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Hydrogeology of the Edmonton area (northeast segment), Alberta

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HYDROGEOLOGY OF THE EDMONTON AREA (NORTHEAST SEGMENT), ALBERTA

ABSTRACT

The northeast segment of the Edmonton map area (NTS 83H) covers about 1750 square miles (4500 km^2) within the Eastern Alberta Plains physiographic region. It has a microthermal climate with long, cool summers and receives an average of 17 inches (430 mm) of precipitation annually, 70 percent as rain.

Glacial and postglacial deposits overlie a succession of Upper Cretaceous shales, siltstones, sandstones, and coals. Within these deposits, aquifers consisting of sand, sand and gravel, gravel, sandstone, and fractured coal and shale are capable of yielding groundwater at rates of up to 100 igpm (7.6 l/s).

Natural groundwater movement is of a complex nature, showing effects of both topography and permeability variations.

Hydrochemistry is highly variable, especially in surficial aquifers, but groundwater is generally of the sodium bicarbonate type with total dissolved solids between 1000 and 2000 ppm. More highly mineralized groundwater occurs locally (total dissolved solids of up to 6000 ppm) and is either of the chloride or sulfate type. Many shallow wells completed in drift aquifers contain substantial amounts of nitrates.

INTRODUCTION

The Edmonton area (northeast segment) hydrogeological map is one of a series which will soon cover the entire province of Alberta. In this series the 1:250,000 NTS map sheets constitute the basic map unit. Because of several interrelated factors unique to the Edmonton area, namely, population density, availability of relatively large amounts of data, and potential increases in population and industrial activity, a more detailed understanding of the hydrogeology than is normally provided by the mapping scale of 1:250,000 is desirable. The NTS 83H map area was, therefore, divided into four quadrants and mapped at a scale of 1:125,000.

The northeast segment of the Edmonton map area comprises about 1750 square miles (4500 km^2) located between longitudes 112° and 113°15' west and latitudes 53°30' and 54° north. With respect to the Alberta land survey system it contains all or parts of townships 52 to 58 and ranges 14 to 22, west of the fourth meridian.

Previous hydrogeologic studies, all or portions of which are located within the area, were conducted by Domenico (1959), Le Breton (1963a, 1963b, 1966), and Akiti (1975). A map of the bedrock surface of the entire area at a scale of approximately 1:400,000 was provided by Farvolden (1963) and for a small portion in the southwest corner of the area by Carlson in 1966 at a scale of 1:50,000. A map of the bedrock topography and drift thickness at a scale of 1:125,000 was prepared simultaneously with this hydrogeological investigation and will be published separately (Stein, in preparation).

Information regarding the surficial geology of all or parts of the map area has been published by Bayrock and Hughes (1962) and Bayrock (1972) at scales of 1:50,000 and 1:250,000, respectively. MacPherson and Kathol (1973) published information regarding sand and gravel occurrences in the Edmonton area and a portion of their report falls within the southwestern part of the map area.

Bowser *et al.* (1962) reported on and mapped the soils of the entire NTS 83H map area at a scale of 1:126,720.

Geology of the bedrock has been reported on by various workers. Most notable of the later studies were Allan and Sanderson (1945), Ower (1958), Elliot (1958), and Irish (1970). All have proposed various subdivisions of the Edmonton Group, the latest proposal by Irish being the one presently accepted. Shaw and Harding (1949) first used the term Belly River as a formation name and their terminology with respect to the formation and its various members is still in present use. Geological maps available for the area include those of Rutherford (1939a, 1939b) and Green (1972) at scales of 1:253,440 and 1:1,267,000, respectively. A paper dealing with occurrence of coal zones in the lower portion of the Horseshoe Canyon Formation was prepared by Pearson (1961).

The land in the region is cultivated, except for Elk Island National Park and areas with unsuitable soils or topography. Such areas include portions of the extensive dune fields east, south and west of Redwater, the dune field northwest of the town of Andrew, and parts of the hummocky moraine south and west of Elk Island National Park. The last-named area has recently experienced a substantial population increase because of its proximity to the city of Edmonton.

Sixteen small towns serve the local farming communities and, except for the towns of (populations in brackets) Fort Saskatchewan (8000), Lamont (1000), Redwater (1500), and Vegreville (4000), depend on groundwater for their water supply. Major industrial activity is limited to the towns of Fort Saskatchewan and Redwater, and is largely petrochemically and metallurgically oriented. Mineral resources of the area include hydrocarbons (the Redwater Oilfield, one of the largest in Alberta, is located in the area), coal, salt, silica sand, gravel, and clay.

With respect to vegetation, the area is situated on the southern fringe of what was originally an aspen forestland. A small portion in the southeast was parkland with aspen poplar and grasses as dominant plant species. Other species whose range presently extends into the area are: jackpine (*Pinus banksiana*) in sand dune areas, white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*) along the North Saskatchewan River, black spruce (*Picea mariana*), tamarack (*Larix laricina*) and water birch (*Betula occidentalis*) in swamps and peat bogs, and balsam poplar (*Populus balsamifera*) and white birch (*Betula papyrifera*) where conditions are favorable.

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TOPOGRAPHY AND DRAINAGE

The map area lies within the eastern Alberta region of the interior plains. With respect to drainage, it is located entirely within the North Saskatchewan River Basin.

Topography within the area is essentially the result of preglacial, glacial, and recent activity, both erosional and depositional, on geologic materials of varying resistance to erosion. Major topographic features follow geological strike directions. Thus, the overall picture is a series of northwest- to southeast-oriented topographic ridges underlain by relatively resistant bedrock, separated by valleys underlain by less resistant bedrock. This pattern is broken only by the North Saskatchewan River which, upon entering the map area in the southwest, flows across strike, then shifts direction until it flows parallel to the direction of strike at its final exit from the northeast portion of the map area.

The ridges are the Elk Island High in the southwest, the Chipman Hills in the central portion, and an unnamed high area in the northeast portion of the map area. Their maximum elevations are about 2500 feet (760 m), 2250 feet (685 m), and 2400 feet (730 m), respectively.

Separating the topographically high areas are broad, flat plains which coalesce in the north-central portion of the map area to form what Le Breton (1966) termed the Star Plain. Beaverhill Lake and Beaverhill Creek occupy that portion of the Star Plain separating the Elk Island High and Chipman Hills and drain entirely towards the northwest, into the North Saskatchewan River. The low area separating the Chipman Hills from the northeasternmost ridge is occupied by the Vermilion River in its southern portion and by Whitford Lake and Egg Creek which drain northwest into the North Saskatchewan River.

Superimposed on the above topographic system are morphological features which owe their existence to the area's glacial and postglacial history. Most of the map area is covered by ground moraine and exhibits a level to undulating topography. The Elk Island High, however, is capped by disintegration moraine and thus is characterized by undulating to gently rolling, knob and kettle topography with numerous surface water bodies occupying local depressions. An approximately 10-mile (16 km) wide band containing numerous glacial meltwater channels extends diagonally across the map area and is responsible for the bisected topography of the northern portions of the Star Plain and the eastern flank of the Chipman Hills. A high local relief and characteristic dune field morphology is associated with extensive areas of aeolian sand and silt in the northwestern and north-central parts of the map area. Finally, the postglacial North Saskatchewan River valley is a striking feature, cutting from 100 to more than 300 feet (30 to 90 m) into the surrounding landscape. The valley is steep-sided and generally less than 1/2 mile wide in areas of thin drift cover and becomes noticeably wider with more gently sloping sides where drift cover is thick.

CLIMATE

According to the Koeppen system of climatic classification (Longley, 1972), the area's climate is microthermal with long cool summers (average temperature of the warmest month above 10°C, and of the coldest month below -3°C; summers with a mean temperature of the warmest month below 22°C and at least four months with mean temperatures of 10°C or more).

Long-term meteorological information is not available for any location within the map area. However, a nearly complete record since 1880 exists for stations in and near Edmonton, about 10 miles (16 km) west of the southwest corner of the map area. A station, located just south of the area, near Vegreville, has complete records available from 1958. Data from the Vegreville and other, more recently established stations have been included on the meteorological side map even though they may not be representative of long-term climatic conditions.

The following information has been taken from maps published in the Atlas of Alberta (Alberta, Government and University, 1969) and is representative of conditions averaged over the period 1931 to 1960 unless otherwise specified.

The mean annual range in temperature is about 32 Celsius degrees. January is the coldest month, with a mean temperature of about -14°C in the southwest and -17°C in the northeast; July is the warmest with an average temperature of 17°C. Between the years 1951 and 1964 the last spring frost usually occurred between May 15 and May 31 over most of the area; however the northern one third occasionally experienced frost in early July. The first fall frost usually occurred between September 1 and 15 and the usual frost-free period was 100 to 120 days long.

Isohyets shown on the meteorological side map are modified from Longley (1968). Mean annual precipitation varied from just under 16 inches (400 mm) in the northeast to just over 18 inches (450 mm) in the southwest. Approximately 70 percent of this fell as rain and 10.5 to 11 inches (270 to 280 mm) fell during the growing season (April to August). Average potential evapotranspiration is approximately 21 inches (530 mm).

GEOLOGY

BEDROCK GEOLOGY

Bedrock formations within 1000 feet (300 m) of the ground surface are entirely of Late Cretaceous age and, in ascending order, the succession is Lea Park, Belly River, Bearpaw, and Horseshoe Canyon Formations. Because of difficulties in recognizing the very thin Bearpaw Formation, it is by convention considered to be absent west of the North Saskatchewan River and the succession from Belly River to Horseshoe Canyon is together termed Wapiti Formation. Boundaries shown on the geological side map are subcrops on the bedrock surface. The regional strike is approximately N45°W and beds dip to the southwest at 15 to 20 feet per mile (3 to 4 m/km).

The Lea Park Formation does not subcrop within the map area but deserves mention since it normally forms the base of groundwater investigations in the area. It is of marine origin, consists of 500 to 600 feet (150 to 180 m) of dark grey shale and pale grey, glauconitic silty shale with ironstone concretions (Green, 1972), and gradually thickens eastward as the overlying Belly River Formation thins.

