RESEARCH COUNCIL OF ALBERTA

Preliminary Report 59-2

GROUNDWATER GEOLOGY
BEAVERLODGE DISTRICT, ALBERTA

by

J. F. Jones

Research Council of Alberta
Edmonton, Alberta
1960

FOREWORD

This report is presented in preliminary form in order that all known information on the groundwater occurrences of the Beaverlodge District will be immediately available to persons who are interested in developing this natural resource. Preliminary reports of similar areal investigations for other districts in Alberta will be published if the need is obvious. Otherwise the results of such investigations will appear as condensed reports of a more scientific nature in bulletin form. Thus, an abbreviated version of this report designed for a scientific audience will appear in a bulletin entitled "Selected Investigations by the Groundwater Division, Research Council of Alberta".

R. N. Farvolden,
Head, Groundwater Division,
Research Council of Alberta.

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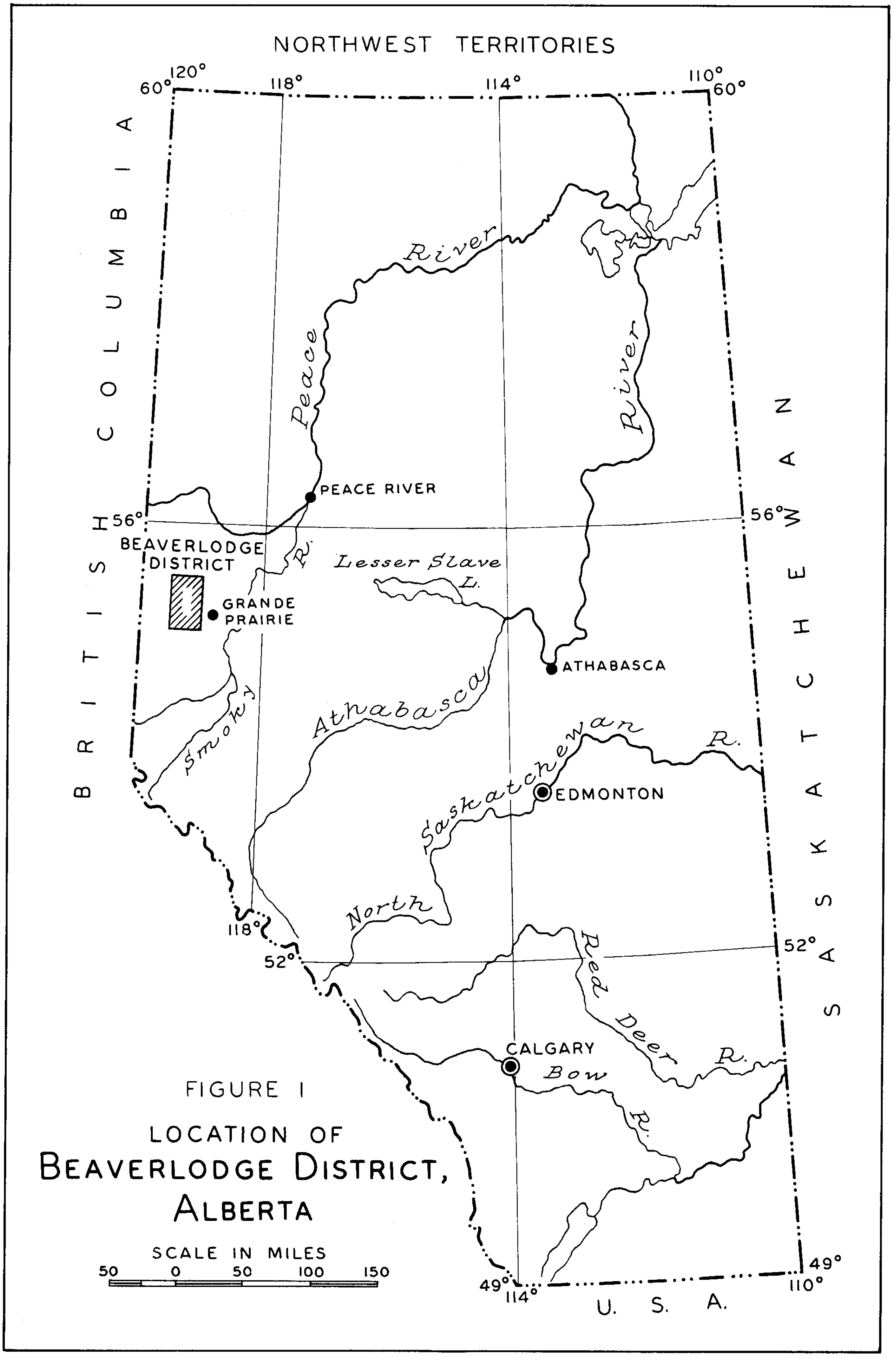


FIGURE I

LOCATION OF BEAVERLODGE DISTRICT, ALBERTA

GROUNDWATER GEOLOGY

BEAVERLODGE DISTRICT, ALBERTA

Abstract

Approximately 85 per cent of the water supply in the Beaverlodge district is obtained from wells in sandstones of the Wapiti formation. The remaining 15 per cent is obtained from wells in Cenozoic sands and gravels. A 'buried channel' which contains water-bearing sands and gravels was outlined from geologic and seismic surveys and by test drilling. An average transmissibility of 4,200 gallons per day foot was determined by pumping tests. Wells of capacities up to 60 gallons per minute might be obtained from the buried gravels with additional exploration. The recharge, movement and discharge of groundwater appear to be controlled by local topography. The water in the bedrock is generally softer than that found in the overlying surficial deposits.

INTRODUCTION

This report presents the preliminary results of groundwater studies carried out during the summer of 1958 and the early part of the summer of 1959 in the Beaverlodge district of northwestern Alberta. Before this study was undertaken practically no information was available concerning groundwater conditions in the district.

The Beaverlodge district is located between 119° 00' and 119° 30' longitude and between 55° 00' and 55° 30' latitude (Fig. 1). The total area comprises about 680 square miles. All locations referred to in the test are west of the Sixth Meridian.

The Beaverlodge district has considerable topographic relief and can be divided into four main physiographic regions: (1) the Saddle Hills, which comprise the northern part of the map-area; (2) Saskatoon Hill, which is located in the central portion of the district; and (3) and (4) the two southeast-trending valleys separated by Saskatoon Hill.

The climate of the Beaverlodge district is typical of the Western Canada prairie. It is characterized by a moderately warm summer and a relatively cold winter. The mean annual temperature is 35 degrees Fahrenheit. The mean annual precipitation is 17.60 inches, most of which falls during the spring and summer months. These figures are based on precipitation records kept by the Dominion Experimental Farm at Beaverlodge over a period of 43 years.

GEOLOGY

Introduction

The Beaverlodge district is underlain by a series of nonmarine sandstones, shales and coals of the Wapiti formation of Upper Cretaceous age. The strata dip southward into the Alberta syncline and thicken in the same direction.

The exposures of bedrock can be found along the river valleys of the district. Scattered outcrops of Wapiti formation strata are present on the highlands where the cover of drift is absent.

Surficial deposits consisting of till, sands, gravels, and lacustrine silts and clays, cover most of the bedrock of the area. In places isolated exposures of buried gravels can be found below till, resting on beds of the Wapiti formation.

Cretaceous Strata

The name "Wapiti" was first applied to a group of sandstones and shales exposed at the mouth of Big Mountain Creek in Tp. 70, R. 5, by G. M. Dawson in 1879.

McLearn (1918) and Rutherford (1930) estimated 900 to 1,100 feet as the thickness of the Wapiti formation overlying the Smoky River shales which are exposed to the east of the map-area. South of the map-area, Evans and Caley (1929) estimated the thickness of the Wapiti strata between the Wapiti River and Nose Mountain as 1,100 feet. Allan and Carr (1946) indicated the maximum thickness of the Wapiti formation to be 4,100 to 4,600 feet. More recent information, from Baysel C. F. P. Regent Nose Mountain well (Lsd. 15, Sec. 20, Tp. 64, R. 11), shows a thickness of 5,381 feet for the Wapiti formation in this area. Greiner (1955) stated that in the Two Lakes area, 35 miles southwest of the Beaverlodge district, 6,000 feet of Wapiti strata are present.

The individual lithologic units within the Wapiti formation are gradational in character, and lens out when traced any distance along outcrop faces. Rutherford (1930, p. 31) gives a description of the Wapiti formation that is typical of the strata:

> Lithologically the Wapiti formation consists of sandstones and shales of fresh-water deposition. The units vary in thickness from a few inches up to as much as 50 feet, the average thickness being more often 10 to 20 feet. All phases of gradation between sandstone and shale are common. The more massive sandstones are frequently crossbedded and concretionary masses are common in eroded faces. Light grey to buff are the prevailing colors, and on the whole fine grained textures are most common. The shales are poorly stratified, a characteristic common to shales of fresh-water deposition.

Thin beds of greyish-green bentonite up to 6 inches in thickness are commonly found associated with some of the coal seams in the area.

TABLE I.

COMPOSITE GEOLOGIC SECTION BEAVERLODGE DISTRICT

ERA	PERIOD	FORMATION	LITHOLOGY	THICKNESS
CENOZOIC	RECENT		CLAY SILT SAND GRAVEL	0 - 20
	PLEISTOCENE		CLAY SILT SAND GRAVEL TILL	0 - 200
		"BURIED GRAVELS"		0 - 20
	TERTIARY			
MESOZOIC	UPPER CRETACEOUS	WAPITI	SANDSTONE SHALE MINOR COAL	1200 - 1900

A typical outcrop of Wapiti strata occurs in the southwest corner of Sec. 22, Tp. 70, R. 10, along the Red Willow River. This section is probably part of 'Member B' of Allan and Carr (1946, p. 16):

	Top of Section
0' 0" - 3' 0"	Recent alluvial silts and sands
3' 0" - 23' 0"	Colluvium, a mixture of Recent and glacial pebbles, boulders and clay, resting on bedrock
23' 0" - 28' 10"	Sandstone, yellowish grey-brown, salt and pepper, weathering light grey-buff, fine- to medium-grained, feldspathic, reasonably well indurated and cemented, massive, shows bedding and crossbedding, fractured in places
28' 10" - 29' 7"	Shale, black, carbonaceous, with coal lenses
29' 7" - 29' 8"	Bentonite, weathers white
29' 8" - 30' 8"	Coal, black, well weathered, in thin bright and dull lenses
30' 8" - 31' 4"	Shale, black, carbonaceous and coaly
31' 4" - 32' 0"	Coal, hard, massive, fairly bright, with thick vitreous bands
32' 0" - 33' 0"	Shale, black, carbonaceous
33' - to river level	Slump and colluvium, covering bedrock to river level.

Outcrops of the Wapiti formation are present along the valleys of the Wapiti, Red Willow and Beaverlodge Rivers. Flat-lying, grey, flaggy sandstones of the Wapiti formation form the bed of Bear Creek in Tp. 73, R. 8.

Many outcrops occur along the tops of the highlands where the drift cover is absent; massive sandstones form a prominent south-facing scarp in the centre of Tp. 72, R. 9 on Saskatoon Hill. In the northern part of the map-area, along the southern edge of the Saddle Hills, in Tps. 74 and 75, Rs. 7 to 10, the drift cover is thin in many places; bedrock is commonly 1 or 2 feet below the surface and is locally exposed. Northeast of the Hamlet of La Glace in Secs. 13 and 24, Tp. 74, R. 8, on the top of a prominent hill, Wapiti sandstones are exposed where glacial beach deposits of sands and gravels have been removed from a local gravel pit.

