Sanderson, 1945, p. 64).

Period	Allan & Sanderson		M.A.Carrigy E.J.W. Irish	Local geology (Le Breton)		Thickness (feet)	Cumulative thickness in feet
TERTIARY	Paskapoo Formation	coarse sandstone disconformity .			Sandstone	40	40
		– – – – – – – – – –	– – – – ?–		– –?– – – – – – – –?– – – – – – – – – –		–
CRETACEOUS	Upper Edmonton Member 290 feet	Freshwater, bentonitic beds	Scollard	Paskapoo Formation	Shale	65	105
					Carbonaceous shale & coal	40	145
		Ardley seam No. 14			Shale & sandstone	80	225
		Grey sandstones	Member		Carbonaceous shale & coal	40	265
		Nevis seam No. 13			Shale	80	345
		Grey & pale buff sand & silt stones					
	Middle Edmonton Member 300 feet	Kneehills Tuff horizon		Edmonton Group			0
		Mauve-colored shale	Battle Fm.		Purple-colored shale	25–40	40
		White sandstone	Whitemud Fm.		White sandstone	40	80
					Shale	15	95
		Thompson seam No. 12			Thompson seam	5	100
		Grey sands & shales	Horseshoe Canyon Formation		Shale sandstone & siltstone	60	160
					Sandstone	10	170
		Carbon seam No. 11			Carbon seam ; zone 3	5	175
					Sandstone	5	180
		Dull grey sandstone			Shale	30	210
					Sandstone, some shale: zone 2	40	250
					Shale	30	280
					Sandstone & shale: zone 1	40	320
					Shale	25	345
					Sandstone	10	355

Table 1. Table of formations

Battle Formation

"In 1924 Sanderson discovered a tuff bed in the Edmonton Formation on the Red Deer River east of the town of Ardley." (Allan and Sanderson, 1945, p. 29). He also mapped it near Morrin. This volcanic ash bed is also found in the Wintering Hills and so occurs 75 miles from Ardley. To this ash bed was given the name Kneehills Tuff. That tuff seldom exceeds 8 inches in thickness. It is a pale grey rock, very fine grained, composed mainly of silica which forms 85% of the rock (Allan and Sanderson, 1945, p. 69). The Kneehills Tuff occurs within a bed of purple-colored shale (mauve-colored in the type area) 25 to 40 feet thick, which in turn is underlain by a white sandstone bed 8 to 50 feet thick. The name Battle Formation was extended by Irish and Havard (1968) to include this purple-colored shale, which had been shown by Ower (1960) and Elliot (1960) to be a widespread reliable marker horizon.

Paskapoo Formation

"The Paskapoo consists chiefly of soft, grey, clayey sandstones, soft shales and clays slightly indurated. In the lower parts of the formation there is a coarse, more or less uncemented sandstone weathering to buff color and of uniform character over a large area." (Allan and Sanderson, 1945, p. 27).

Local geology

The local geology is illustrated by the cross section A-A' (Fig. 2) and the structure contour map of the Battle Formation (Fig. 1). The dip of the strata ranges from about 15 to 20 feet per mile towards the southwest. The cross section shows three siltstone-sandstone zones occurring below the Carbon coal seam. The easternmost and deepest zone (not numbered) is seldom penetrated during drilling in the reserve. Zone 1, ranging from 30 to 40 feet thick, is divisible into an upper and a lower interval; zone 2, of the same thickness, is locally wholly sandstone but it commonly is sandy only in the upper or lower part. The lowest marker bed used in the area is the Carbon coal seam (Fig. 2). The Carbon coal seam is replaced by or is locally immediately underlain or overlain by sandstone, constituting zone 3. Zones 1, 2 and 3 are each separated by 25 to 40 feet of shale. The Thompson coal seam, a good marker bed, is 70 to 80 feet higher in the section than the Carbon seam. The interval between the Carbon and Thompson coal seams is mainly shale; a sandstone bed occurs locally 10 to 15 feet below the Thompson seam. Above the Thompson seam is a bed of shale about 15 feet thick, which in turn is overlain by up to 40 feet of whitish sandstone or sandy shale (the Whitemud Formation). The overlying purple-colored shale, also up to 40 feet thick, constitutes the Battle Formation. Both units are mappable regionally to the northwest and southward to the Cypress Hills. The Kneehills Tuff, a thin (8 inches) silicified bed within the Battle Formation has not been reported on water-well drillers' logs. Though probably present in the area, the tuff bed has been passed unnoticed during drilling.