The Belly River Formation is from 900 to 1000 feet (275 to 300 m) thick and nonmarine in origin. Interfingering of its basal units with Lea Park shales causes difficulties in boundary definitions. Green (1972) describes the Belly River Formation as consisting of grey to greenish grey, thick bedded, feldspathic sandstone; grey clayey siltstone, grey and green mudstone, and concretionary ironstone beds.

The lowermost portion of the Belly River Formation in most of the map area contains usually from one to three traceable sandstone units. Individual thicknesses of these units are up to 50 feet (15 m) and they may or may not be separated by shale intervals of similar thickness. Because these sandstones exhibit hydraulic properties significantly different from higher Belly River beds, they have been grouped together and are referred to as the basal Belly River sandstones in this report. Structure contours shown on the geological side map are on the top of the first significant basal sandstone encountered.

Approximately the top one third to one half of the Belly River Formation again exhibits a marked increase in sandstone content. Numerous individual sandstone units from 10 to 30 feet (3 to 10 m) thick are evident on structure testhole logs in townships 55 and 56, range 22. These, however, are not laterally continuous and correlation is extremely difficult even where logs at 1-mile spacing are available. The entire interval is quite readily recognized on electrologs and thickens to the west.

The Bearpaw Formation is marine and the map area represents a northern margin of the sea in which it was deposited. Green (1972) describes its lithology as grey blocky shale and silty shale, greenish glauconitic clayey sandstone, and bentonite beds.

Only the lower approximately 400 feet (120 m) of the Horseshoe Canyon Formation subcrop in the map area. This is equivalent to Ower's member A of the Edmonton Formation (Ower, 1958) which he (after Allan and Sanderson, 1945) describes as:

> "Grey and brown bentonitic shales containing considerable carbonaceous matter; white and light grey salt and pepper feldspathic sandstones; ironstone bands and concretions common; numerous coal seams and beds of coaly and carbonaceous shale."

SURFICIAL GEOLOGY

Late Tertiary and early Pleistocene erosion of the bedrock produced a surface with a drainage network approximately as outlined by thalwegs of buried valleys on the main map. Generally, this surface was similar to the present-day surface in that present-day and preglacial major topographic features roughly coincide. Gravels and sands deposited in and along the buried valleys are termed Saskatchewan gravels and sands and have important effects on both groundwater availability and flow distribution. The major buried channel in the map area has been named the Beverly Channel by Carlson (1966) and is roughly coincident with the present-day North Saskatchewan River valley. It originates in the Rocky Mountains to the west and its associated channel and terrace gravels and sands are generally coarser than those of its tributaries.

Till, in the form of ground moraine and hummocky moraine, constitutes the bulk of the surficial material and commonly underlies younger deposits. According to Bayrock (1972), till in the area is composed of approximately equal proportions of sand, silt, and clay but generally contains less than 10 percent gravel. Gravel, sand, and silt lenses occurring within the till constitute local aquifers and are relatively more common in the hummocky moraine.

Glaciofluvial deposits are present as outwash gravel, outwash sand and gravel, and outwash sand. They occur both along and in meltwater channels, and as sheet deposits. Examples of the latter are found north of Fort Saskatchewan, near Redwater, and at the ends of meltwater channels in the vicinity of Andrew and Whitford Lake. Aeolian action has modified the more extensive areas and produced the dune fields previously mentioned. Water wells are commonly completed in both the glaciofluvial and aeolian deposits. These can be quite productive (as for example the Andrew municipal well) and some, located in meltwater channels, are flowing wells. Most major outwash channels and areas of glaciofluvial and aeolian deposits are shown on the main map.

Surficial deposits of a small area near the North Saskatchewan River in the southwest portion of the map area are sands, silts, and clays deposited in proglacial Lake Edmonton. The main extent of this lake was to the west and southwest and its sediments are only of minor significance to the map area.

Recent alluvial deposits which have been considered in the hydrogeological map are those of the lower terraces and floodplain of the North Saskatchewan River. Generally, these contain significant proportions of sand and gravel and, where saturated, are known to be good aquifers.

Thicknesses of surficial deposits (including preglacial gravel and sand) vary from less than 10 feet (3 m), east of the Elk Island High, to more than 250 feet (75 m) in the Beverly Channel in the extreme north of the map area in range 18. Areas of thick surficial deposits are usually associated with buried channels, an exception being the Elk Island High in which thicknesses of over 100 feet (300 m) are known.

HYDROGEOLOGY

DATA USED IN MAP PREPARATION

The bulk of the data used in the construction of the hydrogeological map was obtained from water well drillers' reports and chemical analyses filed in the Central Data Bank of the Alberta Research Council's Groundwater Division. Drillers' reports commonly contain information regarding well location and construction, water levels and a simplified lithologic description; occasionally they are accompanied by an electrolog, an apparent yield test or a short pumping test. The quality of such data is quite variable, has an uneven areal distribution, and is usually restricted to depths less than 300 feet (90 m). Approximately 30 pumping tests, conducted largely by Research Council staff and consulting firms, were available for the area. These were commonly of short duration (less than 24 hours) but several were long-term tests (24 hours or longer).

In order to supplement the available data and overcome the shortcomings in distribution and quality, a data gathering procedure was established which included:

1. a program during which about 60 newly drilled water wells were pump tested (with the cooperation of drillers and owners) for as long as was practically possible — usually about 5 or 6 hours,
2. a field survey to obtain a more even distribution of samples for chemical analysis and of water level measurements, to obtain estimates of well yields, and to locate hydrogeological field features,
3. the gathering of structure testhole data provided to the Energy Resources Conservation Board by hydrocarbon exploration companies and electrologs of selected oilwells, and
4. a limited amount of test drilling and pump testing.

In total, the map represents the interpretation and synthesis of approximately 1500 chemical analyses, 1300 water levels, 225 yield values (of which about 50 percent are derived from pumping tests), several hundred lithologs, about 150 structure testholes, 150 oilwell electrologs, and numerous field observations (most of which were originally made and documented by Le Breton (1966)).

Methods used in evaluating aquifer parameters varied with the type of data available. Transmissivity was determined using the Theis non-equilibrium method where observation wells were available and the Jacob modification of the method where only pumping well data were present. In instances where only length and rate of bailing or pumping along with a total drawdown value could be obtained (as presented on drillers' reports), values of apparent transmissivity were calculated (Farvolden, 1961).

Twenty-year safe yield values were calculated by using the formula:

$$Q_{20} = \frac{TH}{2110},$$

where:

Q_{20} = 20-year safe yield in igpm (l/s) and is defined as the constant rate at which a well can produce continuously so that at the end of 20 years the water level will be drawn down to the top of the producing aquifer;

T = transmissivity in igpd/ft ($m^3/d/m$);
H = total available drawdown in feet (m).

Since determination of 20-year safe yield is based on extrapolation of data from pumping tests of relatively short duration, safety factors varying from 25 to more than 50 percent, depending on length of the test, were applied. Emphasis was placed on data of a reliable and long-term nature. Apparent values of transmissivity and safe yield and qualitative judgments based on geological interpretations and well owner interviews were used as guidance between reliable data points.

AQUIFER PARAMETERS AND YIELD ZONES

As was earlier stated, the Lea Park Formation top is the base of any groundwater-oriented investigations within the map area and no water wells are known to be completed in or below this formation.

Belly River Formation

Several pumping tests, ranging in duration from 1 hour to 24 hours are available for *basal Belly River sandstones* in the map area. Yields of wells completed in this unit vary from less than 5 to over 100 igpm (<0.4 to >7.6 l/s) and are represented by the orange, red, and green sandstone areas in the northeast portion of the map. In general, unless information to the contrary was available, the unit was assigned to the yield range of 5 to 25 igpm (0.4 to 1.9 l/s) in areas where it is present at depths of less than 350 feet (100 m). Since a higher available drawdown can be expected where the unit is present at greater depths, it is likely that substantially higher yields can be also expected (perhaps in excess of 100 igpm (7.6 l/s) where the unit is well developed). The presence of gas at depth may, however, be a limiting factor.

Four pumping tests ranging in duration from 2 to 24 hours yielded average values of 330 igpd/ft ($4.9\ m^2/d$), 11 igpd/ft^2 (0.5 m/d), and 38 igpm (2.9 l/s) respectively for transmissivity, hydraulic conductivity and safe yield of basal Belly River sandstones. Variations in safe yield can be attributed to:

1. variations in lithology, thickness, and degree of fracturing (the unit outcrops along the North Saskatchewan River in Tp 57 and 58, R 15, and some fracturing was observed),
2. drainage and hence only partial saturation near and downstream from its outcrop (a well penetrating the unit near its outcrop was abandoned due to a lack of sufficient water),

3. variations in available drawdown, and
4. increase in permeability caused by relatively high groundwater flow intensity where the unit is situated near the highly permeable gravels and sands of the Beverly Channel (cross section A-A').

The approximately 400 to 500 feet (120 to 150 m) of *Belly River sediments immediately above the basal sandstones* subcrop under the Star Plain north and east of the Chipman Hills, north of the Cooking Lake moraine, and northeast of the Redwater River. The unit has been generally assigned to the yield range of 1 to 5 igpm (0.08 to 0.4 l/s) but is incapable of yielding even 1 igpm in some areas. Pumping and bailing tests indicate that individual sandstone (and occasionally coaly) intervals up to 15 feet (5 m) thick have transmissivities and hydraulic conductivities from 1 to 100 igpd/ft (.015 to 1.5 m^2/d) and 0.1 to 10 igpd/ft^2 (.005 to .05 m/d), respectively. Upper values of these ranges are exceptional and transmissivities of less than 20 igpd/ft (0.3 m^2/d) are common. In areas where these sediments are the only available groundwater producers shortages often arise.

The *uppermost 400 feet (120 m) of Belly River sediments* contain sandstone intervals which, in places, are capable of yielding in excess of 25 igpm (1.9 l/s). The lowest portion of this unit subcrops southwest of an approximate line connecting the southeast and northwest corners of the map area. Morphologically, this interval is significant in that it forms topographically elevated areas; it subcrops under most of the Chipman Hills and at the base of the northern limit of the Elk Island High.