As noted previously by Allan and Carr (1946), both invertebrate and vertebrate fossils occur throughout the Wapiti formation, and plant remains are common. The invertebrates are generally small freshwater pelecypods and gastropods. Fragments of dinosaur bones have been found locally.

Rutherford (1930) considered the lower part of the Wapiti formation to be equivalent to the Belly River formation of the plains and foothills of southern Alberta. Allan and Rutherford (1934) recognized the Edmonton formation west of the Smoky River through the Grande Prairie district and correlated it with the upper part of the Wapiti formation on the basis of lithologic similarity. According to Allan and Carr (1946) attempts at limiting the Wapiti formation to those beds correlative with the Belly River of southern Alberta have been based entirely on lithologic evidence and no sure correlation is possible until more adequate studies of these nonmarine Upper Cretaceous strata have been undertaken.

Rutherford (1930, p. 31) suggested that Tertiary strata might be present in the Beaverlodge district. He stated:

> A relatively high, flat topped mesa occurs in the central part of township 72, range 8, west of the sixth meridian, a few miles east of Beaverlodge. This is known as 'Saskatoon Hill' which rises about 600 feet above the surrounding gentle sloped areas at the base. The shape of this hill is mesa-like and about 150 feet of the underlying strata near the top are exposed in steep cliffs. These beds consisting of coarse cross-bedded sandstones and sandy shales are very similar in appearance to the Paskapoo formation as developed elsewhere in Alberta.

Recent drilling in the Swan Hills has proved thicknesses of 3,000 feet to 4,000 feet of strata equivalent to the Wapiti formation. By extrapolation it is estimated that between 3,500 to 4,000 feet of Wapiti beds were present originally in the Beaverlodge district. Well data indicate that between 1,200 to 1,900 feet of Wapiti beds now remain, the remainder having been removed by erosion. Thus the elevation of the original Tertiary peneplain was approximately 2,000 feet above the summit of Saskatoon Hill. Therefore, the beds on Saskatoon Hill that Rutherford (1930) and Allan and Rutherford (1934) considered to be Tertiary are probably middle Wapiti in age.

Detailed studies of the lithology; especially of heavy mineral content, and the careful tracing of groups of coal seams may aid considerably in the correlation of units within the Wapiti formation and with similar equivalent sediments elsewhere.

Buried Gravels

Buried quartzite gravels were found in three localities, resting on Wapiti sandstones and shales, and overlain by till and by lake deposits of glacial and postglacial age. Other occurrences of similar gravels have been noted elsewhere in the Peace River region (Allan and Carr, 1946, p. 23; Rutherford, 1930, p. 34).

An excellent exposure of such gravels occurs in the southwest corner of Sec. 4, Tp. 71, R. 9, along the west bank of the Beaverlodge River:

Top of Section

0' - 15'	Silts and clays, varved and bedded, grey to greyish-brown, individual varves one-eighth inch to one foot thick
15' - 112'	Till, grey-brown, boulders, pebbles and clay
112' - 132'	Gravels, coarse, 2- to 6-inch yellow-white quartzite cobbles and pebbles, some chert pebbles with some minor lenses of coarse sand; face of gravel almost vertical in outcrop
132' - 133'	Slump and colluvium to river level.

About 600 feet farther downstream, fractured and crossbedded sandstones of the Wapiti formation are exposed at river level.

In the southeast corner of Sec. 30, Tp. 70, R. 9, a 5- to 10-foot bed of gravel overlain by till rests on sandstones and shale about 100 feet above the level of the Beaverlodge River. The gravels are of smaller size than those of the other exposures and the sand content is higher.

In the northeast corner of Sec. 29, Tp. 70, R. 8, along the bottom of Pipestone Creek, 10 to 15 feet of similar-type gravels occur, resting on 7 feet of grey shale, siltstone and a small 4- to 6-inch bed of greyish-green bentonite associated with a small stringer of coal.

The buried gravels in the Beaverlodge district may be glacial or preglacial in age. All these gravel deposits are found in a broad valley that trends in a westerly and northwesterly direction through the Town of Beaverlodge. The existing rivers and streams appear to be following the depressions in an old preglacial land surface that was developed on the Wapiti strata. Subsequent uplift of the land and downcutting of the rivers and streams has exposed the buried gravels below the covering surficial materials.

Additional information obtained from water well logs and test drilling carried out in the early part of the summer of 1959 indicates buried gravels at depth extending over a considerable area (Fig. 2).

The coarse, well-rounded and well-sorted nature of the exposed gravels suggests that they were deposited by rivers and streams. No fossils were found in the buried gravels examined. Granites, granite gneisses and other rock types that are found associated with glacial materials derived from the Canadian Shield areas are absent, and the gravels consist only of quartzites and a few chert pebbles.

There are two possible origins for the gravels: (1) they form part of preglacial deposits in a drainage system that was developed prior to continental or Cordilleran

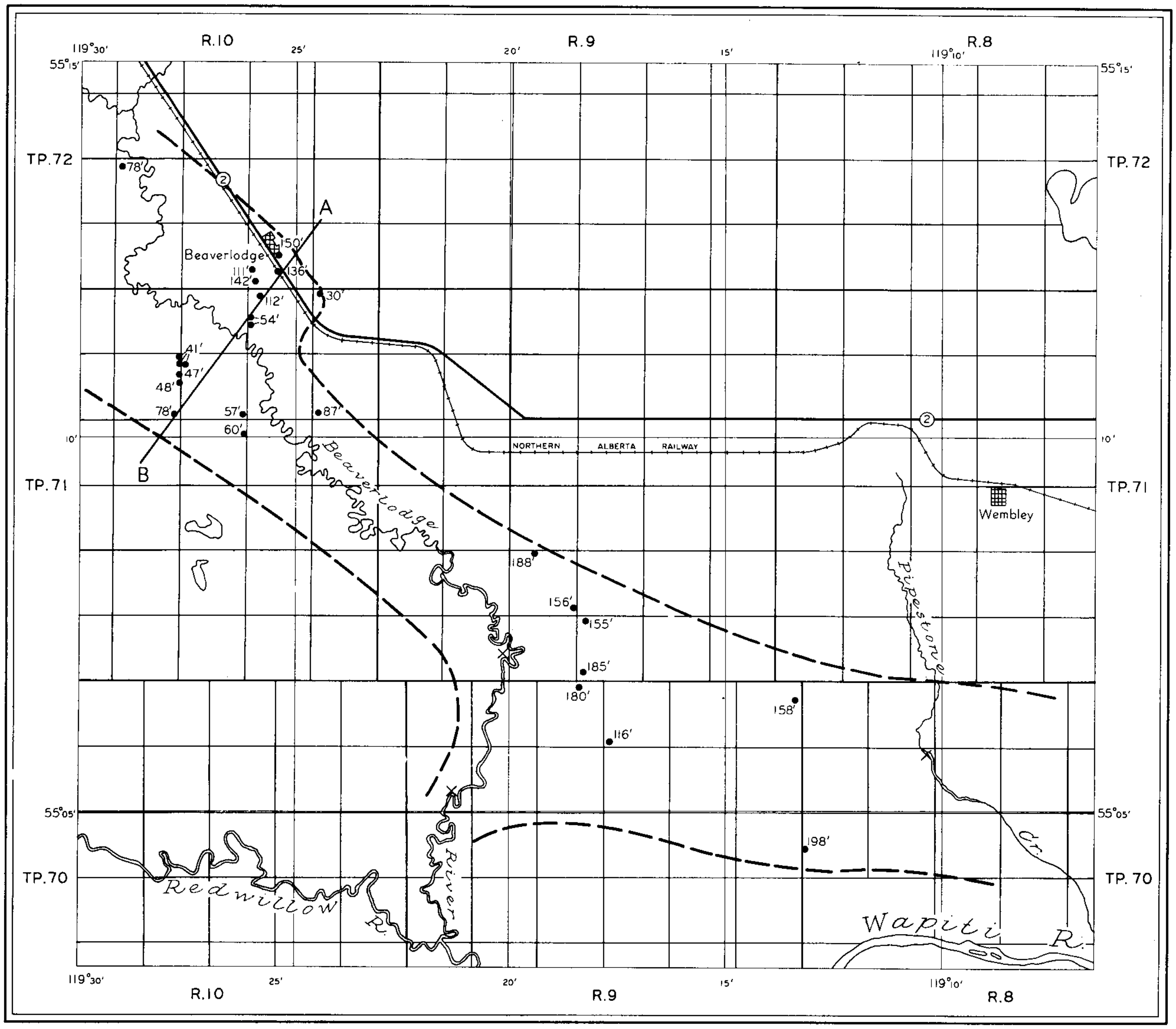


FIGURE 2.

Buried Channel, Beaverlodge District, Alberta

WEST OF SIXTH MERIDIAN

Scale in Miles

LEGEND

Depth to top of buried sand and gravel from ground surface, established from water well and test drilling data .... ●47′

Approximate boundary of buried channel .... — — —

Outcrop of buried sand and gravel .... ×

Section perpendicular to hydraulic gradient across buried channel .... A———B glaciation; or (2) they represent glacial-meltwater stream or river deposits, the source material being quartzites and cherts derived from Cordilleran drift that came from the Rocky Mountains to the west. Subsequent readvance from the last continental glacier from the northeast overrode the gravels and covered them with till and associated deposits.

No evidence has been found of a Cordilleran till overlying the buried gravels. All the buried gravels examined appear to be resting on sandstones and shales of the Wapiti formation. Further study of similar occurrences outside the district may lead to clarification of their relationship to existing stratigraphy.

Pleistocene and Recent Deposits

Till, sand, silts, clays and gravels of glacial and Recent ages cover most of the bedrock of the district. These deposits are generally thick in the valleys and reach a maximum of 200 feet. The surficial deposits thin considerably towards the highlands, and in many places near the crests of the hills they are only a few feet thick or absent.

Outwash and Aeolian Deposits

In the southern portion of the Beaverlodge district, along the Wapiti River, there is a large area of glacial-outwash sand with some gravel. This deposit is well developed in the southern parts of Tp. 70, Rs. 9 and 10. The surface portion of the outwash sand has been modified by wind action and large east-striking dunes have been developed that in some places extend more than one mile. In most instances the sand was not carried far beyond the area of original deposition.

Alluvial Terrace Deposits

Extensive alluvial terrace deposits of sand, silt and gravel have been formed along the Wapiti River. Some of these lie 50 to 150 feet above the present river level, indicating that they were formed at an earlier stage of the river. Recent alluvial terraces are found through the district, along the drainage courses, at present river levels.

Structure

The strata of the Wapiti formation within the district are located on the east limb of the Alberta syncline. The rapid facies changes within the Wapiti formation and the lack of definite marker beds make it difficult to estimate strike and dip. Studies based on information obtained from structure-test holes and deep test well electrologs indicate that the regional strike on the base of the Wapiti formation is south 85 degrees west to due west and the dip is to the south at 44 to 55 feet per mile. Southwest of the Beaverlodge district the strike of the Wapiti beds changes to a more northwesterly direction and dips become steeper towards the foothills.

