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Hydrogeology of the Southwest Segment, Edmonton area, Alberta

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ABSTRACT

The southwest quarter of the Edmonton map area (NTS 83H) has an area of about 2850 km^2 (1100 mi^2). Climate is microthermal with warm summers, and the area receives about 460 mm (18 in) of precipitation annually.

In the area thin drift, primarily of glacial origin, overlies Tertiary and Cretaceous bedrock. The Paskapoo Formation, which is capable of yielding up to 38 L/sec (500 igpm), is the best bedrock aquifer. Basal deposits of sand known as the Saskatchewan gravels and sands, and located within the preglacial Stony Valley, are the best aquifer in the surficial deposits; these deposits are capable of yielding up to 8 L/sec (100 igpm).

The dominant direction of groundwater flow is from the upland areas toward the Stony Valley and North Saskatchewan River.

Drift waters are predominantly of the calcium-magnesium type with a total dissolved solids concentration of usually less than 1500 mg/L. To the depths considered, sodium bicarbonate type water is the dominant bedrock water type. Highly mineralized groundwaters, associated with total dissolved solids concentrations as high as 5000 mg/L and of the chloride or sulfate type, are found locally in the northeast corner of the study area.

INTRODUCTION

The study area, which comprises the southwest quarter of the Edmonton map area (NTS 83H), has an area of approximately 2850 km^2 (1100 mi^2) and is situated between longitudes 113 15 N and 114 N and between latitudes 53 and 53 30 W. According to the Dominion land survey system, the study area comprises all or part of Tp. 46 to 52, R. 23 to 28, W. 4th Mer.

The southwestern portion of the city of Edmonton (pop. 461,000 – 1977) is located in the northeastern corner of the study area. Major towns in the study area are Leduc (pop. 8,498 – 1977), Devon (pop. 2,764 – 1977), Millet (pop. 756 – 1977), Calmar (pop. 862 – 1977), and Beaumont (pop. 846 – 1977). Only Millet and Calmar use groundwater as a water supply. Numerous small villages scattered over the map area, which serve local farming communities and provide recreational facilities, obtain a water supply exclusively from water wells. Development of fringe areas around Edmonton in recent years has resulted in significant use of groundwater resources.

About 70 percent of the study area is cultivated. The southwestern corner of the area is about 50 percent cultivated. The main industries within the map area are farming and petroleum production. The two largest oil fields are the Leduc-Woodbend and Glen Park-Wizard Lake fields. A minor industry is the mining of sand and sand and gravel from the dune fields north of Devon and from alluvial deposits along the North Saskatchewan River.

According to the Atlas of Alberta (1969), the study area is in the Forest Land area of Alberta. Vegetation consists of aspen poplar with aspen ecotone to spruce (black and white) in the southwest corner. The dominant tree species are black spruce (*Picea mariana*), white spruce (*Picea glauca*), and balsam poplar (*Populus balsamifera*). Less abundant tree species include jack pine (*Pinus banksiana*), lodgepole pine (*Pinus contorta*), tamarack (*Larix laricina*), trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*) and water birch (*Betula occidentalis*). Species distribution varies because of local differences in growing conditions; however, the jack pine is usually found in sandy areas and the black spruce, water birch, and tamarack in wet lowlands.

Hydrogeological investigations within the study area have been conducted by Gabert (1968) in the Devon area, and by Kathol and McPherson (1975) in the northeastern part of the map area. Stein (1977) discussed the hydrogeology of a portion of the area in the Edmonton Regional Utilities Study. Numerous local groundwater investigations have been completed by groundwater consultants under contract to acreage developers.

The surficial geology of the study area has been described by Bayrock and Hughes (1962) and Bayrock (1972). Locations and thicknesses of sand and gravel deposits in the northeastern part of the area are given by Kathol and McPherson (1975). Gabert (1968) described the nature of the surficial deposits in the Devon area.