Several good pumping tests are available for the lowest interval as it has for some years provided groundwater for the towns of Mundare and Bruderheim. In addition, the pump testing field program provided reliable data west of Bruderheim and south of Redwater. In general, the zone is from 50 to 100 feet (15 to 30 m) thick and consists usually of 50 percent or more sandstone. Transmissivity and hydraulic conductivity of individual sandstones within the zone range from 50 to 3000 igpd/ft (0.75 to 45 m^2/d) and 1 to 150 igpd/ft^2 (.05 to 7.3 m/d), respectively, and the probability of encountering highly permeable sandstones increases from southeast to northwest. This permeability distribution results in safe yields of about 5 igpm (0.4 l/s) at Mundare, 8 igpm (0.6 l/s) at Bruderheim, about 15 igpm (1.1 l/s) west of Bruderheim, and more than 25 igpm (1.9 l/s) — possibly as high as 100 igpm (7.6 l/s) — south of Redwater.

South of Redwater the most permeable portion of the unit is conspicuously intersected by a buried channel (cross sections C-C' and A-A') which in turn is overlain by glacial drift and a dune field. The combination suggests that the high permeability of the sandstones is, at least in part, the result of solution of cementing material by persistent and relatively intense groundwater flow caused by a combination of high rates of infiltration of precipitation and the close proximity of relatively highly permeable surficial materials.

The remainder of the upper 400 feet (120 m) of Belly River sediments have, for the most part, been assigned to the yield range of 1 to 5 igpm (.08 to 0.4 l/s). A zone of greater coal content is present approximately 100 feet (30 m) below the top and is capable of yielding just over 5 igpm (0.4 l/s) at Partridge Hill but does not appear to be of regional significance. Locally areas exist where wells produce less than 1 igpm (0.08 l/s).

Bearpaw Formation

The Bearpaw Formation does not appear to behave significantly differently from the underlying low permeability portions of the Belly River Formation and no break in assigned yield values occurs.

Horseshoe Canyon Formation

Within the Horseshoe Canyon Formation several good producing zones exist. These are, without exception, related to highly fractured coal seams and, due to the existence of large numbers of wells and pumping tests, their areal extent is well defined.

Individual fractured coal seams vary in reported thickness from less than 1 to 10 feet (0.3 to 3 m) but are characteristically discontinuous and difficult to trace with water well data. The situation presented on the main map and cross sections is thus a highly simplified one. Relatively higher yield zones (red and green) are zones consisting largely of shale with occasional sandstone within which individual coal seams are common. For the sake of stratigraphic reference, the top of the 25 to 100 igpm (1.9 to 7.6 l/s) yield zone (cross sections C-C' and D-D') correlates with the Clover Bar Coal Zone as mapped by Pearson (1961).

Transmissivities calculated from four pumping tests in the 5 to 25 igpm (0.4 to 1.9 l/s) Horseshoe Canyon yield zone average about 400 igpd/ft (6 m^2/d), varying from 170 to 750 igpd/ft (2.5 to 11 m^2/d). In the 25 to 100 igpm (1.9 to 7.6 l/s) yield zone the variation encountered was much greater, ranging from about 500 igpd/ft (7.5 m^2/d) to occasionally as high as 10,000 (150 m^2/d). In some instances, the total amount of coal present is known with a fair degree of certainty, and where these were considered to be the only contributing aquifers, hydraulic conductivity values ranging from 50 to 500 igpd/ft^2 (2.4 to 24 m/d) were calculated.

The observed fracturing is undoubtedly the result of glacial overriding and is most pronounced in this portion of the bedrock for two reasons:

1. relatively large amounts of brittle coal are present, and
2. the area is topographically elevated and presented more resistance to ice movement than the surrounding lower and flatter areas.

It is expected that the degree of fracturing is higher in shallow coal zones and diminishes with depth, thus effectively reducing groundwater yields of deeper zones.

Saskatchewan Gravels and Sands

Saskatchewan gravels and sands have been assigned to the yield categories of 5 to 25 (0.4 to 1.9 l/s) and 25 to 100 igpm (1.9 to 7.6 l/s). The major occurrences of these deposits are in and along the preglacial Beverly and Vegreville Channels.

Hydraulic conductivity of 110 igpd/ft^2 (5.4 m/d) was measured in 55 feet (17 m) of saturated Beverly Channel deposits east of Redwater. This is thought to be a representative value although it is recognized that lithologic variations will cause local deviations of perhaps an order of magnitude. The channel deposits are known to be hydraulically connected with the North Saskatchewan River and water withdrawals will thus be easily replenished.

No pumping test results were available for wells completed in higher terrace gravels and sands along the western flank of the Elk Island High; however, based on apparent tests and lithologic considerations, yields of 5 to 25 igpm (0.4 to 1.9 l/s) should be readily available.

A pumping test in a small tributary channel in township 53, range 21 yielded transmissivity and hydraulic conductivity values of 4000 igpd/ft (60 m^2/d) and 46 igpd/ft^2 (2.3 m/d), respectively. This and similar channel deposits were consequently placed in the 5 to 25 igpm (0.4 to 1.9 l/s) yield range.

A pumping test yielded values of 12,000 igpd/ft (180 m^2/d) and 650 igpd/ft^2 (32 m/d) for transmissivity and hydraulic conductivity for gravel and sand in the Vegreville Channel near Vegreville. These channel deposits were assigned to the 25 to 100 igpm (1.9 to 7.6 l/s) yield range; however, their extent is inferred largely from bedrock topography (Stein, in preparation) and may not be exact.

Surficial Sediments

Numerous water wells in the map area are completed in *till*. These are usually large-diameter bored wells and often obtain water from local sand and gravel lenses within the till. Permeability of the sand and gravel lenses may be quite high; however, well yield is ultimately determined by the ability of groundwater to enter lenses from the surrounding till matrix and thus is usually low. For mapping purposes, it was considered that wherever drift thickness exceeds 50 feet (15 m) the probability of encountering sand and gravel lenses is high enough to enable the drift to yield from 1 to 5 igpm (0.08 to 0.4 l/s) to water wells.

Permeability data for *glaciofluvial deposits* found in meltwater channels and as sheet outwash deposits is scarce and the yield categories assigned are based largely on qualitative considerations. A pumping test at the town of Andrew established transmissivity and hydraulic conductivity values of about 21,500 igpd/ft (320 m^2/d) and 1000 igpd/ft^2 (50 m/d), respectively. These values are thought to be exceptional, however, and representative of very clean deposits only.

Data available for the meltwater channel system near Andrew indicate that lithology is highly variable. Sand and gravel deposits may or may not be present and often contain large amounts of clay. Because of these features and their linear nature, the channels were assigned to the yield category of 1 to 5 igpm (0.08 to 0.4 l/s). It should be recognized, however, that where these channels are present they usually offer the best groundwater prospects in the drift and yields in excess of the assigned values should locally be available.

Sand dune areas were assigned yield values of 5 to 25 igpm (0.4 to 1.9 l/s) where evidence suggested thicknesses in excess of 25 feet (8 m). Pumping tests were not available for wells completed in aeolian deposits. Such wells, however, usually are reported to yield a plentiful supply of water and the 5 to 25 igpm (0.4 to 1.9 l/s) yield category seems reasonable, especially where the dunes are underlain by glaciofluvial deposits.

Recent North Saskatchewan River alluvium typically consists of varying proportions of gravel, sand, silt, and clay and, according to Bayrock (1972), is composed predominantly of sand east of Fort Saskatchewan. The lowermost occurrences are the most likely to be saturated and were usually assigned to the yield category of 25 to 100 igpm (1.9 to 7.6 l/s). It is expected, however, that local permeability and water level variations will result in local yield variations beyond both ends of this range.

WATER LEVELS AND GROUNDWATER FLOW DISTRIBUTION

The bulk of the water level data used in constructing water level contours is derived from drillers' reports. Water level measurements from the field survey and pumping tests were given relatively greater emphasis but water levels have not been separated with respect to season or time.

The data was, however, separated in such a manner that water levels of the map area's various main aquifers could be shown. The initial breakdown was on the basis of water levels from bedrock and drift wells and, where any one particular aquifer was dominant (as for instance the Beverly Channel, Vermilion Channel, sand dune, and basal Belly River sandstone aquifers) a further selection on an aquifer basis was made. Contours on the main map thus represent long-term average water levels of the map area's main aquifers.

Water level values for the cross sections were selected from wells which were open to the strata over relatively short depth intervals only (less than 50 feet). These thus represent an averaged vertical distribution of fluid potential as accurately as can be determined with presently available data.

The overall pattern of groundwater flow in the map area shows quite strongly the effects of both topography and permeability configurations and can be summarized as follows:

1. The controlling effect on flow direction is the topography. Water level contours generally show a marked correlation with topographic contours and the horizontal component of groundwater flow is from high to low areas.

2. Permeability variations introduce extensive modifications to groundwater flow patterns with the net result of increasing the area with predominantly downward components of groundwater flow. The most obvious examples of this phenomenon can be seen by the influence of the highly permeable Beverly Channel deposits, Horseshoe Canyon fractured coals, and the basal Belly River sandstones.

The Horseshoe Canyon Formation is situated in a topographically elevated area and is underlain by the much less permeable beds of the Bearpaw and Belly River Formations. This results in predominantly downward and lateral flow in the Horseshoe Canyon and is responsible for the discharge areas characterized by flowing wells, springs, and seepages on the southwestern portion of the Elk Island High. These discharge areas are conspicuously coincident with the maximum extent of Horseshoe Canyon subcrop and are situated well above the midpoint in regional slope.

The Beverly Channel aquifer is in direct hydraulic connection with the North Saskatchewan River, the water levels in the channel varying with river stage. This results in an unsaturated upper portion of the channel deposits where these occur above river stage. More importantly, however, this phenomenon results in a thick, approximately 3-mile wide, highly permeable zone in which fluid potentials are everywhere the lowest of the map area. The effect of this feature on groundwater flow is that of a highly effective potential sink, inducing flow towards itself from all directions (cross sections A-A' and C-C').