GENERAL OCCURRENCE OF GROUNDWATER IN ALBERTA

Meinzer (1923a) has defined groundwater as that part of the subsurface water which is held in the zone of saturation. In the zone of saturation all the pore spaces and cracks in the rocks are filled with water. The top of the zone of saturation is called the water-table. Above the water-table, in the zone of aeration, water is still present, but it is held by earth materials in such a manner that it can be utilized only by plant growth.

The source of groundwater is rain and snow which falls on the surface of the earth. Most of this water runs off the land and is eventually returned to the atmosphere by evaporation and transpiration. A good portion, however, percolates downward through the pores and crevices of many different kinds of earth materials and reaches the zone of saturation, thus recharging the groundwater reservoir.

In order that a water well may be successful, the bore hole must penetrate a formation which carries water and can transmit it readily. Such a formation is called an aquifer. The ability of an aquifer to store and transmit water depends primarily on two of its properties — its porosity and its permeability. Porosity is the amount of pore space or void in a given volume of rock or soil, while permeability is the ability of a rock or soil to transmit a fluid. Where a water-bearing formation has many interconnected pores and water can move readily, the formation is said to be both permeable and porous.

In the Alberta plains region, the water-bearing zones or aquifers show considerable variation in these properties.

Clean well-sorted sands and gravels have the highest permeabilities and porosities, and as a consequence it is common to search for them where large capacity wells are required.

Consolidated sandstones usually have much lower permeabilities and porosities depending upon the degree of cementation or fine material in the pore spaces between the sand grains. All gradations are found between clean well-sorted sandstones (with fair to medium production of groundwater), down to silty and shaly sandstones (with little or no production). In the Alberta plains, wells completed in sandstone seldom produce more than 100 gallons per minute.

Shales and clays sometimes contain considerable water compared to an equivalent volume of sand and gravel, but though they may be highly porous and absorb water readily, the openings are so small that water is not transmitted to a well bore.

Locally a formation will yield water, even though it has little or no porosity. Commonly a cemented sandstone with low porosity is fractured and creviced and thus sufficiently permeable to be an aquifer. Similarly some coal seams are aquifers.

Groundwater is said to be under water-table conditions when there is no impermeable confining bed between the aquifer and the land surface and the water is at atmospheric pressure at the free water surface. Where the water-table intersects the surface of the land, groundwater is discharged through springs. The water-table level does not remain constant, but fluctuates depending upon the amount of groundwater gained or lost due to changes in the relationship between recharge and discharge. A perched water-table condition results when water accumulates over impermeable strata above the general water-table.

Where an aquifer, such as a water-bearing sandstone is overlain by less permeable strata such as shale, the water in the sandstone may be confined and under pressure. If the water level in a well drilled into it rises above the top of the aquifer, the well and the aquifer are termed artesian. If the pressure is sufficient to make the water rise above the ground level, the well is called a flowing artesian well.

The rate at which water can be withdrawn from a well is dependent upon the following factors: the permeability of the aquifer, the thickness of the water-bearing horizon, the hydrostatic head (the height above the aquifer to which water will rise), and the efficiency of the well.

Under both water-table and artesian conditions the hydrostatic head in the immediate vicinity of the well lowers during pumping and a cone of depression is produced around the well. This cone of depression expands as pumping continues and eventually may extend for a considerable distance, lowering the water levels in neighboring wells and reducing the pressure in the aquifer until equilibrium is established (i.e. the amount of water withdrawn from the system is balanced by the amount of water coming into the system). In some cases equilibrium is reached quickly, in others it may take considerable time or may never be reached. If more water is taken out of the system than is replaced by natural or artificial recharge, the aquifer will eventually be depleted.

In the Alberta plains region there are many kinds of aquifers important in the development of groundwater resources. These can be divided into two major types, those found in the bedrock and those found in the overburden.

The bedrock underlying the plains region consists essentially of a series of sandstones and shales with all gradations between. The formations concerned in the development of groundwater supplies are mainly Upper Cretaceous in age. The important aquifers are found in the sandstone members, with coal seams occasionally providing a source of groundwater.

Important aquifers are associated also with the overburden or surficial deposits which overlie the bedrock. Sand and gravel terraces along recent streams and rivers often provide large quantities of water. Sand and gravel aquifers are found associated also with glacial deposits and in preglacial bedrock channels, sometimes buried by more recent deposits. Examples of these types of aquifers are shown diagrammatically in figure 4.

In Alberta the water from surficial aquifers is usually hard, while that from the bedrock aquifers is usually soft. Salty or brackish water is encountered within 200 to

300 feet of the surface in many parts of Alberta. The chances of obtaining fresh water below a formation containing salt water are slight in the Alberta plains.

Each area in Alberta presents its own problems in the finding, utilization, and conservation of its groundwater resources, of which the Beaverlodge District is just one of many.

HYDROLOGY

Introduction

Information was obtained from more than 350 water wells during the summer of 1958; these data were synthesized and general conclusions drawn. The water wells are classified on the accompanying maps (maps 59-2A and 59-2B) according to the nature of the material in which they are completed.

The piezometric surface, showing the generalized hydrostatic head of the groundwater during the summer of 1958, is shown on map 59-2C.

Well information is tabulated and included at the end of the report (Appendix II).

Bedrock Aquifers

Approximately 85 per cent of the groundwater in the Beaverlodge district is obtained from wells drilled into water-bearing sandstones of the Wapiti formation. There is considerable variation in the depths of the water wells because of the discontinuous, irregular and lenticular nature of the sandstones. Depths of fresh water-bearing sandstones in the Wapiti formation range from 30 to 400 feet. Not every sandstone zone encountered in drilling is water-bearing. Where a sandstone is sufficiently permeable and porous, a well drilled into it will yield water. Commonly, however, sandstone is cemented, and the movement of groundwater can take place only where the formation is fractured.

Most of the wells drilled in the sandstones are nonflowing artesian wells producing around 3 to 5 gallons per minute, which is usually sufficient for most farm and domestic needs. A few wells have been drilled and tested which will pump over 20 gallons per minute, but these are rather exceptional.

The flowing artesian wells throughout the area generally produce water at rates of 1 to 5 gallons per minute; however, a flowing well in the northeast corner of Sec. 36, Tp. 74, R. 10 produced water at the measured rate of 60 gallons per minute.

A few shallow wells below the crests of local topographic highs — along the southern edge of the Saddle Hills – obtain water from permeable sandstone lenses that underlie clayey till at depths of 30 to 50 feet. The recharge area is on or near the tops of these highs, where the till cover is thin, sandy and porous, or absent. The till cover becomes thicker and more impermeable downslope and acts as a confining bed over the bedrock. Wells which penetrate this impermeable cover and encounter porous bedrock commonly flow.

A few scattered wells obtain groundwater from coal seams that are fractured sufficiently to allow the movement of groundwater. This type of well is rare and difficult to locate because of the extreme variability of the occurrence of coal in the Wapiti formation.

Buried Gravel Aquifer

Several water wells in the Beaverlodge district obtain groundwater from buried sands and gravels that lie on top of the bedrock covered by varying thicknesses of till and other surficial deposits. The wells are found most commonly within a northwesterly-trending valley in which the Beaverlodge River lies. The wells drilled in the buried sands and gravels along the Beaverlodge River have depths ranging from 50 to over 180 feet. The shallower wells lie in Tp. 71, R. 10 and the wells gradually become deeper to the southeast, especially in Tp. 71, R. 9.

A seismic survey was carried out in areas where the presence of these gravels was suspected. As a result, several areas were delineated, suggesting the presence of an old buried river channel.

In the spring and early summer of 1959, a test-drilling program was carried out which verified the seismic predictions and geological inferences and delineated the channel. Figure 2 shows the location of the buried gravel channel as shown by the test-drilling and water well data.

At the northwestern end of the buried channel, a well field was established in this aquifer and a pumping test carried out. The pumping test results are presented and discussed under aquifer hydrologic characteristics.

The buried channel was not visible on aerial photographs, but was suspected by the finding of buried gravel outcrops, as mentioned earlier, and by the presence of a few water wells completed in sands and gravels along the trend of the Beaverlodge River (map 59-2A).

Other Aquifers

A few wells obtain water from recent alluvial terrace deposits of sand and gravel along the streams and rivers of the map-area. A well of this type lies in the northwest corner of Sec. 23, Tp. 71, R. 10. Water is obtained from a shallow 15-foot well in sands and gravels on a small terrace adjacent to the Beaverlodge River. Terraces of this type, where they are extensive and thick, commonly make excellent aquifers with high production of water. The water infiltrates through the gravel from the nearby river to the well.

In the southern part of the district, along the Wapiti River, a few shallow wells obtain groundwater from glacial-outwash sand, part of which has been reworked by wind to form dunes. Wells of this type are present in Sec. 33, Tp. 69, R. 10 and Tp. 70, Rs. 7, 8 and 9. These are perched water-table wells above shales and sandstones of the Wapiti formation.

The catchment area for groundwater recharge is local and dependent on rainfall which percolates readily through the sands to replenish the groundwater reservoir. In these areas, close to the major river valleys, the water-table is depressed and water discharges into the valleys. Thus, if a suitable groundwater supply is to be obtained it may be necessary to drill at a considerable distance away from river valleys.

Some wells are found in till, sands, silts, and clays, close to lakes and sloughs. Water is usually obtained in small shallow cribbed wells by seepage. These are not the most satisfactory wells, because the nature of their construction often permits pollution.

Springs

There are many springs throughout the area which are used for local water supplies. These are usually found along the valleys of the rivers, creeks and streams in the district, where many of the aquifers intersect the land surface.

Piezometric Surface

According to Meinzer (1923b, p. 38):

> The piezometric surface of an aquifer is the imaginary surface that everywhere coincides with the static level of water in the aquifer. It is the surface to which water from a given aquifer will rise until its full head.......

The elevations of the piezometric surface were determined by subtracting the depth of the static water levels from the elevations of the wells and they are shown on map 59-2C. Contours were drawn at 100-foot intervals. The contours are isopiestic lines and represent imaginary lines, all points along which have the same static level (Meinzer, 1923b). The movement of groundwater is from a zone of high pressure to a zone of low pressure, perpendicular to the contour lines.

The piezometric surface shown on map 59-2C is the average for the summer of 1958; the shape of the surface may vary with time, depending on the amount of groundwater received or lost. A few of the reasons for the fluctuations are: seasonal climatic changes, man-made changes such as those due to removal of forest and plant cover, water production from new wells drilled, and increased or decreased production of groundwater from old wells.

There are two major piezometric highs within the area, one associated with Saskatoon Hill in Tp. 72, R. 9, the other with the Saddle Hills (maps 59-2A and 59-2B).

Movement of groundwater from Saskatoon Hill is mainly in two directions, southward and northward. Movement of groundwater from the south slope of Saskatoon Hill is in a general southerly direction, with the hydraulic gradients becoming steeper towards the Wapiti, Red Willow and Beaverlodge Rivers. On the north slope of Saskatoon Hill the pressure gradient is in a northerly and northeasterly direction indicating movement of groundwater into the topographic low situated around La Glace Lake.

Movement of groundwater from the south slope of the Saddle Hills is towards the same topographic low situated around La Glace Lake, and thence in a southerly and southeasterly direction towards Bear Lake.

In Tp. 73, R. 8, there are a few anomalous static water levels that do not appear to fit the general pattern. These wells are interpreted as obtaining their groundwater from isolated aquifers that are not connected with the over-all system.

Along the Beaverlodge River the piezometric contours follow the river, indicating movement and discharge towards it. Similarly the Red Willow and Wapiti Rivers are effluent, that is, the pressure gradients and discharge are towards the rivers.