Above the Battle Formation occur shales, thin bentonitic sandstone beds, and coal seams of the lower and upper Ardley coal zones (Scollard Member of the Paskapoo Formation). Both the lower and upper Ardley zones contain coal seams commonly developed over an interval up to 40 feet thick. The lower zone is about 80 feet and the upper about 200 feet above the Battle Formation. The bedrock strata associated with the Ardley coal zones are confined largely to the Bear Hills part of the area. Capping the Bear Hills is a local sandstone bed about 40 feet thick, which is the only post-Scollard Member stratum of the Paskapoo Formation present in the area.

Bedrock topography

The bedrock topography map (Fig. 3) shows that the present-day land surface is very similar to the bedrock surface. A major preglacial river (Farvolden, 1963) crossed the map-area from the southwest, and at various stages in its history it possibly flowed in three different directions across the Hobbema Reserve. The present-day Battle River occupies part of one of those courses. Changes in flow direction may have been due to the influence of ice movement in glacial times. Only from samples of the deposits lining the old river beds can this be verified. Such samples are not available for this study.

Surficial deposits

Water-well records indicate that sand and gravel deposits rest in places directly on the bedrock surface in the preglacial river valley. At some sites there are several beds of gravel and sand separated by silt and clay. The upper part of the surficial deposits is commonly till, an unsorted, unstratified mixture of sand, silt, clay and boulders with lenses of sand and gravel. Locally at ground surface sand deposits up to 60 feet thick occur.

The most important deposit within the surficial material is gravel and sand, commonly 20 feet thick, capping a relatively flat area of the bedrock surface (Figs. 3 and 4). This is found chiefly in the southeast of township 44 and southwest of township 44 in ranges 24 and 23. This gravel is likely continuous over an area of about 4 square miles and occurs between elevations of 2,500 to 2,520 feet above sea level. However, gravel occurs over a larger area, up to 15 square miles, between elevations of 2,470 to 2,525 feet above sea level but may not be a continuous deposit. These gravels are commonly encountered at depths ranging from 60 to 90 feet below ground surface. Other sand and gravel deposits (Fig. 4) occur to the south and west of the main body and may be divided into lower and upper terrace deposits associated with the preglacial drainage pattern.

GROUNDWATER

Occurrence and movement

Groundwater occurs in the pore spaces of the materials composing the various strata. The rate of groundwater movement through the strata depends upon the size of the pore spaces and degree of interconnection between them. Clean, well sorted gravel and coarse sands permit high rates of groundwater movement (100,000 gal/day/ft^2), and clayey (bentonitic) sandstones and shales allow only low rates of groundwater movement (0.01 gal/day/ft^2) (Todd, 1959, p. 53). Strata through which water can move sufficiently fast to become economically suitable to development of wells, relative to a particular demand for water, are called aquifers.

Bedrock aquifers

Figure 5 shows the areal distribution of the development of groundwater from the main aquifers in the Hobbema area. Southeast of the village of Hobbema wells commonly tap aquifers ranging from 200 to 250 feet below ground surface (Fig. 6). The variation in occurrence of aquifers over the upper to lower parts of the zones, combined with the regional dip of the beds, gives rise to the development of a series of main aquifers two miles wide trending in a northwest to southeast direction. Wells are sometimes completed in an aquifer over wider intervals of up to 4 miles, as in the Whitemud Formation. Water supplies are also developed from sources above and below the main aquifers (Fig. 2). Delineation of aquifers in the Bear Hills region has not been attempted because of the thick, vertical interval over which many aquifers are developed and the siting of wells on a steeply sloping land surface (Fig. 6).

Aquifers in the surficial deposits

Aquifers also occur in the surficial deposits. The most important of these are believed to be the gravel deposits 20 feet thick, capping the bedrock surface in the southwest of range 23, and southeast of range 24 in township 44. Also, gravel deposits 3 miles to the west and south, described as "terrace gravels" may possibly prove to be sources of groundwater supply.

Water levels

The grouping of wells with similar depths (Fig. 7) shows that generally the deeper wells have the lower water levels. However, water levels do not always decline at the same rate as well depths increase. This is a significant fact because it is a well-established principle that, other factors (e.g. permeability and aquifer thickness) remaining constant, the greater the column of water in the well the greater will be the available drawdown to the top of the aquifer, and consequently the higher will be the well yield. So in the southeast region wells 230-270 feet deep, probably reflecting completion in the main aquifers (200 to 250 feet deep), and with water levels at about 35 to 45 feet below the land surface, have up to 200 feet of available drawdown to the top of the aquifer. This contrasts with those wells 160 to 190 feet deep completed above the main aquifer with only 150 feet of available drawdown.