A similar behavior is exhibited by the basal Belly River sandstones. This unit outcrops along the North Saskatchewan River and is, wherever water level measurements were available (except where Beverly Channel deposits occur in close proximity) at a lower fluid potential than overlying deposits. The net result is again an increase in downward groundwater flow, the effect being most pronounced where the basal Belly River sandstones are nearer to the ground surface.

The prime example of this type of hydraulic behavior is found in the northeast of the map area near the town of Willingdon and east and north of Whitford Lake. A mound in hydraulic head is actually built up in the basal Belly River sandstones under sand and gravel deposits near Willingdon, indicating that the sandstones receive water from the overlying channel deposits. The general hydraulic behavior of the basal Belly River sandstones is thus that of a permeable, low-potential sheet which attracts flow towards itself vertically and disperses it laterally.

Groundwater field features of the above area suggest a situation which at first glance appears to contradict the above conclusion, in that many features indicate upward movement of groundwater. The area contains occasional flowing wells, Solonetzic soils, abundant salt precipitates at the surface, and surface water bodies which must receive some groundwater contribution.

The information with respect to relative water levels is, however, indisputable and the conclusion must be that groundwater discharge features are the result of shallow, local flow systems restricted to the drift. The area receives groundwater from topographically higher areas via the permeable outwash channel and sheet deposits, sand and gravel within the till, and diffuse flow through the till. Permeability of the near-surface bedrock is such, however, that only some unknown portion of this groundwater can move downward towards the basal Belly River and the remainder must discharge locally.

A rather complex flow configuration exists in the vicinity of Beaverhill Lake. Based on topographic considerations and field observations, the low, flat area containing the lake appears to be an area of groundwater discharge. It is flanked to the west and east by the Elk Island High and Chipman Hills, respectively, both being topographically elevated areas of regional significance. A conspicuous line of springs exists along almost the entire eastern and northern flanks of the Elk Island High. Again, Solonetzic soils, salt precipitates at the surface, and occasional flowing wells indicate groundwater discharge.

The potential and flow distribution in the vicinity of Beaverhill Lake on cross section D-D' was derived from three carefully drilled testholes (Le Breton, 1966), specifically designed to determine permeability and fluid potential variations with depth. All three testholes indicate a zone of low fluid potential at an approximate elevation of 2025 feet and parallel to bedding. Groundwater movement is towards this zone from above and below, and must be lateral within the zone.

A possible explanation to reconcile these seemingly contradictory situations is as follows:

1. The line of springs along the Elk Island High is the result of a permeability contrast between the hummocky disintegration moraine overlying the low permeability Bearpaw Formation.

2. Groundwater discharge in the vicinity of Beaverhill Lake is the result of shallow flow systems restricted largely to the drift and possibly the upper few tens of feet of bedrock.

3. The zone of low potential is the result of a hydraulic connection to a highly permeable, potential sink south of the map area. The Vegreville Channel thalweg is located about 5 miles (8 km) south of the map area and the elevation of its floor coincides with the elevation of the low potential zone. The channel is known to contain highly permeable sands and gravels near Vegreville and was reported by Farvolden (1963) to contain a thick gravel sequence just south of the map area near Tofield. It is highly likely that this channel provides the potential sink necessary to move groundwater laterally as required by water level data in the vicinity of Beaverhill Lake.

HYDROCHEMISTRY

Side maps show the areal distribution of the chemical composition of water from bedrock and surficial aquifers separately. Vertical variation in hydrochemistry is shown on the hydrogeological profiles. The maps and profiles show the major constituents (Na+K, Ca+Mg, CO_3+HCO_3^-, SO_4, and Cl). Separate maps for fluoride content were constructed.

Chemical analyses of waters from the basal Belly River sandstones were not available in sufficient numbers to allow separate contouring, so chemistry shown on the bedrock side map is representative (with some exceptions) of strata above this unit. Also, blank areas under the Beverly Channel and Elk Island Park indicate a lack of data rather than mixed bedrock waters.

Bedrock waters contain total dissolved solids of from less than 1000 to more than 6000 ppm but generally fall in the 1000 to 2000 ppm range. Areas of high total dissolved solids content correspond primarily to areas of high chloride and secondly to areas of high sulfate content.

The predominant bedrock water type is sodium bicarbonate but varying amounts of sulfates and chlorides are often present. Waters with sulfate as the dominant anion are distributed in a spotty fashion throughout the map area and are often associated with chloride waters. Where this association occurs, the sulfate waters are usually situated upstream in the flow system from the chloride waters.

The interpretation of this situation is that bedrock waters containing bicarbonate as the dominant anion represent the recharge ends of flow systems, that mixed (bicarbonate and sulfate) and sulfate waters are found in discharging portions of local flow systems, and that chloride waters are present in relatively deeper zones and in areas where waters from such deeper zones come close enough to the ground surface to be encountered by water wells of average depth. In at least one instance (under the Chipman Hills northeast of Beaverhill Lake) sulfate waters are found in a recharging situation and probably reflect bedrock composition.

The chemical composition of water in drift aquifers is much more variable than in bedrock, reflecting the more local nature of groundwater flow systems within the drift. Total dissolved solids content varies from less than 500 to more than 3000 ppm and can exceed 6000 ppm locally. Waters in sand dunes, in some portions of near-surface outwash sands and gravels and in Beverly Channel deposits near the North Saskatchewan River contain total dissolved solids of less than 500 ppm. Salinities in excess of 1500 ppm are generally associated with high sulfate content and typically occur in sands and gravels along the west flank of the Cooking Lake Moraine, west of the Vegreville Channel, and in buried channels of the Star Plain near Willingdon.

Except for waters in the Beverly Channel, waters with calcium and magnesium as the dominant cations are usually confined to shallow zones in areas where downward vertical flow components exist in the drift. The natural changes in chemical composition with respect to flow direction and residence time are from calcium-magnesium bicarbonate to sodium-potassium sulfate water type.

Apart from hardness usually due to the presence of some calcium and magnesium, drift waters in the map area are characterized by high iron content. Most drift waters require iron removal for normal household use and concentrations of up to 15 ppm have been noted in some Beverly Channel wells. Iron staining and bacteria are common features at spring localities. In one instance, a bog collecting groundwater seepage from adjacent sand dunes in the northeast quarter of section 9, township 57, range 20 was found to be depositing highly concentrated iron oxide to depths sometimes greater than 2 feet.

A rather alarming situation with respect to nitrate content of waters from drift wells exists in the map area. Of the more than 700 drift water analyses considered, only 30 percent showed no nitrates present, 27 percent contained from 1 to 15 ppm, and 43 percent contained nitrates in excess of the recommended limit of 15 ppm. Of the latter, many were in excess of 100 ppm. Numerous analyses with extremely high nitrate values were not included in this count since they would mask patterns of natural groundwater chemistry; the 43 percent figure is thus a conservative one.

The most likely source of nitrates is from animal and human waste and the appearance of nitrates in 70 percent of drift wells suggests strongly that improvements either in present practices of well construction or well location, or in waste disposal location are necessary.

CONCLUSIONS

The northeast segment of the Edmonton map area contains bedrock and drift aquifers capable of yielding from less than 1 to 100 igpm (0.08 to 7.6 l/s). The best aquifers are permeable sands and gravels of the buried Beverly and Vegreville Channels, fractured coals of the Horseshoe Canyon Formation, and relatively clean sandstone units near the center and at the base of the Belly River Formation.

Groundwater flow directions are complex and strongly influenced by variations in permeability.

The total dissolved solids in bedrock waters range from less than 1000 to more than 6000 ppm. High salinities are associated with chloride and sulfate water types but generally bedrock waters are of the sodium bicarbonate type and contain total dissolved solids from 1000 to 2000 ppm.

Hydrochemistry of waters from surficial aquifers is more variable than for waters from bedrock. Total dissolved solids range from less than 500 to more than 3000 ppm and high total dissolved solids is correlative with sodium sulfate water type.