Drilling close to major drainage valleys for bedrock wells is commonly unsuccessful because, as the contours show, the static water levels are depressed considerably. It is often necessary to drill deeper in these places than farther from the edge of the valley, sometimes to river level or below. The reason for this is that the aquifer has been exposed by the downcutting of the rivers and streams so that groundwater drains readily into the zone of lower pressure, resulting in a lowering of the static water levels. Spring lines commonly develop along the stream and river valleys, and show the position of the intersection of the aquifer with the surface of the land.

Near the Town of Beaverlodge the 2,300-foot contour (map 59-2C) bends slightly off the regular upstream trend of the piezometric surface, which indicates a cone of depression produced by the greater local withdrawal of groundwater.

The general movement of the groundwater appears to be controlled by local topography and the water moves from the highlands to the lowlands (map 59-2C). In addition, the water-bearing zones appear to behave as a single homogeneous unit. This is to be expected, as the Wapiti formation sandstones and shales are interbedded and lenticular in nature, and connections and cross-connections are possibly common. Two flowing wells in Secs. 20 and 21, Tp. 72, R. 7 illustrate these features. The wells are located in a lowland adjacent to a lake and are completed in Wapiti formation sandstone. The recharge area of the water in these wells is in the hills immediately to the west of the lake (map 59-2A). The strata dip from the wells toward the hills and the groundwater must move up-dip to the wells, showing that the structure does not control the movement of groundwater.

Wells completed in glacial or nonglacial sands or gravels fit into the over-all pattern and their static levels can be contoured with those of other wells. The dominant over-all movement of groundwater appears to be in a southerly direction, following the general slope of the land.

In Sec. 16, Tp. 70, R. 9, a shallow well on a small hill is completed in sandstone. Its static level is quite different from those of the wells close by, and it appears to be drawing water from a perched water-table.

Aquifer Characteristics

Pumping tests, recovery measurements after bail testing during drilling, and pressure-recovery measurements of shut-in flowing wells were carried out to determine the hydrologic characteristics of the aquifers.

The hydrologic characteristics of an aquifer are commonly expressed in terms of the coefficients of transmissibility and storage (Theis, 1935). These aquifer constants are used in determining the amount of water available from an aquifer, and future decline of water levels due to pumping. In addition, by analysis of the pumping-test data, it is sometimes possible to predict the location and effect of hydrologic boundaries.

The coefficient of transmissibility of an aquifer is defined as the rate of flow of water in gallons per day which will pass through a vertical strip of an aquifer one foot wide, with a unit hydraulic gradient. Stated in another way, the transmissibility is the product of the thickness and the permeability of the aquifer.

The coefficient of storage may be defined as the amount of water, in cubic feet, that will be released from storage in each vertical column of an aquifer with a height equal to the thickness of the saturated portion of the aquifer and a base one foot square when the hydrostatic head is lowered one foot.

The nonequilibrium formula as developed by Theis (1935) is used in calculating the coefficients of transmissibility and storage. This formula is based on certain assumptions: (1) the aquifer is homogeneous and isotropic; (2) the aquifer has infinite areal extent; (3) the discharge or recharge well penetrates and receives water from the entire thickness of the aquifer; (4) water taken from storage in the aquifer is discharged instantaneously with a decline in head; (5) the coefficient of transmissibility is constant at all times and at all places; and (6) the diameter of the well is infinitely small. The non-equilibrium formula for determining the drawdown in the vicinity of a pumping well which fully penetrates an ideal aquifer may be written as:

$$s = \frac{114.6\, Q\, W(u)}{T}$$

$$\text{where } W(u) = \int_u^{\infty} \frac{e^{-u}}{u}\, du$$

$$= -0.577216 - \log_e u + u \quad \frac{4^2}{2.2!} + \frac{4^3}{3.3!} - \frac{4^4}{4.4!} + \ldots\ldots$$

$$\text{and} \quad u = \frac{1.56\, r^2 S}{Tt}$$

where s = drawdown in feet at the observation well

Q = discharge or recharge of well, in imperial gallons per minute

T = coefficient of transmissibility, in gallons per day foot

r = distance in feet from the observation well to pumped well

S = coefficient of storage

t = time in days since pumping started.

Pumping tests were carried out at two localities to attempt determination of the hydrologic characteristics of the buried gravel.

In pump test #1, carried out in Sec. 28, Tp. 71, R. 10, one pumping well and three observation wells were used. The length of the pumping test was 48 hours and the rate of pumping was 20 gallons per minute. An average transmissibility of 4,400 gallons per day foot was determined by the Theis (1935) nonequilibrium method. The storage coefficient varied considerably from well to well, and reliable figures were not obtained. A possible reason for the extreme variance in the storage coefficients from one observation well to another is their inefficiency, especially in the early stages of the pumping test.

In pump test #2, carried out in Sec. 35, Tp. 71, R. 10, one pumping well and one observation well were used. The length of test was 48 hours and the rate of pumping was 42 gallons per minute. A transmissibility of 3,100 gallons per day foot was determined by the nonequilibrium formula. The storage coefficient was determined to be 9.0×10^{-4}. The transmissibility determined prior to the pumping test by the Theis (1935) recovery formula on a bail test of the pumped well, was 5,300 gallons per day foot. It has been found through experience, however, that bail tests usually indicate transmissibilities greater than those proved by eventual production, and allowance has to be made for these higher values. Generally the bail test is a good indicator of order of magnitude.

The amount of water moving through the buried gravel aquifer through the line A – B (Fig. 2) south of the Town of Beaverlodge was computed by Darcy's law, which may be expressed as $Q = PIA$, where

Q = amount of water discharged in a unit of time

I = the hydraulic gradient

A = the cross-sectional area through which the water moves.

The transmissibility, T, has been defined as the permeability multiplied by the saturated thickness of the aquifer, m. Therefore $T = pm$, and since $A = Lm$, where L is equal to the length through which the water moves perpendicular to the direction of flow, then:

$$Q = PIA = \frac{TIA}{m} = \frac{TILm}{m} = TIL .$$

The hydraulic gradient (I) was determined from the elevations of static water levels in wells within the buried channel. It was found to be 66 feet per mile perpendicular to the line A — B (Fig. 2). The average transmissibility (T) of the buried sands and gravels was 4,200 gallons per day foot. The length across the buried channel (L) on section line A — B (Fig.2) is 3.5 miles. The resulting amount of water moving perpendicularly across the line A — B of the channel was found to be 9.7×10^5 gallons per day.

At present, the approximate withdrawal of groundwater from the buried channel south of the town of Beaverlodge is probably in the order of 7.5×10^4 gallons per day, and thus there is an adequate amount available for considerable future development. Though hydrologically it is impossible to obtain all the water moving through the buried channel, a large proportion of this water could be developed with a thorough exploration and development program. Yields of up to 60 gallons per minute might be developed from wells in this buried sand and gravel.

The sandstone aquifers in the Wapiti formation vary considerably in transmissibility due to the rapid facies changes that are prevalent throughout the formation. The transmissibilities shown in table II are calculated from water wells finished in sandstone.

Table II. Coefficients of Transmissibility

Location of well 1/4	Sec.	Tp.	R.	Nature of well	Nature of test	Coefficient of transmissibility, gpdf.
SW.	36	74	10	flowing	press. recovery	11,300
SW.	7	74	7	flowing	press. recovery	400
SW.	21	72	7	flowing	press. recovery	300
NE.	20	72	7	flowing	press. recovery	1,500
NE.	36	71	10	nonflowing	bail test	7,700

UTILIZATION OF GROUNDWATER

Over 350 water wells are found in the Beaverlodge district which supply the needs of a population of approximately 5,500 people. Estimated daily consumption for domestic, farm and community water needs is slightly over 500,000 gallons per day, most of which is obtained from water wells.

Municipal Groundwater Supplies

Town of Beaverlodge: Consumption of groundwater within the Town of Beaverlodge was approximately 25,000 gallons per day in 1958. Consumption varies slightly above or below this figure depending on the season of the year.

Water is supplied from two wells through a central distribution system to approximately 180 services. One well is completed in sandstones of the Wapiti formation at a depth of 232 feet, and the other obtains water from sand and gravel above the bedrock at a depth of 135 feet. The water in the sand and gravel well is considerably harder than that of the well finished in bedrock; however, the bedrock well is considerably higher in soda. The bedrock well is used more during the winter months, because when used during the summer the soda content has an injurious effect on plant growth. Both wells are pumped at approximately 20 gallons per minute.

Water storage is in a 30,000 gallon reservoir located north of the town. Both water wells are metered and have airline gauges for taking water-level measurements.

Village of Wembley: Consumption of groundwater in the Village of Wembly is estimated at 5,000 gallons per day, and water is supplied through a central distribution system to approximately 50 services. An elevated storage tank provides a water reservoir within the village.

Production of approximately 8 gallons per minute is from a well completed in sandstone of the Wapiti formation at a depth of 105 feet. At present no regular system of keeping water-level measurements and production records is in force.

Hamlet of La Glace: The hamlet has no central distribution system and water is obtained from individual household wells drilled into sandstones of the Wapiti formation at depths ranging from 140 to 175 feet.

Domestic Groundwater Supplies

The geologic conditions are, for the most part, favorable for the development of water wells for domestic use at a reasonable cost. Sandstone throughout most of the area, and coal seams, locally, yield water in sufficient quantity for small wells. In addition, water-yielding sands and gravels are present in some localities. Difficulty may be encountered close to some of the major drainage channels, such as the lower Beaverlodge River, the Red Willow and Wapiti Rivers, as they have cut down as much as 200 and 300 feet below the level of the surrounding land. Thus it may be necessary to drill water wells to river level or below. The subsurface bedrock geologic conditions vary considerably with depth and areal extent, due to the lenticular nature of the water-bearing zones within the Wapiti formation. The depths at which groundwater is obtained vary considerably throughout the area (maps 59-2A and 59-2B).

GROUNDWATER QUALITY

The chemical quality of groundwater shows considerable variation throughout Alberta and depends on the type of materials that the groundwater has encountered in its migration to the water-bearing zone. The amounts of the individual and various combinations of the dissolved mineral constituents are usually expressed in water analyses as parts per million (p.p.m.).

Several chemical analyses of water in the Beaverlodge district are presented in the accompanying figures (Fig. 3, Table III). Graphs plotted on a logarithmic scale show the chemical concentration in parts per million. The shaded portions represent the variation in amounts of dissolved solids in water samples obtained from the two principal types of aquifers.

In the Beaverlodge district, as has been noted elsewhere in Alberta (Foster and Farvolden, 1958), hard waters generally occur in glacial and Recent deposits, and soft water in the bedrock. Fresh water percolating downward through the glacial materials apparently picks up calcium and magnesium. When these hard waters enter bedrock containing a high content of the clay mineral montmorillonite, the calcium and magnesium are exchanged for sodium and the water becomes softer, depending upon the length of time and degree of contact with the montmorillonite. As a consequence of this exchange, many domestic wells are drilled through glacial deposits containing hard water in search of softer water in the bedrock.

Hardness: The hardness of water is dependent on the concentration of calcium and magnesium sulfates or bicarbonates. Hardness is of two types, temporary and permanent. Temporary hardness is caused by the bicarbonates of calcium and magnesium, which precipitate on boiling. Permanent hardness is caused by the presence of the sulfates of calcium and magnesium, which cannot be removed by boiling. Temporary and permanent hardness are not distinguished in most water analyses, which are usually expressed in terms of hardness in parts per million of calcium carbonate.