It has been suggested by Tóth (1968, p. 30-32) that the materials of higher permeability and the depth of active (faster) groundwater flow occurs within 300 feet of the ground surface. This fact, economic limitations, and the common occurrence of more salty water at greater depths combine to restrict the main interval of groundwater development to depths of 200 to 300 feet. Experience in much of Alberta indicates that most aquifers of high well yield and better quality water are at depths of less than 300 feet. Figure 8 shows the water-level surface for wells completed in the most common depth range in the area, 200 to 250 feet deep. It reveals that the water levels closely follow the topography of the area, though in a more subdued manner, and thus indicates that the water table receives much of its recharge from local precipitation; a flat water table surface would imply a different situation. Consequently, if some idea of the amount of recharge to aquifers in the area could be calculated or estimated, then the amount of water available for consumption without incurring depletion would become known.

Well yields

Well yield is calculated from two factors: the transmissivity value in igpd/ft (imperial gallons per day per foot) and the head of water in feet above the aquifer (Fig. 6). Yield calculations (based on data mainly from two well drillers) show that considerable variation in yield exists. The Bear Hills region is one of low yield suited to development of wells producing less than 5 igpm (imperial gallons per minute). This is an area where well depths vary considerably, possibly reflecting rapid changes in geology and aquifers of limited areal extent. Data for the southeast part of the area indicate well yields up to 100 igpm.

It is important to note that some small areas with transmissivity values above 500 igpd/ft exist in the southeast region (Fig. 9), most of which are in the east half of range 24 and the west half of range 23 in township 44. Within the main aquifers almost half of the wells have transmissivity values in excess of 500 igpd/ft, but this is the case for only 20 per cent of the wells completed above the main aquifers (zones 2 and 3). In this particular part of the southeast region the topography is fairly level, and so should provide a surface favorable to storing potential recharge from precipitation. Water-bearing gravels about 20 feet thick cover the bedrock surface, and the main aquifers beneath these gravels commonly have the highest transmissivity values and highest well yields in this part of the area. Aquifers are doubtless more extensive in this part of the Hobbema Reserve and of higher yield. Consequently, this area deserves prime emphasis in future groundwater exploration programs for municipal and light industrial water supplies. Aquifers in both bedrock and the surficial deposits should be evaluated by comprehensive test drilling, pump testing, and water sampling projects.

Water balance

An area receives annually from the atmosphere a certain amount of moisture through precipitation. Much of this moisture is returned to the atmosphere through evapotranspiration. The small remaining surplus is available for surface runoff and for recharge to the groundwater system. Where adequate data are available, estimates can be made of the amount of groundwater recharge that takes place, and thus of the amount of groundwater that can safely be used without bringing about depletion.

The Thornthwaite method (1948) was used to calculate evapotranspiration in the Hobbema area from data (30-year average) collected at the weather station near Wetaskiwin. This method permits an approximate estimation of the water surplus, which amounts to 0.2 inches for streamflow and groundwater recharge (Fig. 10). Analysis of the data was made in a similar way to that of MacIver (1966). This compares to an average water surplus for the whole Battle River drainage basin, measured at Unwin, Saskatchewan (16-year average, of 315 cfs (cubic feet per second) or 0.425 inches over the whole basin area.*

The discharge of 0.425 inches is equivalent to a water yield of 11.75 igpm per square mile per year, or close to 3 igpm per quarter section. Water yields predicted from the Thornthwaite method are 5.5 igpm per square mile per year (1.25 igpm per quarter section), somewhat lower than that obtained by measuring stream discharge. These values should be considered as giving an indication of the order of magnitude of water theoretically available for recharge if it were not lost to runoff. In other words, this represents the total quantity of water available for use in the area without causing depletion. Safe well yields, calculated for 20 years of pumping, of up to 3 igpm are common in eastern Alberta. These are, however, average values, so that yields may be higher or lower according to variations in topography and geology. The southeast part of township 44, range 24 may possibly fall within a higher than average water yield or water surplus area.

Groundwater chemistry

Unfortunately insufficient data were available in this study to relate fully the geology, yield and quality of water within the known aquifers. However, the following comments may be made (see Figs. 2, 6).

The shallower wells, in the depth range of 140 to 180 feet below ground surface, locally drawing water from bedrock sources above the main aquifers (above zones 1, 2, and the Whitemud Formation) show two groups of water quality character-

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*The discharge in inches for the basin was calculated using a modification of Freeze's (1964) method:

$$DI = \frac{Q}{A} \times 13.5$$; where DI = runoff in cfs measured as inches on the basin, Q = river flow in cfs, A = drainage area in square miles, and 13.5 is a constant.

istics. One group has total dissolved solids ranging from 1,200 to 1,500 ppm (parts per million) and water mainly of sodium sulfate (30 to 60% of total ions) and sodium bicarbonate (30 to 60% total ions) types. The second group has total dissolved solids from 700 to 1,000 ppm and is of sodium bicarbonate type (60% to 70% of total ions). Below the main aquifers (below zone 2, location Sec. 22, Tp. 44, R. 24, compare Figs. 2 and 6), possibly from sources about 200 feet deeper, waters show significant concentrations (up to 35%) of sodium chloride. The indications are that groundwater from the main aquifers is of the sodium bicarbonate type (60% to 80% of total ions) and ranges in total dissolved solids from 700 to 1,000 ppm (e.g. zone 2 and the Whitemud Formation).