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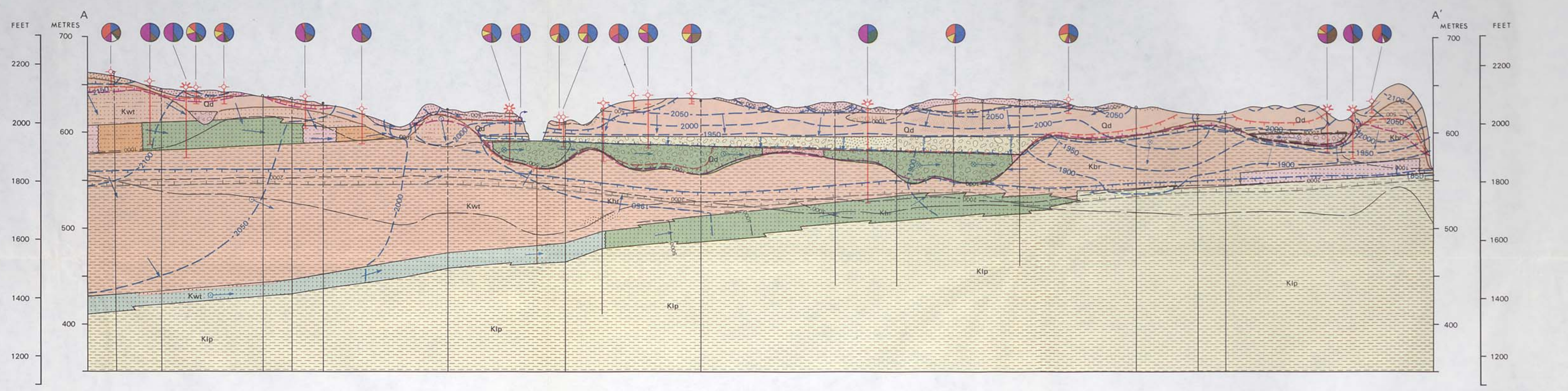
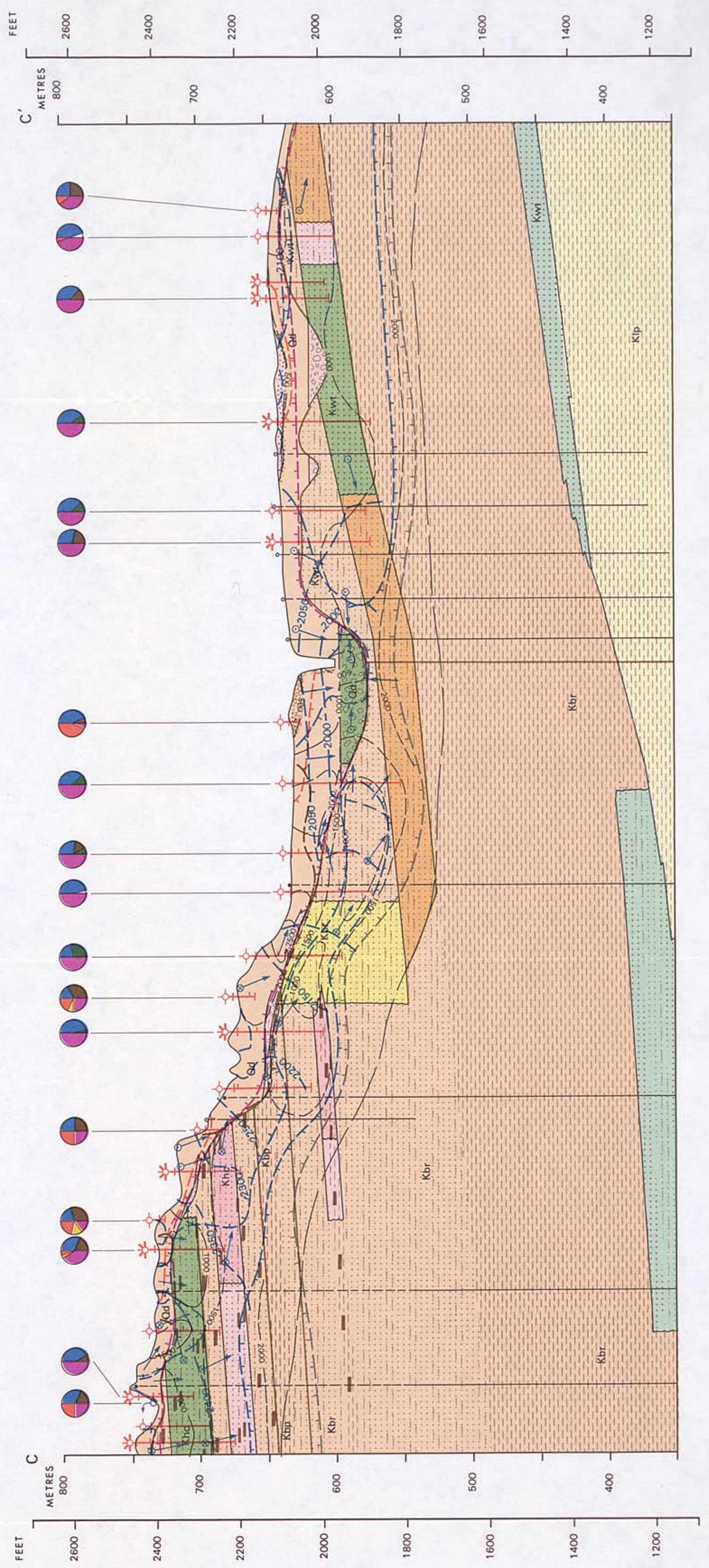
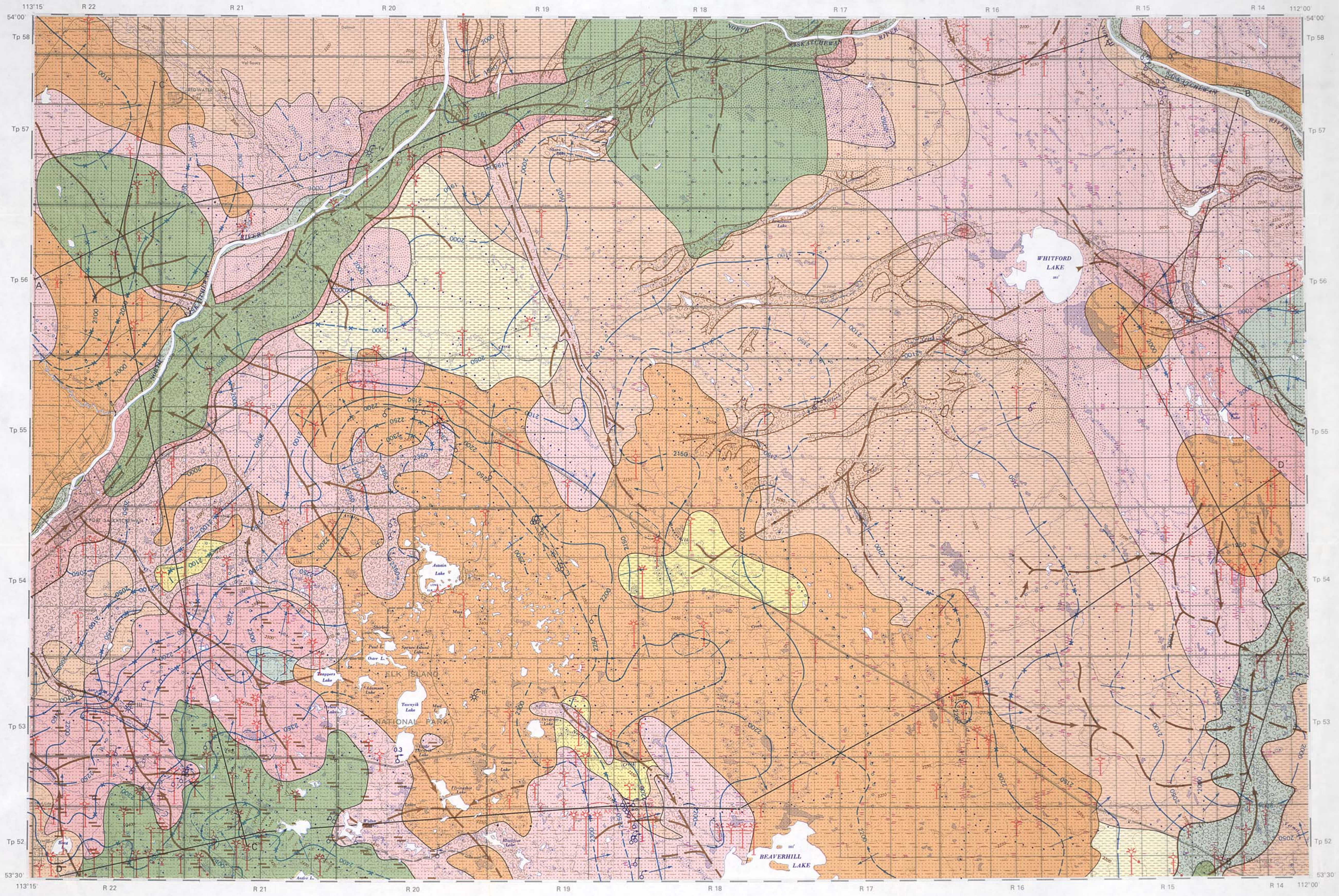
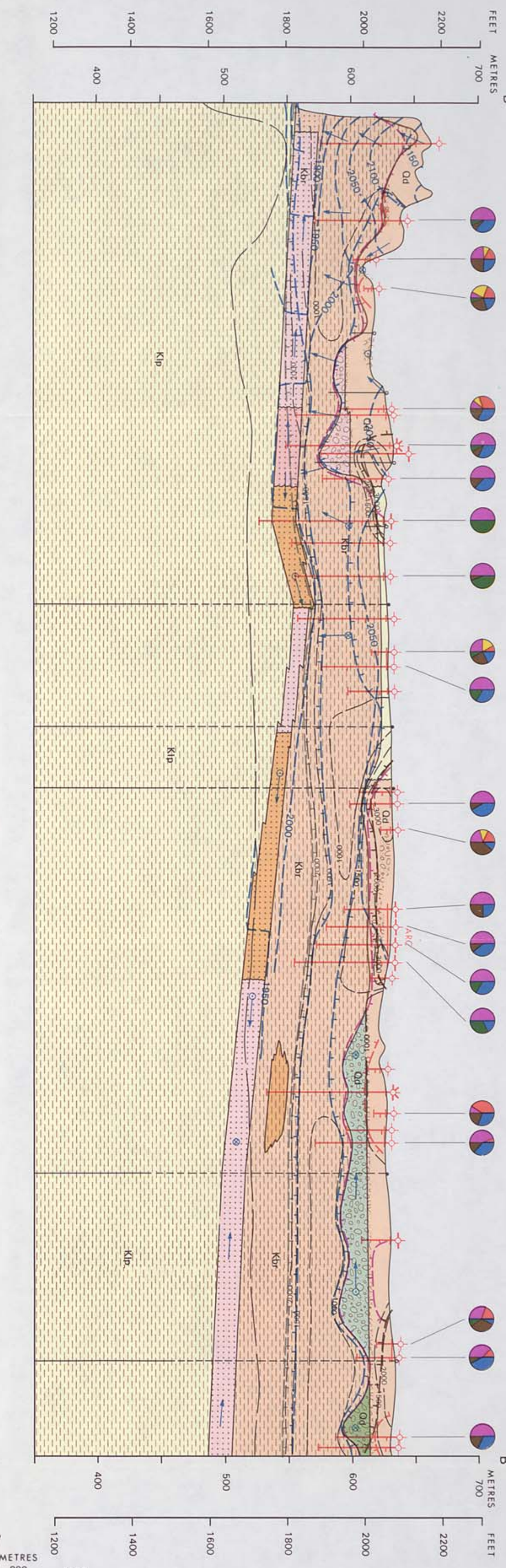
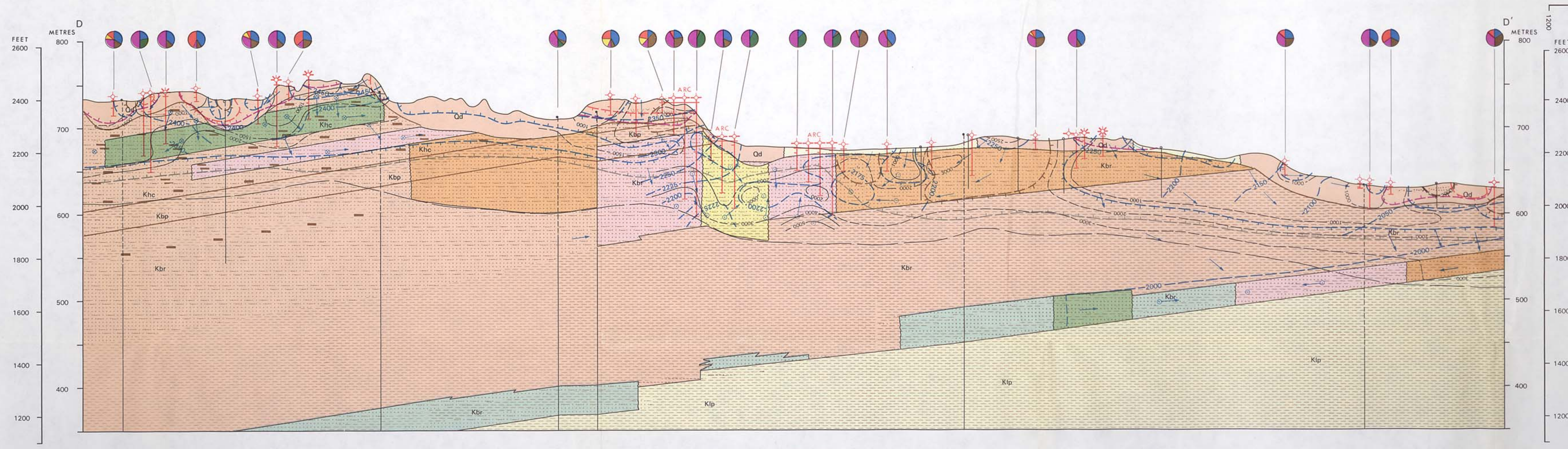