Sulfates: The sulfates referred to in most Alberta water analyses reports are those of calcium, magnesium and sodium (Table III, Fig. 3). Magnesium sulfate (commonly known as "Epsom salts") if present in large amounts has a pronounced laxative effect on persons unaccustomed to it.

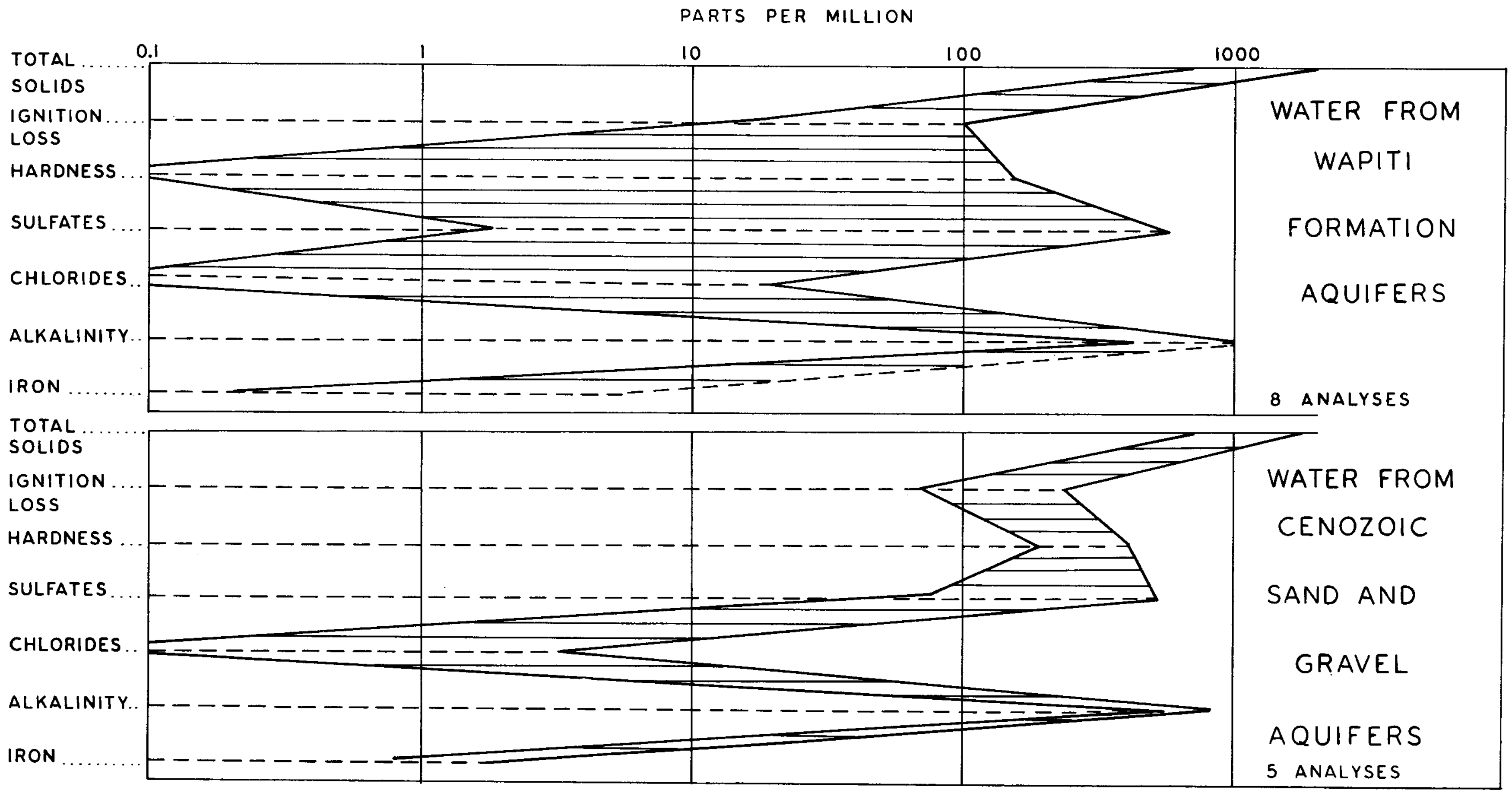
Chlorides: Chlorides are usually expressed as sodium chloride (common salt). They are usually found in all waters. Usually no taste is imparted unless concentrations of over 300 p.p.m. are present in the water. In the Beaverlodge district, the chloride content is higher in water from wells completed in bedrock than in the water obtained from wells in Cenozoic sands and gravels (Table III, Fig. 3).

Sodium: Compounds of sodium with carbonates and sulfates are very common in Alberta groundwater. Sodium sulfate combines with water to form what is known as "Glauber's salt" and excessive amounts make the water unsuitable for drinking purposes.

Table III. Selected Groundwater Analyses
(conc. p.p.m.)

Village, town or other locality	Location, W. 6th Mer. Sec.	Tp.	R.	Aquifer	Total solids	Ignition loss	Total hardness	Sulfates	Chlorides	Alkalinity	Nitrites	Nitrates	Iron	Nature of alkalinity	Soda, grains/ gallon
Beaverlodge	2	72	10	Wapiti	1244	100	0	75	18	925	-	-	0.2	Bicarb. Na	68.2
Beaverlodge	2	72	10	sand & gravel	1358	70	195	315	3	775	-	-	1.4	Bicarb. Na, Ca & Mg	43.0
La Glace	15	74	8	Wapiti	684	16	20	38	-	575	tr.	1.2	0.2	Bicarb. Na, Ca & Mg	41.18
Buffalo Lakes	4	74	7	Wapiti	1230	28	155	256	6	770	tr.	1.2	0.8	Bicarb. Na, Ca & Mg	45.63
Wembley	15	71	8	Wapiti	1790	100	20	586	16	600	-	-	0.4	Bicarb. Na, Ca & Mg	43.04
Farm well	28	71	10	sand & gravel	1554	230	425	508	-	600	-	-	1.5	Bicarb. Na, Ca & Mg	-
Farm well	7	74	7	sand & gravel	668	110	320	76	-	550	-	-	1.8	Bicarb. Na, Ca & Mg	17.07
Observation well	36	71	10	Wapiti	2116	64	30	616	4	915	-	-	5.0	Bicarb. Na, Ca & Mg	65.67
Test well	28	71	10	sand & gravel	1184	176	345	370	-	495	-	-	1.2	Bicarb. Na, Ca & Mg	11.13
Test well	35	71	10	sand & gravel	1176	112	180	235	1	695	-	-	1.0	Bicarb. Na, Ca & Mg	38.21
Farm well	21	72	7	Wapiti	930	108	140	2	11	820	-	-	0.2	Bicarb. Na, Ca & Mg	
Farm well	8	74	8	Wapiti	1228	148	240	208	12	765	-	-	0.7	Bicarb. Na, Ca & Mg	38.90
Farm well	20	72	7	Wapiti	960	130	160	22	14	800	tr.	0.5	0.5	Bicarb. Na, Ca & Mg	47.49

FIGURE 3 RANGE OF CHEMICAL COMPOSITION OF GROUNDWATER



Sodium carbonate, commonly known as "black alkali", is usually associated with soft waters.

Soda is generally expressed as grains per gallon and in excessive amounts is harmful to plants and corrosive to aluminum. The recommended upper limit for soda concentration in water is usually established at about 50 grains per gallon.

In the Beaverlodge district both bedrock- and drift-well waters are characterized by high soda concentrations, some of which are above the recommended limit.

Alkalinity: Alkalinity generally represents the content in parts per million of carbonates, bicarbonates and hydroxides present in water. The nature of the alkalinity is shown by the various cations that are listed, i.e. calcium, magnesium, and sodium.

In the Beaverlodge district the alkalinity is high (Table III, Fig. 3).

Iron: Excess amounts of iron are objectionable in a water supply because it stains clothing, plumbing fixtures, and often causes bad tastes and odors. Combined with sulfates it will corrode ferrous metals and brass. Although iron is present in most waters, amounts in excess of 0.5 p.p.m. are undesirable.

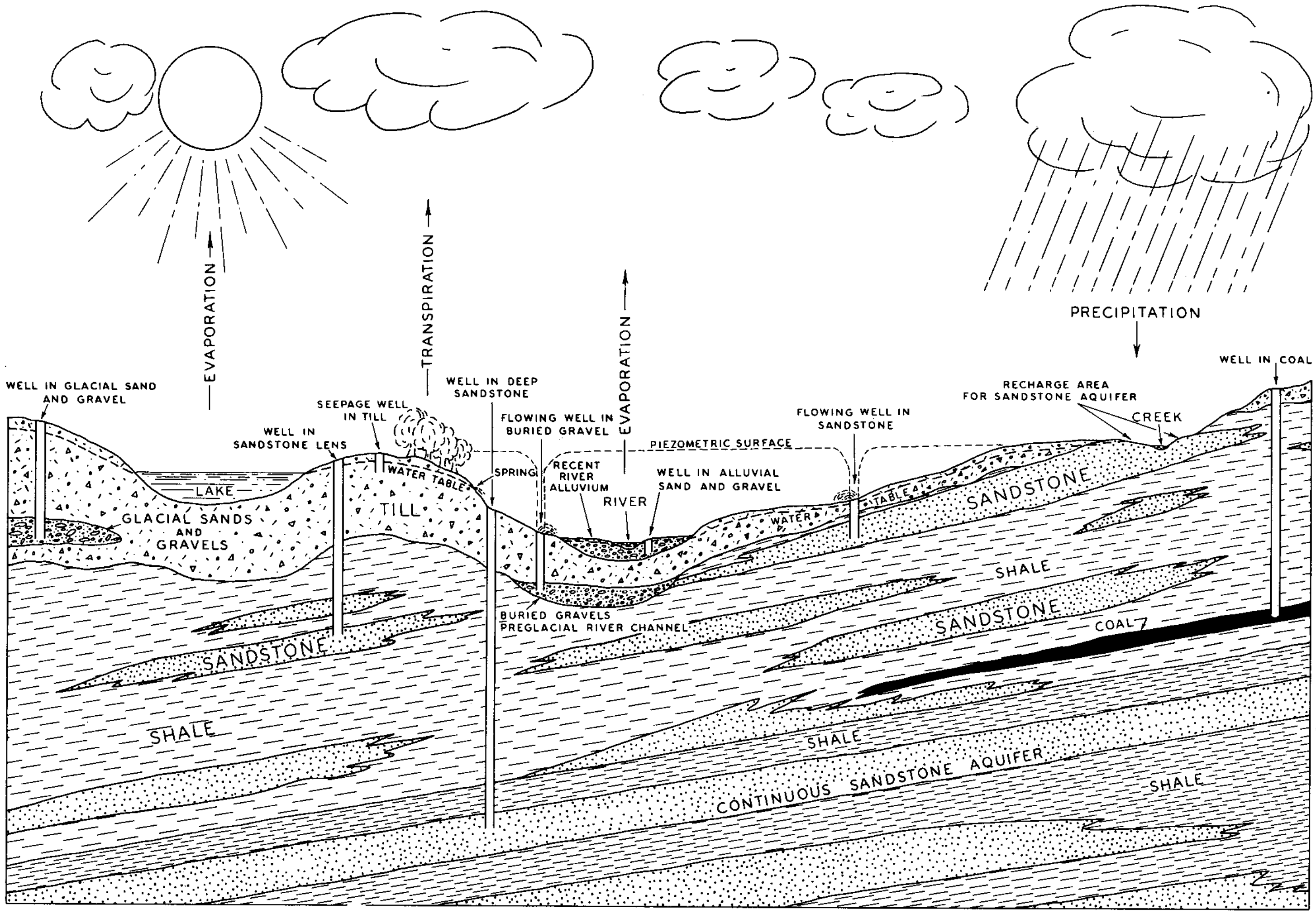
In the Beaverlodge district the iron content of the water obtained from Cenozoic sands and gravels is higher than that of water obtained from the Wapiti formation (Table III, Fig. 3).