Water from the gravel deposits near the southeast corner of township 44, range 24, is commonly hard and high in iron and is therefore seldom developed for domestic use. It is mainly calcium-magnesium bicarbonate, with some sulfate, and has about 1,200 ppm total dissolved solids. Water treatment could be carried out to reduce both the hardness and iron contents of the water.

In the Bear Hills region water samples range from 800 to 1,400 ppm total dissolved solids and are mainly of the sodium bicarbonate type (60% to 80% of total ions). Sodium chloride (10% to 60%) is an important constituent in groundwaters in this region and increases over the flat-lying area to the north of the reserve to as high as 70% of the total ions.

The best quality groundwater is thus in the southeast region. The water is primarily sodium bicarbonate type with total dissolved solids less than 1,000 ppm. It is believed that most of the best quality water is drawn from wells completed in the 'strips' of main aquifers (Fig. 5) at depths from 200 to 250 feet. However, some equally good quality water is obtained from above and below the main aquifers.

Groundwater exploration

Test drilling procedures may be conducted either by the cable tool or rotary methods. In each case careful sampling should be made of drill cuttings at 5-foot intervals, and water samples from each aquifer or group of aquifers: two-hour bail tests should be conducted on each aquifer or group of aquifers, and evening and morning water-level measurements should be taken.

The cutting samples are needed in order to relate the geology of the test holes to the local geological interpretation as given in this report, the water samples to give data regarding water chemistry of aquifers to consider the suitability of the water supplies for different purposes, the bail tests to aid selection of the most favorable sites for pump tests, and the water levels to aid determination of the flow systems from which the groundwater is obtained.

Following test drilling, the best bail-test site or sites should be selected for week-long pump tests. The pumping well should be accompanied by at least two observation wells so that measurements can be made of water level changes as the pumping progresses. The pumping rate must be kept constant throughout the test and water samples taken near the beginning of pumping and about every 24 hours to note possible changes in water chemistry.

If the rotary method is adopted then the writer suggests a 10- to 12-hour day of 'controlled rotary drilling'. The reason for suggesting this approach is to take advantage of the speed of rotary drilling and gather more groundwater information in a given day's drilling. The framework of the approach envisages five hours of drilling at 20 feet per hour giving 100 feet of drilling per day. This should be followed up with about an hour's time devoted to cleaning the mud out of the hole in preparation for a two-hour bail test carried out the next day and two hours of recovery measurements, including water samples. Five to six hours then remain for 100 feet of drilling. This schedule takes a full 10-hour working day, but a 12-hour day would allow time for miscellaneous activities at the drill site or slight variation in the above schedule. This method would also allow some coring for laboratory permeability tests. A 500-foot deep hole could be drilled in about a week with quite a comprehensive amount of groundwater information being obtained.

CONCLUSIONS

In the Bear Hills region, only well yields of less than 5 igpm, suited to domestic and livestock water supply requirements, may be anticipated. In the southeast region well yields of up to 100 igpm appear to be a distinct possibility. However, as this study has been based entirely on records submitted by water-well drillers an exploration program similar to that suggested must be conducted competently to verify some of the foregoing opinions. With specific reference to the southeast region, one area is delineated as the most favorable for developing groundwater supplies from aquifers both in the bedrock and in the surficial deposits. This is where groundwater seems to be in plentiful supply and is recommended for consideration in development of water supplies for municipal and light industrial purposes.

The shape of the water-level surface closely corresponds to that of the present-day land surface, indicating that recharge takes place by local precipitation. A water balance analysis shows some surplus water to be available for runoff and groundwater recharge.

The chemistry of the groundwaters shows the water supplies are mostly suitable for human consumption, but water developed from surficial deposits may have to be treated to lower the hardness and to remove the iron.

RECOMMENDATIONS

In any program considering the development of groundwater supplies of up to 100 igpm for municipal or light industrial uses, test drilling should be undertaken first within the boundary of the favorable area (Fig. 9) (i.e. in the southwest part of township 44, range 23, and the southeast quarter of township 44, range 24). Testing should be limited to depths of 350 feet; and aquifers in both the bedrock and surficial deposits should be tested for yield and quality. Following this, if necessary, test drilling may be carried out successively northward of the area defined, and to about the same depth.

Other possible favorable sites for groundwater development with yields estimated to be up to 50 igpm may occur within the two mile strip on the west side of township 43, range 24 and township 44, range 24. As stated previously, testing of yield and water quality should be carried to depths of 350 feet.

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Fig 2