MAIN MAP LEGEND

Topography

Surface contours and elevation in feet

Geology

Geological boundary
Glacial meltwater channel
Buried valley boundary
Thalweg of buried valley: defined, approximate

QUATERNARY

Qd — Unconsolidated deposits

CRETACEOUS

Kwt — Wapiti Formation
Khc — Horseshoe Canyon Formation
Kbp — Bearpaw Formation
Kbr — Belly River Formation
Klp — Lea Park Formation

Lithology

Gravel
Sand and gravel
Sand
Sandstone
Silt
Shale
Fractured rocks
Coal

Hydrography

Lake or slough, perennial
Saline lake
Marsh
Stream, perennial
Stream, intermittent
Surface water divide
Area of noticeable salt precipitates

Hydrogeology

Spring, flow rate unknown
Spring, flow rate known (in igpm)

Spring information
soap hole — III
iron — Fe
sand — s

Water table contour (elevation in feet) — 2000

Nonpumping water level contour (elevation in feet) and vertical component of groundwater movement: — Upward flow / 2000 / Downward flow

Component of groundwater flow perpendicular to profile:
Out of profile (i.e. towards reader)
Into profile (i.e. away from reader)
Component of groundwater flow parallel to profile
Flow through unsaturated sediments
Groundwater divide
Boundary of area of artesian flow

Groundwater Probability †

Range of average expected yield of wells (in igpm)

Probable: estimated from quantitative information (pump tests, bail tests, etc.)

Possible: estimated from qualitative information (flow regime, lithology, etc.)

25 - 100
5 - 25
1 - 5
< 1

Yield boundary
Maximum depth of investigation for yield values on main map

† The indicated average expected yields to wells are based on the best available data at the time of map compilation; due to data shortcomings and special conditions, local discrepancies between predicted and actual yields are inevitable. Multiaquifer completion may be necessary to obtain the yield indicated.

Wells and Other Artificial Works

Depth Scale — FEET 0, 100, 200, 300, 400 — Depth to water — Depth of well or seismic shot hole

Water well, nonflowing
Water well, flowing
Water well, 20 year safe yield calculated from apparent transmissivity
Water well, 20 year safe yield calculated from a good bail test or a short pump test
Water well, 20 year safe yield calculated from a pump test of sufficient length to reflect regional hydraulic conditions
Adjacent wells
Test well with more than one piezometer in a single borehole or with groundwater data collected from several depths during drilling
Observation well with automatic recorder
Mean annual water level fluctuation in feet — 0.3
Year of commencement of observations — 1968
Years of record averaged for mean annual water level fluctuation figure — 6
Location of Alberta Research Council test well — ARC
Oil well
Structure testhole
Exploratory hole for coal
Depth of exploratory well

The vertical line portion of exploratory well symbols indicates the well depth; the dashed portion indicates the surface casing intervals where applicable or where known (otherwise, a solid line is used).

Line of hydrogeological profile — A A'

Hydrochemistry

Calcium, Magnesium, Sodium + potassium (Cations) | Carbonate + bicarbonate, Sulfate, Chloride, Nitrate (Anions) — 0, 50%, 100%

Note: When the yellow Mg pie sector is absent, Ca+Mg are represented as a unit by the red pie sector.

Total dissolved solids in parts per million: approximate

Isogram along which calcium + magnesium constitute 60 percent of total cations;* teeth indicate direction of lesser calcium + magnesium conter.t: approximate

Isogram along which sodium + potassium constitute 60 percent of total cations;* teeth indicate direction of lesser sodium + potassium content: approximate

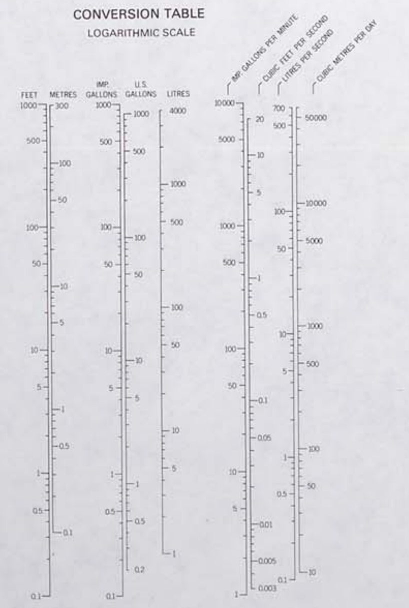
Isogram along which carbonate + bicarbonate constitute 60 percent of total anions:* teeth indicate direction of lesser carbonate + bicarbonate content: approximate

Isogram along which sulfate constitutes 60 percent of total anions;* teeth indicate direction of lesser sulfate content: approximate

Isogram along which chloride constitutes 60 percent of total anions;* teeth indicate direction of lesser chloride content: approximate

* Determined on equivalents per million basis.

CONVERSION TABLE
LOGARITHMIC SCALE



SCALE 1:125,000
Miles 5 0 5 10 Miles
Kilometres 5 0 5 10 15 Kilometres

All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 50X.

An expanded legend and explanatory notes for use with this hydrogeological map series is available from the Alberta Research Council, Edmonton, Alberta, Canada.

Map to accompany Report 76-1.

Hydrogeology by R. Stein, 1975, based on data collected in 1974 and 1975.

Drafted by R. Swenson.

Edited by A. Campbell.

HYDROGEOLOGICAL MAP EDMONTON AREA (Northeast Segment) ALBERTA

NTS 83H-NE

KEY MAP

Sheet 1 of 2

Alberta
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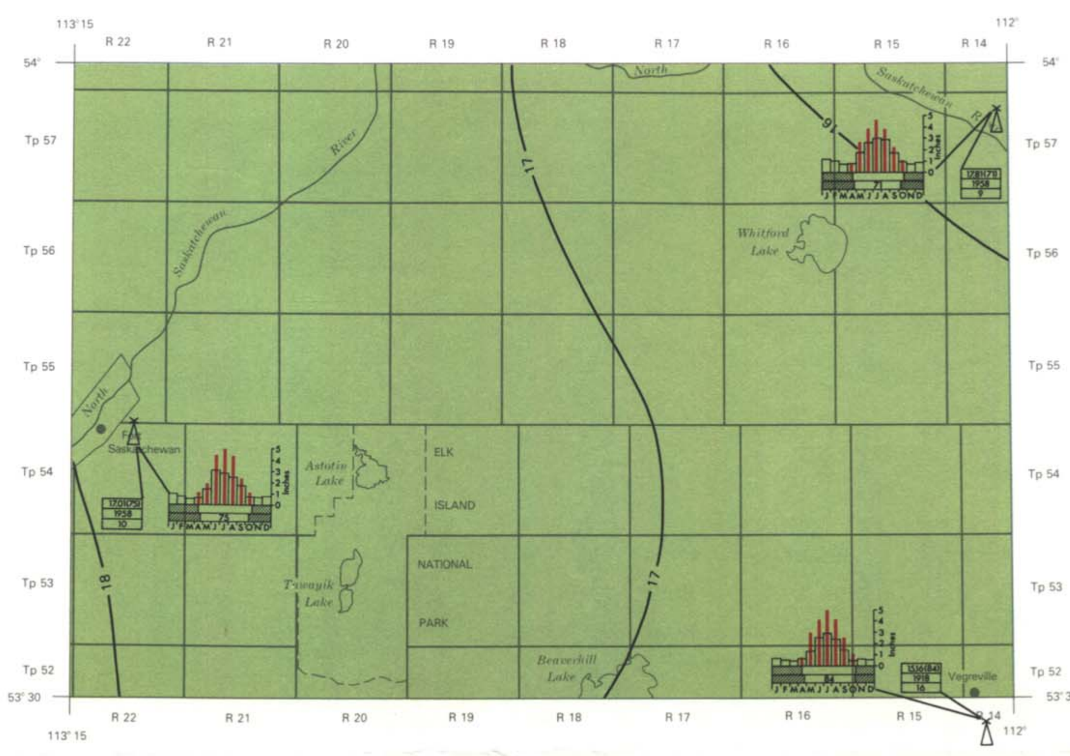
METEOROLOGY