Nitrates and Nitrites: Nitrates and nitrites indicate the presence of organic matter in the water and if present in large quantities may indicate that the water supply is being contaminated.

Fluorides: Fluorides are commonly found in natural waters and are desirable to aid in the prevention of dental caries. The suggested permissible limit for fluorides in water has been established at 1.0 p.p.m.

FIGURE 4

Diagram Illustrating General Occurrence of Groundwater, Alberta Plains.



RECOMMENDATIONS AND CONCLUSIONS

The Beaverlodge district is one of the few known areas in the Peace River region where, at the present time, an adequate supply of potable water can be obtained from water wells for most municipal and domestic use. The successful delineation by geological and geophysical means of a buried channel containing water-bearing sands and gravels in the district adds to the hope that similar conditions will be found elsewhere in the Peace River region where groundwater is difficult to obtain from wells.

The most favorable place for the development of large capacity water wells in the Beaverlodge district appears to be in: (1) the sands and gravels of the buried channel, and (2) the sand and gravels of recent river terraces adjacent to present river and stream courses. In the river terraces the groundwater would infiltrate from the river through the sand and gravel to the well. To determine the most favorable locations will entail a thorough exploration and development program.

The Wapiti formation strata, which supply most of the water for wells in the district at present, show extreme variability in lithology and therefore in aquifer coefficients. When setting up a test drilling program close control is necessary in order to establish the local aquifer characteristics.

It is recommended that the communities of the district which obtain groundwater from wells conduct pumping tests under proper supervision to determine local aquifer hydrologic characteristics. In this way the maximum utilization can be made of existing water wells and proper direction can be given to obtain additional supplies of groundwater as the communities grow. In addition, it is recommended also that the communities set up a regular system of recording water usage and keep systematic water-level records on existing wells. Each community should have its own observation wells in the aquifers being used, in order to keep a check on the groundwater level fluctuations.

The establishment of an observation well at the Dominion Experimental Farm at Beaverlodge in Wapiti formation strata is part of a program of the Groundwater Division in establishing water-level recorders in the major aquifers in different parts of the Province. It is hoped that over a considerable period of time the records will show a relationship between fluctuations of groundwater levels, and seasonal and major climatic changes.

Additional data concerning the hydrologic characteristics of the Wapiti strata are needed to make a more accurate analysis of the recharge and discharge, and to determine the aquifer coefficients. Collection of water-level and pumpage data should continue so that the effect of pumpage on water levels can be analyzed. It is hoped that more hydrologic data will become available for use in the future as the basic data are collected and synthesized. Every effort should be expended to obtain all the groundwater information so that the best policy for the maximum utilization and conservation of this most important resource can be established.

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APPENDIX I

LOCATIONS AND DEPTHS OF SEISMIC SHOT HOLES WHICH FLOWED WATER WHEN DRILLED
(Locations west of 6th Meridian)
1954 - 1958

	Sec.	Tp.	R.	Elev. (feet) above sea level	Depth (feet)
5290' W., 2490' S. of NE. cor.	20	73	10	2431	40
3550' W., 150' S. " " "	9	72	10	2332	55
3150' W. " " "	7	73	9	2481	20
725' W. " " "	31	73	9	2390	40
2780' S. " " "	20	73	10	2434	38
4100' S. " " "	20	73	10	2432	27
100' W. " " "	6	73	10	2414	35
680' S. " " "	31	73	9	2398	30
2590' W. " " "	11	74	9	2384	55
2725' W., 50'N. " " "	12	74	10	2401	40
1630' W., 4070'S. " " "	9	74	10	2483	35
2710' S. " " "	6	74	9	2376	40
4030' S. " " "	6	74	9	2389	40
4630' S. " " "	6	74	9	2394	18
580' S., 38' W. " " "	33	75	8	3023	--
540' S., 20' W. " " "	15	75	7	2756	--
SE. Lsd. 16	35	74	8	2511	62
SE. Lsd. 4	19	75	7	2936	42
2650' W , 10' N. " " "	9	72	10	2339	65

APPENDIX II.

WATER WELL RECORDS
(complete to July, 1959)

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 69, R. 10				
SW.	33	127	--	--	--	ss	-	
NW.	33	14	2308	--	--	sd	H	
				Tp. 70, R. 7				
NE.	18	385	2240	264	1976	ss	-	
NE.	21	15	--	-	--	-	H	
				Tp. 70, R. 8				
NE.	14	8	--	2	--	clay	H	water-table well
SE.	30	286	2240E	180	2060	ss	S	
SE.	34	266	2297	215	2082	ss	S	
SE.	34	395	--	200	--	ss	S	
NW.	35	217	--	60	--	ss	S	
NW.	35	217	2279	120	2159	ss	S	
NW.	36	327	2275E	150	2125	ss	S	

Key to appendix:

sd	- sand	H	- hard
ss	- sandstone	S	- soft
gr	- gravel	MH	- medium hard
c	- coal	VH	- very hard