LEGEND

Isohyet, mean annual precipitation in inches .... —17—

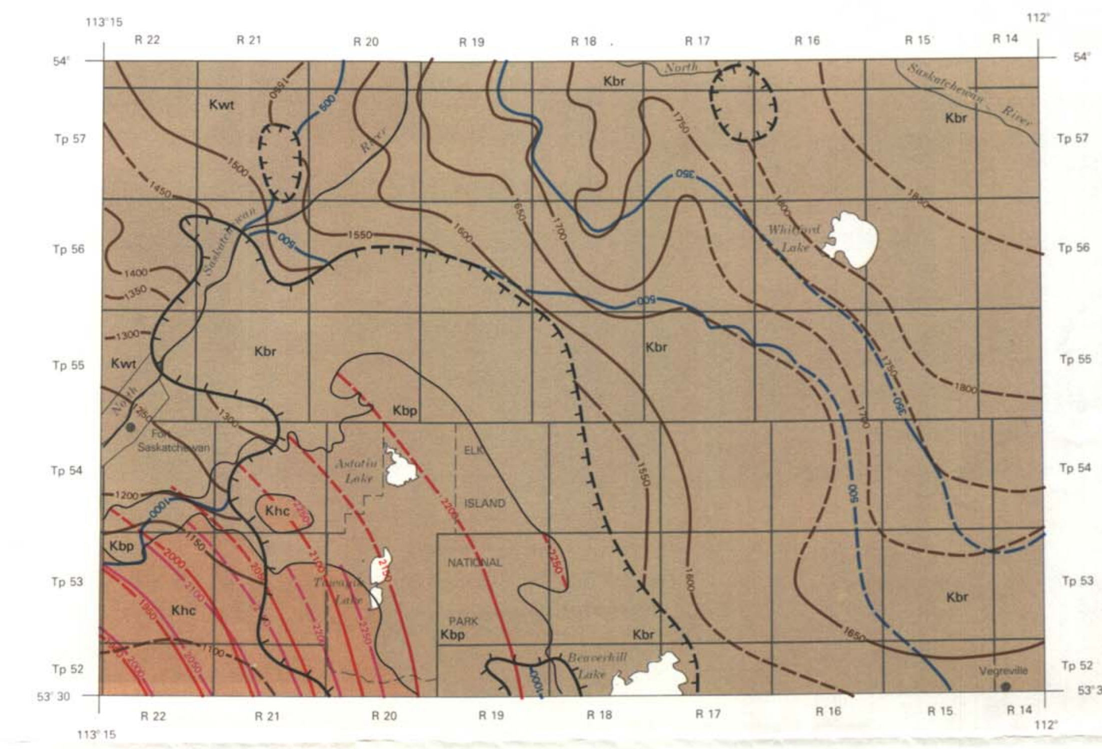
Mean annual precipitation:
15-20 inches ....

Meteorological station ....

Precipitation data:
- Mean annual precipitation in inches (percent rainfall)
- Year of commencement of observations
- Number of years of record used to calculate mean annual precipitation figure
- Mean monthly potential evapotranspiration
- Mean monthly precipitation
- Period when surface is usually snow covered
- Period with mean daily temperature below freezing
- Figure indicates percentage of mean annual precipitation falling as rain

Source of data: Longley, R. W. (1968): Climatic maps for Alberta; University of Alberta, 8 pages.

GEOLOGY



LEGEND

- Kwt — Wapiti Formation: *sandstone, mudstone, bentonite, coal beds*
- Khc — Horseshoe Canyon Formation: *sandstone, bentonic mudstone, shales, ironstone beds, coal*
- Kbp — Bearpaw Formation: *shale, sandstone, thin ironstone and bentonite beds*
- Kbr — Belly River Formation: *sandstone, siltstone, mudstone, ironstone beds*

Rock unit boundary: defined, approximate ....

Structure contour on top of Bearpaw Formation 2200

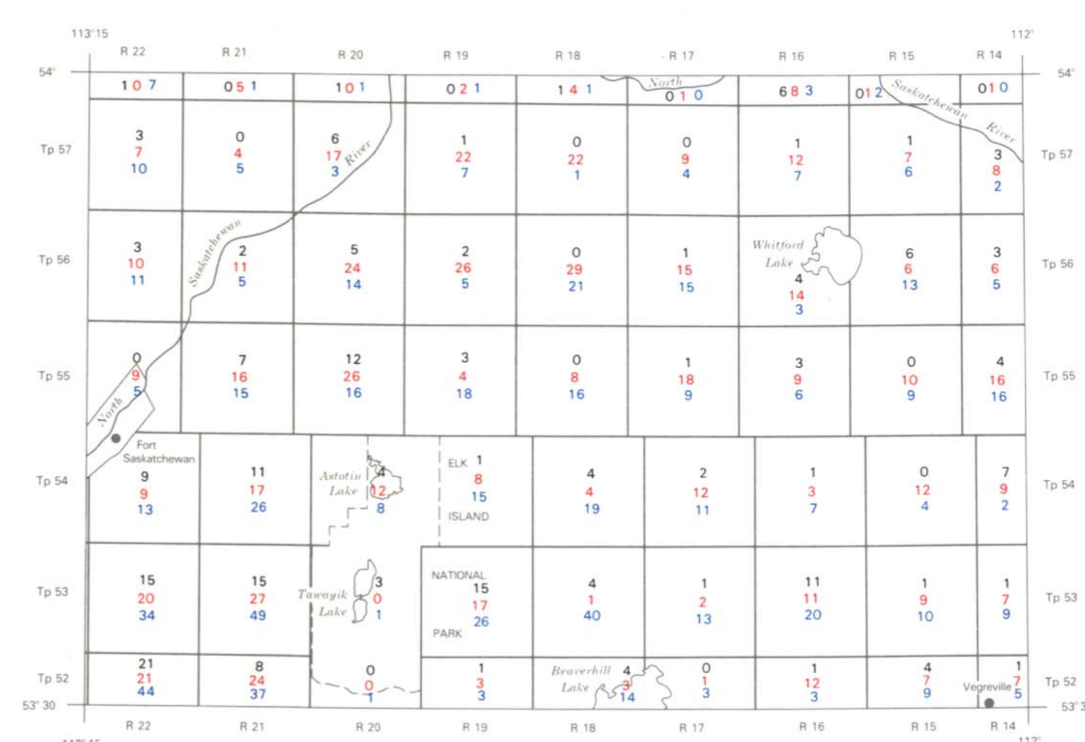
Structure contour on top of Belly River Formation 2000

Structure contour on top of basal Belly River sandstone 1800

Depth to top of basal Belly River sandstone 500

Boundary of area within which basal Belly River sandstone is absent or poorly developed ....

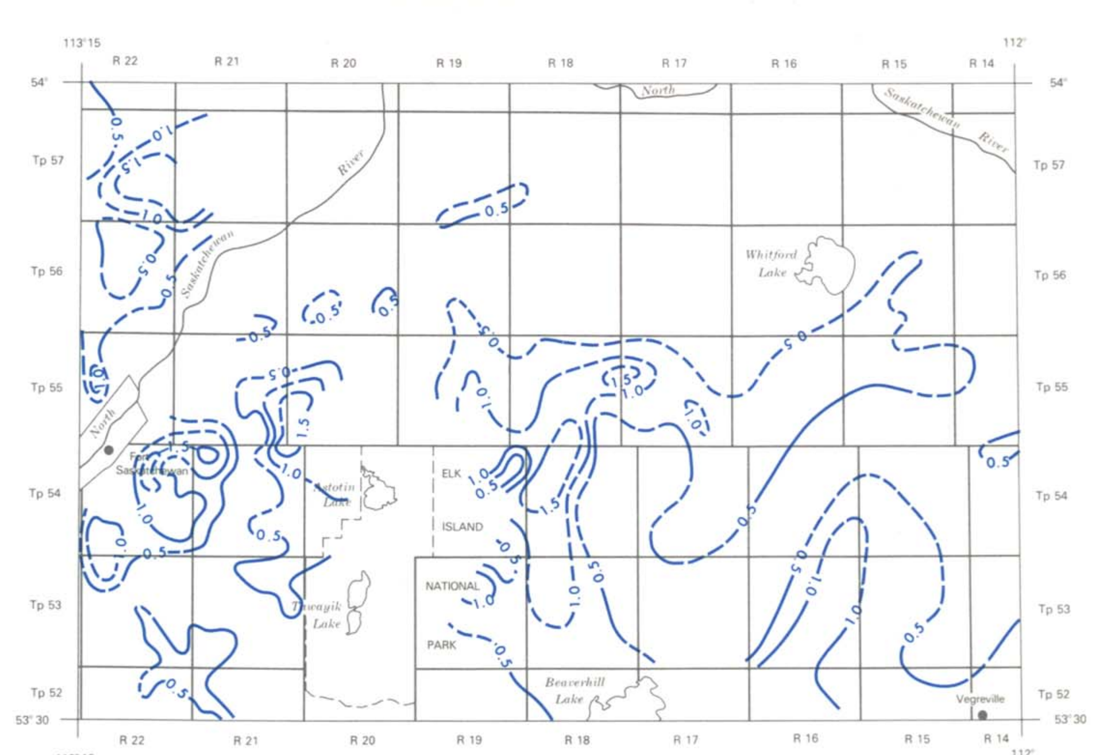
DATA DENSITY



LEGEND

Number of data points used in each township and range in determining:
- Yield values and apparent transmissivities 3
- Water levels in drift 4
- Water levels in bedrock 3

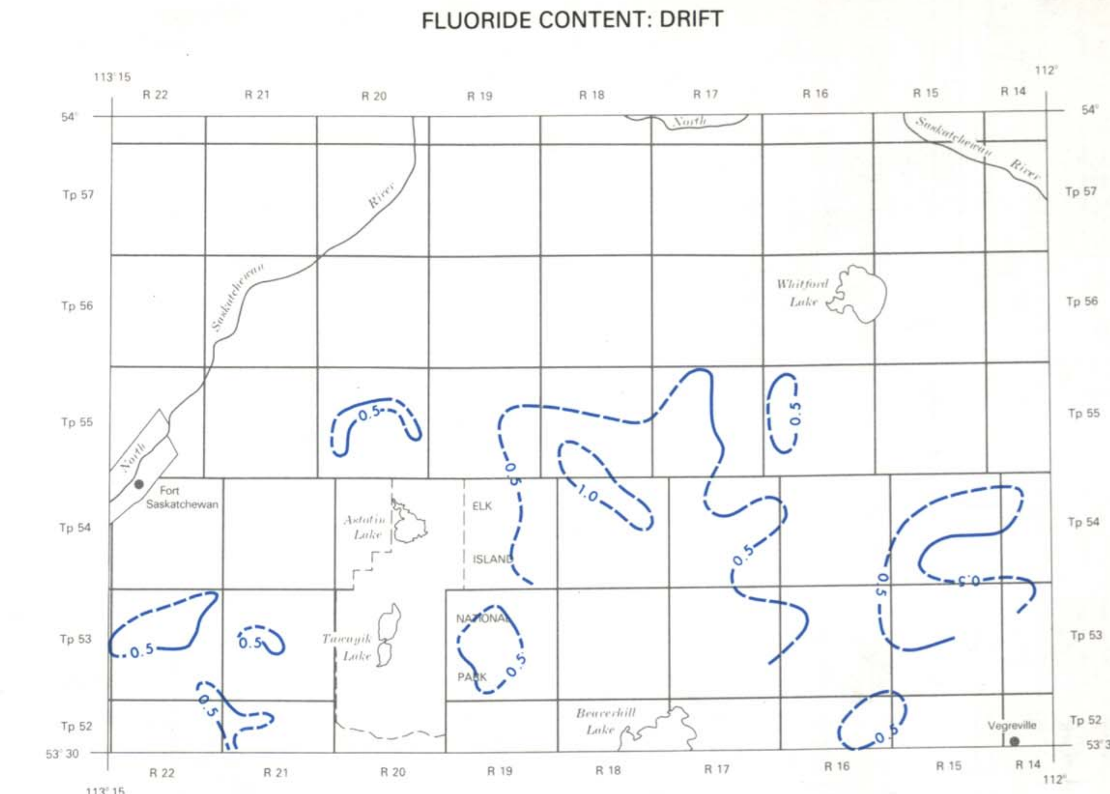
FLUORIDE CONTENT: BEDROCK



LEGEND

Fluoride content in parts per million:
- defined 1.0
- approximate 1.0

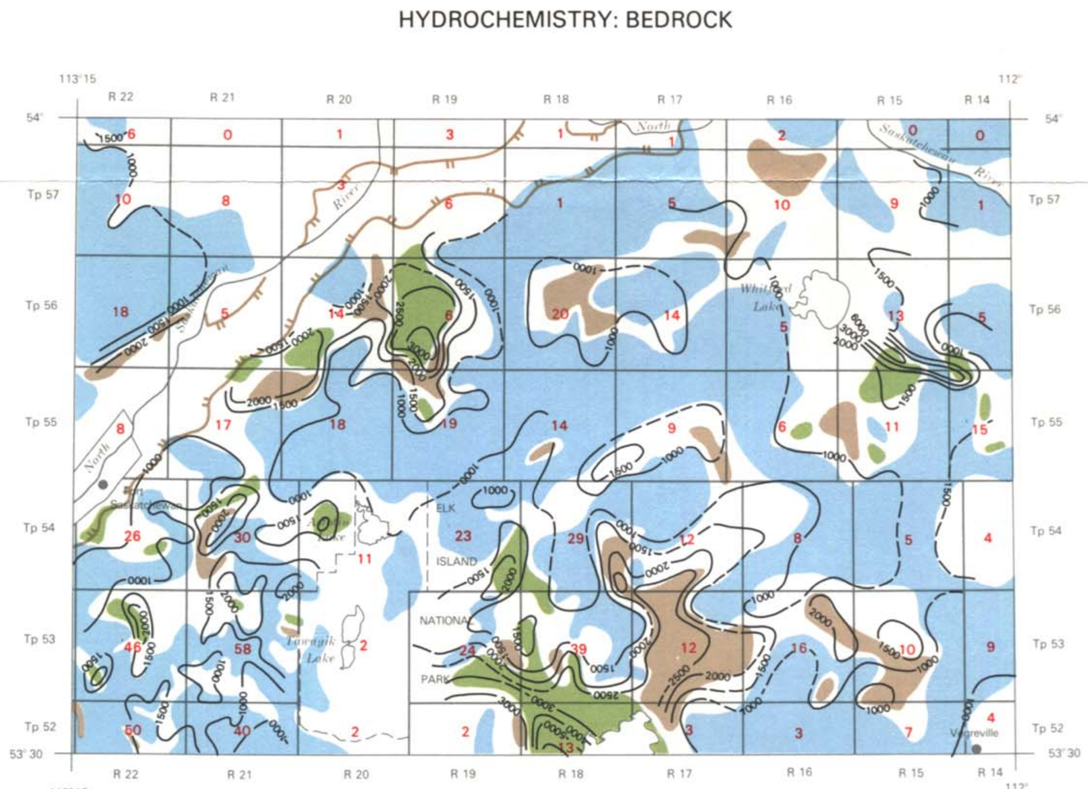
FLUORIDE CONTENT: DRIFT



LEGEND

Fluoride content in parts per million:
- defined 1.0
- approximate 1.0

HYDROCHEMISTRY: BEDROCK



LEGEND

Number of data points used in each township and range 3

Total dissolved solids in parts per million:
- defined 1000
- approximate 1000

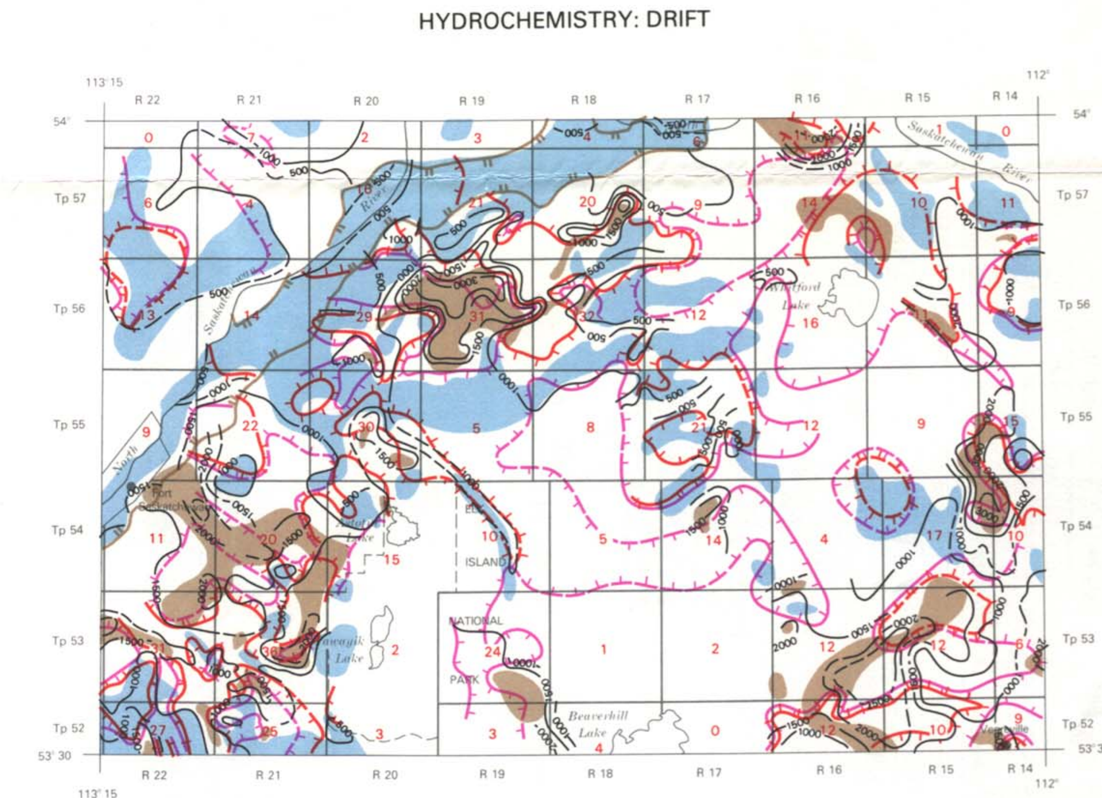
Carbonate + bicarbonate constituting over 60 percent of total anions* ....

Sulfate constituting over 60 percent of total anions* ....

Chloride constituting over 60 percent of total anions* ....

Buried valley boundary ....

HYDROCHEMISTRY: DRIFT



LEGEND

Number of data points used in each township and range 3

Total dissolved solids in parts per million:
- defined 1000
- approximate 1000

Carbonate + bicarbonate constituting over 60 percent of total anions* ....

Sulfate constituting over 60 percent of total anions* ....

Isogram along which calcium + magnesium constitute 60 percent of total cations;* teeth indicate direction of lesser calcium + magnesium content:
- defined ....
- approximate ....

Isogram along which sodium + potassium constitute 60 percent of total cations;* teeth indicate direction of lesser sodium + potassium content;
- defined ....
- approximate ....

Buried valley boundary ....

* Determined on equivalents per million basis

SCALE 1:500,000
Miles 5 0 5 10 15 20 Miles
Kilometres 5 0 5 10 15 20 25 30 Kilometres

HYDROGEOLOGICAL MAP
EDMONTON AREA
(Northeast Segment)
ALBERTA

NTS 83H-NE

112 (2 of 2)

Sheet 2 of 2

112