* 2297 - Altimeter surveyed
2240E - Estimated from topographic maps

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 70, R. 9				
SW.	13	42	--	8	--	sd	MH	
NE.	16	60	2372	20	2352	ss	S	
SE.	21	325	2361	240	2121	ss	S	
NW.	21	254	2275E	109	--	ss	S	
NE.	22	235	2286	220	2066	ss	S	
SE.	22	240	2322	80	2242	ss	S	
SE.	23	175	2291	162	2129	ss	S	
SE.	28	165	2287	--	--	ss	S	
NE.	33	180	--	--	--	gr	H	
SW.	34	140	2265	65	2200	ss	S	
				Tp. 70, R. 10				
NE.	7	210	2326	50	2276	ss	-	
NW.	8	200	--	--	--	ss	-	
NW.	9	331	--	66	--	ss	-	
SE.	17	225	2313	--	--	ss	-	
SW.	17	170	2311	90	2221	ss	S	
SE.	18	160	--	130	--	ss	-	
SW.	18	80	2313	45	2268	--	S	
NE.	20	240	2250	100	2150	ss	S	
NW.	20	203	2150	20	2130	ss	-	
SW.	28	180	2280E	160	2120	ss	-	
NW.	32	98	2391	40	2351	ss	-	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 70, R. 10 (continued)				
SE.	33	228	2375E	150	2225	ss	-	
SW.	33	--	--	--	--	-	-	Well abandoned
				Tp. 71, R. 7				
SE.	17	190	2283	30	2253	ss	-	
SW.	21	160	2308	140	2168	ss	-	
				Tp. 71, R. 8				
N. 1/2	2	120	2300	80	2220	ss	H	
NW.	2	121	2317	80	2237	ss	MH	
SW.	3	310	2320	80	2240	ss	S	
SE.	4	8	2252	2	2250	drift	H	
SW.	8	180	--	--	--	ss	-	
SE.	12	85	--	60	--	-	-	
NW.	12	12	--	6	--	drift	H	
NE.	14	85	2365	60	2305	ss	-	
NE.	15	127	2390	46	2344	ss	S	
NW.	15	145	2403	70	2333	ss	S	Village well
NE.	18	118	2375	20	2355	ss	S	3 wells about same depth
NW.	21	90	2407	--	--	-	H	
NE.	22	153	2408	65?	2333?	ss	-	
NW.	22	80	2275E	30	2245	-	H	
SE.	33	152	2445	150	2295	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 71, R. 9				
SW.	3	185	2260E	95	2165	gr	S	
NW.	3	155	2280E	90	2190	sd & gr	H	
NW.	5	77	2250E	72	2178	gr	H	
SW.	6	365	2360E	65	2295	ss	S	
SW.	6	405	--	260	--	ss	S	
NE.	9	276	2350E	140	2210	ss	S	
NW.	9	188	2330E	120	2210	gr?	H	
SE.	10	166	2360E	30	2330	ss	-	
NE.	12	160	2375E	19	2356	ss	S	
SE.	19	128	2340E	60	2290	ss	-	
NE.	22	136	--	19	--	-	S	
NE.	22	30	2465	1	2464	c	S	
SW.	22	115	2430E	18	2412	-	S	
NW.	23	105	--	5	--	ss	S	
NW.	23	37	2464	1	2463	ss	S	
NW.	24	40	2487	--	--	-	MH	abandoned
SE.	25	101	2517	80	2437	ss	S	
NW.	30	125	--	--	-	ss	MH	
NE.	32	186	2521	45	2476	ss	S	
SW.	32	--	2427	flowing	-	gr	-	spring
NW.	33	185	2546	--	--	ss	-	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 71, R. 10				
W. 1/2	1	180	--	--	--	ss	S	
NE.	2	140	--	--	--	ss	S	
SW.	2	294	2355	70	2285	ss	S	
NE.	5	138	--	60	--	-	MH	
SE.	8	80	2350E	35	--	ss	MH	
NE.	9	120	2375	20	2350	sd & gr	H	
NE.	10	220	2381	100	2281	ss	S	
SE.	11	46	--	6	--	sd & gr	H	
SW.	11	150	2408	70	2338	ss	S	
NW.	11	163	2417	79	2338	ss	S	
NE.	15	275	2388	--	--	ss	MH	
NW.	15	108	2405	80	2325	ss	H	
SW.	16	240	2408	90	2318	ss	S	
SE.	17	120	2401	--	--	-	H	
NE.	20	84	2500	80	2420	ss	S	
SW.	21	78	2500E	68	2432	-	MH	
NW.	23	15	2248E	8	2240	sd & gr	H	
SW.	25	87	2307	25	2282	gr	-	
SE.	27	57	2298	12	2286	gr	MH	
SW.	28	78	2334	45	2289	sd & gr	VH	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
NE.	32	6	--	flowing	--	gr	H	spring
NE.	35	214	2420	64	2356	ss	S	
NW.	35	112	2335	40	2290	gr	H	
SW.	36	64	2325E	25	2300	ss	S	
NW.	36	30	--	20	--	gr	H	
				Tp.72, R. 7				
SE.	7	341	2346	100	2246	ss	S	
SW.	17	385	--	--	--	ss	S	
NW.	18	183	2364	--	--	ss	S	
NE.	20	104	2180	flowing	2180+	ss	MH	
SW.	21	110	2174	flowing	2174+	sd?	S	
				Tp. 72, R. 8				
SE.	4	270	2518	220	2248	ss	S	
SE.	9	28	2589	flowing	2589+	c	MH	
SE.	9	32	2594	4	2590	c	MH	
NE.	12	140	2339	45	2294	ss	S	
NW.	13	141	2360	--	--	ss	S	
SE.	23	247	2432	120	2312	ss	S	
SW.	28	130	2428	75	2353	ss	S	
SE.	33	248	2351	65	2286	ss	S	
NE.	34	196	--	8	--	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 72, R. 9				
SW.	6	97	2381	15	2366	sd?	H	
NW.	6	186	2404	75	2329	ss	S	
SE.	8	206	2604	10	2594	ss	S	
SE.	18	80	2459	65	2394	ss	S	
SW.	19	271	2595	--	--	ss	S	
NE.	25	105	2486	45	2441	ss	S	
SE.	30	185	2595	130	2465	ss	S	
SW.	31	195	2493	30	2463	ss	S	
NW.	33	185	--	5	--	ss	S	
				Tp. 72, R. 10				
SW.	1	295	--	143	--	ss	S	
NW.	1	180	2475E	170	2375	ss	S	
SE.	2	162	--	27	--	ss	-	
SW.	2	142	--	110	--	sd?	H	
SW.	2	137	--	30	--	sd	S	
NW.	2	150	2363	68	2295	sd & gr	H	town well
NW.	2	232	2380	79	2301	ss	S	town well
NW.	2	157	--	--	--	ss	-	
NW.	9	78	2360	flowing	2360+	-	MH	
NE.	10	215	--	100	--	ss	-	
SE.	10	171	2416	80	2336	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 72, R. 10 (continued)				
NE.	11	50	--	3	--	ss	S	
NW.	11	--	--	flowing	--	-	-	spring
SE.	13	160	2575E	15	2560	ss	H	
SW.	13	126	--	20	--	c	-	
SW.	14	22	2519	18	2501	ss	H	
SE.	16	165	2364	9	2355	ss	S	
NE.	20	125	2400E	flowing	2400+	sd or ss?	-	
SE.	21	135	--	8	--	gr	MH	
NE.	25	105	--	45	--	ss	S	
SW.	25	98	--	40	--	ss	-	
SE.	27	280	2485	--	--	ss	S	
SW.	27	150	2418	9	2409	-	MH	
SE.	28	157	2422	7	2415	ss	S	
NW.	33	121	2476	61	2415	ss	S	
SW.	34	50	2457	--	--	-	S	
				Tp. 73, R. 7				
SE.	8	135	2220	flowing	2220+	ss	S	
SW.	16	125	2296	40	2256	ss	S	
SE.	17	135	2353	130	2223	ss	S	
SW.	20	80	2302	40	2262	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
			Tp. 73, R. 7 (continued)					
NW.	21	211	2382	156	2226	ss	S	
SW.	28	180	2404	40	2364	ss	S	
SE.	29	263	2386	140	2246		S	
			Tp. 73, R. 8					
SW.	3	172	2296	14	2282	ss	S	
SE.	4	200	2317	20	2297	ss	S	
NE.	7	280	2428	40	2388	ss	S	
NE.	9	280	2441	150	2291	ss	S	
SE.	9	190	2387	45	2342	ss	S	
NW.	10	280	2387	115	2272	ss	S	
SW.	14	200	2272	flowing	2272+	ss	S	
SE.	15	354	2325	45	2280	ss	S	
SW.	15	312	2431	150	2281	ss	S	
NE.	16	300	2472	180	2392	ss	S	
SW.	16	390	2477	190	2287	ss	S	
SW.	17	280	2423	100	2323	ss	S	
SE.	18	317	2422	144	2278	ss	S	
SE.	20	330	2490	154	2336	ss	MH	
SW.	20	8	2456	6	2450	sd	S	water-table well
NE.	24	120	2252	flowing	2252+	sd?	S	
SE.	25	207	2336	55	2281	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 73, R. 8 (continued)				
SE.	26	140	2275	flowing	2275+	ss	S	
NE.	30	175	2466	140	2326	ss	-	
SE.	30	164	2468	34	2434	ss	S	
NW.	30	160	2438	90	2348	ss	H	
SW.	31	286	2427	30	2397	ss	S	
NW.	31	320	2414	20	2396	ss	S	
NW.	32	308	2377	32	2345	ss	S	
SE.	33	440	--	8	--	ss	S	
NE.	34	80	--	12	--	ss	S	
NE.	36	180	2415	60	2365	ss	S	
				Tp. 73, R. 9				
SW.	6	185	--	14	--	ss	S	
NE.	9	263	2502	60	2442	ss	S	
SW.	9	243	2513	70	2443	ss	S	
NW.	16	182	2556	140	2416	ss	S	
NW.	18	82	2509	50	2459	ss	S	
NW.	20	272	--	130	--	ss	S	
SE.	28	178	2467	100	2367	ss	S	
NW.	29	250	2437	60	2377	ss	S	
NE.	31	32	--	flowing	--	drift	-	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 73, R. 9 (continued)				
NE.	31	215	2405	15	2390	ss	S	
SE.	33	60	2399	44	2355	gr	H	
NE.	35	105	--	55	--	-	-	
				Tp. 73, R. 10				
SW.	2	160	2482	60	2422	ss	S	
NW.	2	55	2494	20	2474	ss	S	
SW.	9	10	2542	8	2533	ss	H	water-table well
NW.	9	165	2529	70	2459	ss	S	
SW.	12	101	2484	27	2457	ss	S	
NW.	12	238	2452	4	2448	ss	H	
SW.	14	132	2516	62	2454	ss	S	
SW.	16	240	2509	65	2444	ss	S	
SE.	17	64	2524	57	2467	ss	H	
NW.	20	100	--	flowing	--	ss	S	3 wells to same depth
SE.	21	165	2517	50	2467	ss	H	
NW.	21	82	2460	flowing	2460+	ss	S	
NW.	21	64	--	1	--	ss	S	
SW.	22	140	2553	70	2443	ss	S	
NE.	23	120	2469	18	2451	ss	S	
SE.	26	80	2494	28	2466	ss	S	
NW.	35	150	2487	55	2432	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 74, R. 7				
SW.	4	220	--	--	--	ss	S	village well
SW.	7	120	--	flowing	--	ss	H	
NE.	8	32	2482	5	2477	-	H	
NE.	17	6	--	flowing	--	gr	H	
SE.	18	110	--	50	--	sd	H	
NW.	18	60	--	18	--	sd	H	
NE.	19	--	2539	flowing	2539+	ss?	-	
SE.	20	12	2501	flowing	2504	-	MH	
SW.	28	176	2546	25	2521	c	S	
NE.	29	208	2631	90	2541	ss	S	
SW.	29	43	2556	37	2519	ss	H	
NW.	31	125	2611	60	2551	ss	S	
NW.	32	7	2667	flowing	2667+	drift	-	
				Tp. 74, R. 8				
SW.	4	295	2422	140	2282	ss	S	
NE.	7	209	2398	20	2378	ss	-	
NE.	8	103	--	63	--	sd & gr	-	
NE.	9	134	--	90	--	sd	-	
SW.	9	196	--	100	--	ss	S	
NW.	9	110	--	--	--	ss?	H	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 74, R. 8 (continued)				
NW.	9	262	2435	70	2365	ss	-	
SE.	10	199	--	17	--	ss	S	
NW.	12	58	2456	35	2421	ss	H	
SE.	14	77	2466	9	2455	ss	H	
SW.	15	140	--	60	--	ss	S	village well
SW.	15	140	--	60	--	ss	-	village well
SW.	15	103	--	--	--	ss	S	village well
SW.	15	149	--	46	--	ss	S	village well
SW.	15	146	2402	60	2342	ss	S	village well
SW.	15	170	--	100	--	ss	S	village well
SW.	15	170	2416	--	--	ss	-	village well
SW.	15	60	--	49	--	-	MH	village well
NE.	16	90	--	60	--	ss	S	
NW.	16	200	2500	125	2375	ss	S	
SW.	17	105	2409	35	2364	ss	S	
SE.	18	87	2418	20	2398	ss	S	
SE.	20	206	--	100	--	ss	S	
NE.	21	150	2431	32	2399	ss	-	
SE.	22	120	2433	60	2373	sd?	S	
SE.	23	23	2465	18	2447	ss	-	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 74, R. 8 (continued)				
SE.	24	180	--	100	--	ss	MH	
NW.	24	221	--	60	--	ss	-	
NE.	26	145	2504	90	2414	ss	-	
SW.	26	125	2510	80	2430	ss	-	
NE.	27	138	--	40	--	ss?	S	
SE.	29	115	2425	20	2405	ss	-	
NE.	32	123	2545	115	2430	ss	H	
NE.	33	70	2518	45	2463	ss	MH	
SW.	33	48	--	8	--	ss	H	
NW.	34	165	2511	28	2483	ss	H	
NE.	36	215	2588	30	2558	ss	-	
				Tp. 74, R. 9				
NW.	3	170	2395	8	2387	ss	S	
SE.	4	80	2392	20	2372	ss	H	
SE.	6	70	2388	flowing	2388+	ss	S	
NE.	8	130	2423	30	2393	ss	S	
SE.	8	30	--	26	--	sd?	MH	
NW.	12	100	2393	20	2373	ss	S	
SW.	13	122	2397	12	2385	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation* (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 74, R. 9 (continued)				
SW.	14	76	2422	60	2362	ss	H	
SE.	17	100	2440	50	2390	ss	S	
SW.	17	90	2412	42	2370	ss	S	
NW.	17	96	2440	31	2409	ss	S	
SE.	18	240	2416	15	2401	ss	S	
SW.	18	124	--	0	--	ss & c	S	
NE.	19	207	2557	60	2480	ss	S	
NW.	19	27	--	10	--	-	H?	
NE.	21	110	2516	70	2446	ss	S	
NE.	22	92	2557	77	2480	sd	-	
NW.	23	188	2530	100	2430	ss	S	
SE.	24	33	2433	20	2413	ss	S	
SW.	26	98	2546	20	2526	ss	S	
SE.	27	120	2569	110	2450	ss	H	
SW.	27	85	2532	40	2492	sd	-	
NW.	27	11	--	1	--	gr	H	
NE.	28	140	2527	50	2477	ss	S	
SW	30	171	--	40	--	ss	S	
NE.	36	90	--	2	--	-	H	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation * (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 74, R. 10				
SE.	1	116	2400E	20	2380	ss	S	
SE.	2	149	2477	26	2451	ss	S	
NW.	2	92	2467	14	2453	ss	S	
SE.	3	145	2480	40	2440	gr	-	
NE.	10	120	2492	25	2467	ss	S	
SW.	10	124	--	8	--	ss	-	new well
NW.	10	130	2484	9	2475	ss	S	
NW.	11	112	2467	23	2444	ss	H	
NE.	12	108	--	8+	--	ss	S	
SW.	13	90	2435	2	2433	ss	S	
SE.	14	125	--	35	--	ss	-	
SW.	22	60	--	--	--	ss	S	
SW.	23	75	2490	40	2450	sd	H	
NW.	24	82	--	30	--	ss	-	new well
NE.	25	78	--	19	--	ss	H	
SE.	27	130	2463	2	2461	ss	S	
NW.	28	121	2529	9	2520	ss	S	
NW.	32	99	2517	--	--	ss	S	
NE.	34	104	2475	10	2465	ss	S	
NE.	36	--	--	flowing	--	ss	S	60 g.p.m.

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 75, R. 8				
SW.	1	6	2532	flowing	2532+	-	H	
NE.	4	50	--	27	--	ss	H	
SE.	4	55	2501	35	2466	ss	H	
NE.	6	130	2599	80	2519	ss	S	
SE.	6	26	2528	20	2508	ss	H	
NW.	9	87	2590	30	2560	ss	S	
SE.	18	60	2642	20	2622	ss	H	
SW.	18	20	--	4	--	-	S	
				Tp. 75, R. 9				
SE.	3	160	2707	--	--	ss	S	
SW.	3	28	2670	23	2647	ss	S	
NW.	3	140	2672	70	2602	ss	S	
SW.	4	142	2546	60	2486	ss	S	
SW.	5	143	2544	65	2479	ss	H	
NW.	5	178	--	30	--	ss	MH	
NW.	6	131	2552	29	2523	ss	H	
NE.	7	240	2562	12	2550	ss	S	
SW.	7	150	2559	19	2540	ss	S	
NW.	7	95	2565	20	2545	sd?	H	
NW.	8	175	2535	flowing	2535+	ss	S	

Location W. 6th Mer. 1/4	Sec.	Well depth (feet)	Surface elevation (feet)	Depth to water level (feet)	Piezometric surface elevation (feet)	Aquifer	Quality	Remarks
				Tp. 75, R. 9 (continued)				
NE.	9	77	--	24	--	ss	-	
NE.	18	62	2578	9	2569	ss	S	
SE.	19	145	--	12	--	ss	S	
				Tp. 75, R. 10				
SE.	2	90	--	46	--	ss	-	
SE.	2	10	2493	4	2489	ss	H	
SW.	2	40	2487	26	2461	ss	H	
SW.	3	46	2495	11	2484	ss	S	
SW.	4	40	2513	10	2503	ss	S	
NW.	4	80	2513	15	2498	ss	S	
NE.	9	12	2525	flowing	2525+	ss	S	
SW.	11	59	2548	20	2528	ss	S	

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LEGEND

FLOWING WELLS COMPLETED IN:

- Sandstone .... ▲
- Coal .... ●
- Sand, gravel .... ■

SPRING .... ♀

NON-FLOWING WELLS COMPLETED IN:

- Sandstone .... △
- Coal .... ⊕
- Sand, gravel or both .... □

Depth of well in feet .... 130△

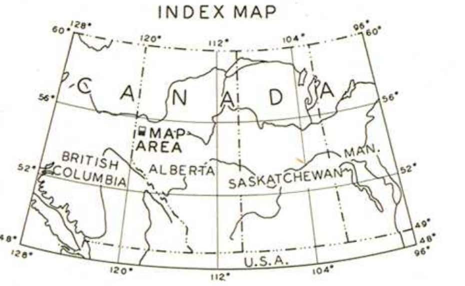
Groundwater geology by J.F. Jones, 1959.

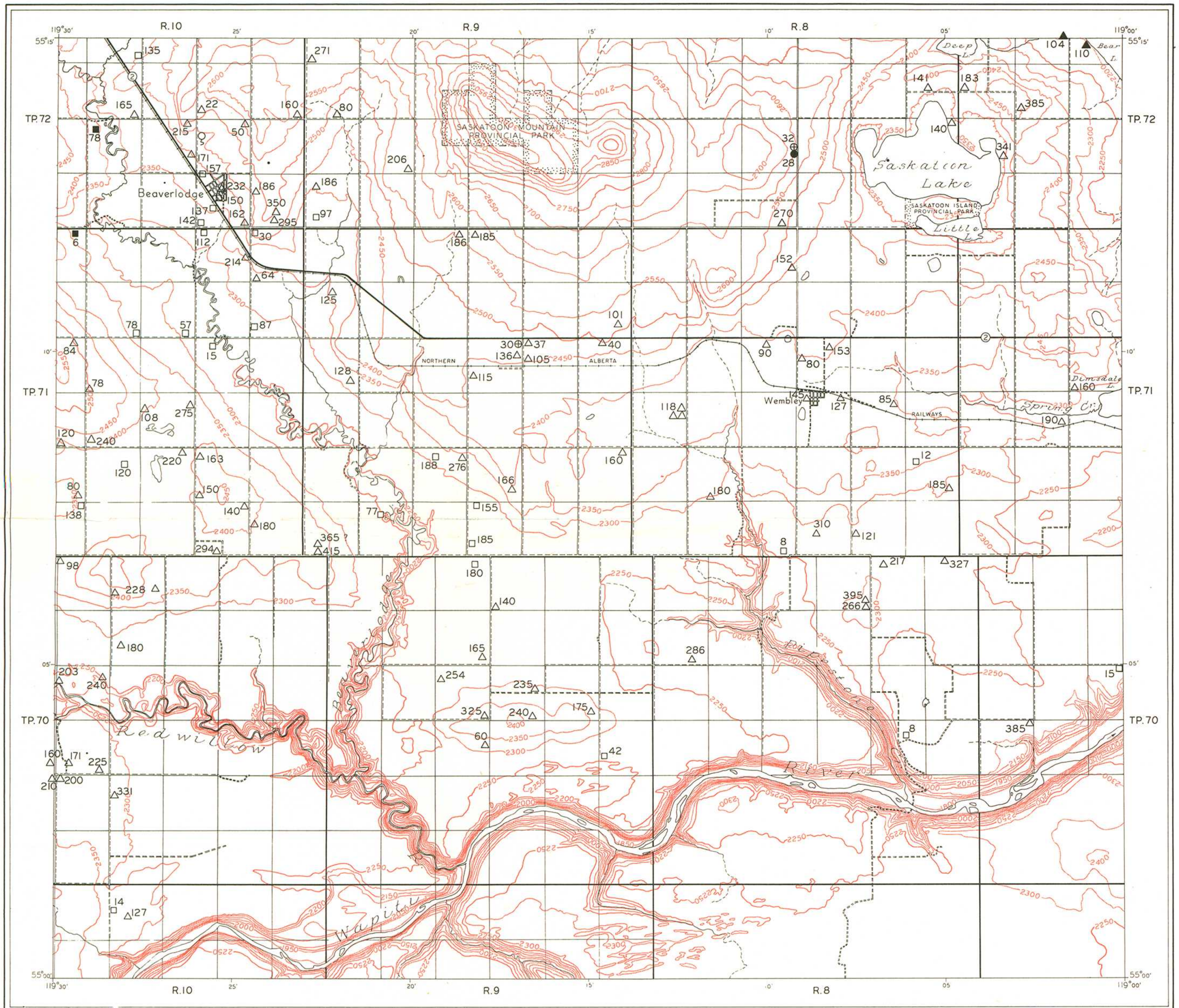
- Main highway .... ②
- Local road, well travelled
- Local road, not well travelled
- Trail
- Railway
- Township boundary (surveyed)
- Township boundary (unsurveyed)
- Section line
- Town or village
- Post office or railway station .... ○
- Stream (intermittent)
- Contours, elevation (interval 50 feet) 2200
- Contours, depression 1800
- Height in feet above mean sea-level .... 2372±

Base map compiled from Department of Lands and Forests, Alberta, Planimetric Sheet 83 M/3.

Topography taken from Department of National Defence, National Topographic Series Sheet 83 M/3 East half and 83 M/3 West half.

INDEX MAP





Map to accompany Preliminary Report 59-2.

Published in 1960.

MAP 59-2A

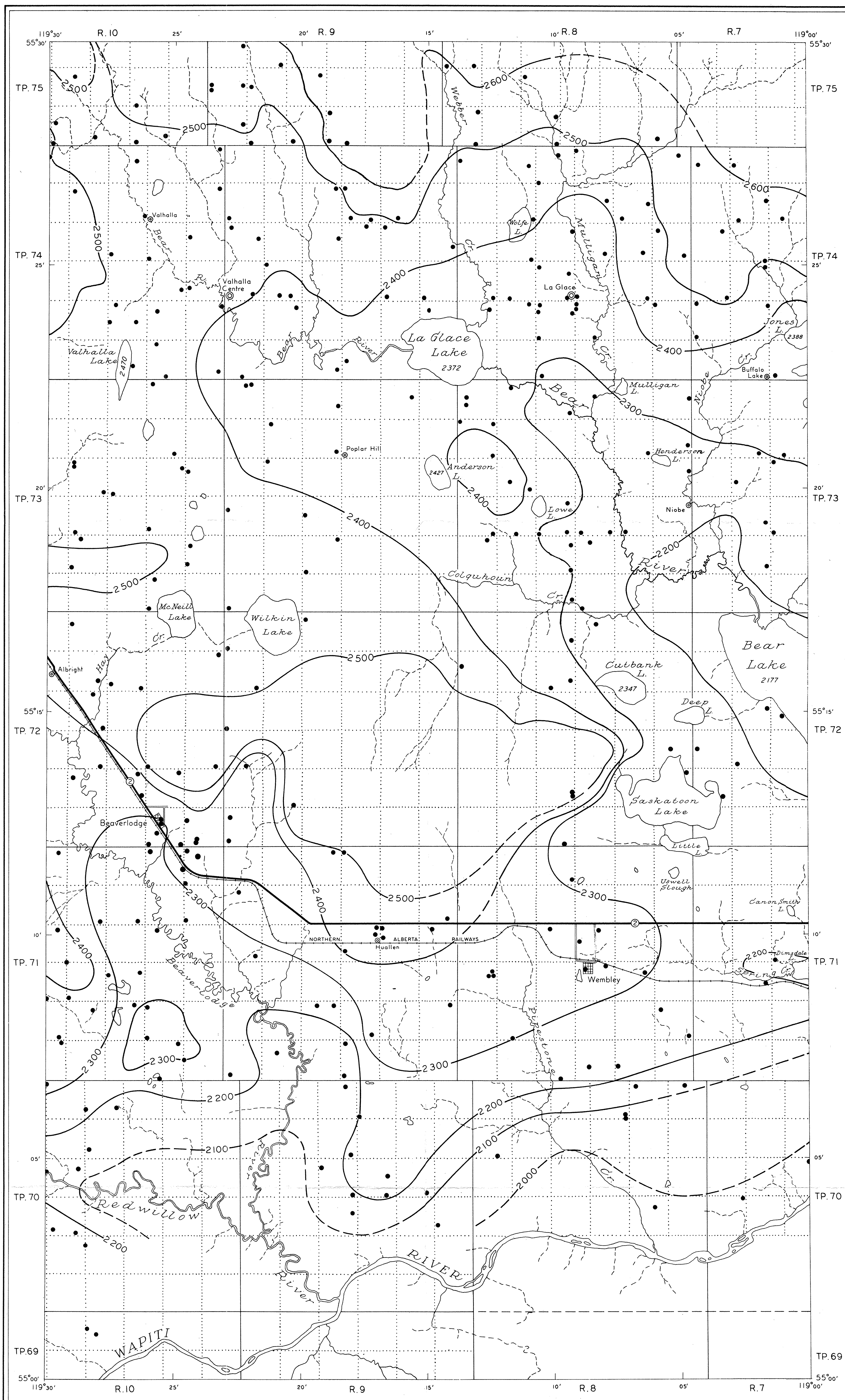
GROUNDWATER GEOLOGY

BEAVERLODGE DISTRICT, ALBERTA

WEST OF SIXTH MERIDIAN

Scale: One Inch to Two Miles = 1/126,720

RESEARCH COUNCIL OF ALBERTA
GROUNDWATER DIVISION



Map to accompany Preliminary Report 59-2

Published in 1960

MAP 59-2C

Piezometric Surface, Summer 1958, Beaverlodge District, Alberta

WEST OF SIXTH MERIDIAN

Scale in Miles

1 0 1 2 3 4 5 6 MILES

LEGEND

Water well location .... •

Contour on piezometric surface (location known) .... —2300—

Contour on piezometric surface (location approximate .. – –2500– –

Contour interval 100 feet

Height in feet above mean sea-level 2177

AGS 1959-2C c.1