Bedrock geology information is available from Rutherford (1939) and Green (1972). The Ardley coal zones, within the Scollard Member of the Paskapoo Formation, are described by Holter, Yurko, and Chu (1975). Subdivision of the Edmonton Formation into distinct units has been attempted by numerous workers including Allan and Sanderson (1945), Ower (1958), Elliot (1958), and Irish (1970).

The bulk of the hydrogeological data used to compile this report, consisting of chemical, lithologic, hydraulic, and well completion information, was obtained from the Alberta Research Council Groundwater Division Data Bank. Typically much more and more detailed information is available for those areas immediately adjacent to major settlements. All data and the interpretation are presented in the format given by Badry (1972).

Fieldwork consisted of field surveys, testhole drilling, and pump testing during the summers of 1972, 1973, 1975, and 1976. The field survey, conducted by truck, involved the collection of groundwater samples for chemical analysis and the documentation of geological and hydrogeological features. Nine testholes were completed to obtain stratigraphic information (Appendix). Seven were pump tested to obtain aquifer parameters.

Owing to the large amount of data available, the Edmonton map area has been divided into quarters and the maps of the quarters are being published at a scale larger than is customary for Alberta Research Council reconnaissance hydrogeology maps. The main map is presented at a scale of 1:125,000 and the side maps at a scale of 1:500,000.

ACKNOWLEDGMENTS

Preliminary hydrogeologic work was done by G.M. Gabert in 1972-73 and by R. Stein in 1975. Numerous informative discussions with R. Stein and R.I.J. Vogwill concerning various aspects of the hydrogeology in the study area were greatly appreciated.

Initial testhole drilling and aquifer testing was performed by H.W. Warnke Drilling of Wetaskiwin and subsequent work was performed by Garritty and Baker Drilling Company of Edmonton.

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TOPOGRAPHY AND DRAINAGE

The study area lies within the Interior Plains physiographic region and is included within the Eastern and Western Alberta Plains physiographic subdivisions (Atlas of Alberta, 1969). The topography is largely the result of differential erosion and glacial deposition. The highest elevation is over 915 m (3000 ft) above mean sea level (amsl) in the unnamed topographic high adjacent to Pigeon Lake and the lowest is less than 640 m (2100 ft) amsl in the North Saskatchewan River valley. High relief areas, lying mainly in the southwestern part of the map area, owe their existence to the erosional resistance of the Paskapoo Formation. Most of the area has a low relief due to the uniform erosion of the Horseshoe Canyon Formation. Local topographic highs within the low relief areas are primarily results of glacial deposition. The North Saskatchewan River valley, with a width rarely exceeding 0.8 km (0.5 mi), is incised to depths of over 46 m (150 ft).

Approximately 75 percent of the map area lies within the North Saskatchewan River drainage basin and 25 percent in the Battle River drainage basin, both of which drain to the Atlantic by way of the Hudson Bay. Most of the lakes within the study area are shallow and elongated since they occupy glacial meltwater channels. Pigeon Lake, which is over 10 m (35 ft) deep in places (Alberta Department of Environment, unpublished data), is the largest lake within the study area.

CLIMATE

According to the Koeppen system of climatic classification (Longley, 1972), the climate of the study area is microthermal with warm summers: the mean temperature of the warmest month is below 22°C, and the area has at least four months with a mean temperature of 10°C or more.

Mean annual precipitation varies from approximately 460 mm (18 in) in the northeast to approximately 483 mm (19 in) in the southwestern part of the map area. Approximately 70 percent of the total precipitation falls as rain. The isohyets presented on the meteorological side map have been modified from Longley (1972). Average annual potential evapotranspiration is about 533 mm (21 in) and exceeds precipitation both annually and during the months of May to September (Bruce and Weisman, 1967).

January is the coldest month with a mean temperature of about -16°C and July the warmest with a mean temperature of about 16°C. Meteorological records from 1941 to 1970 indicate the average annual frost-free period to be about 135 days. The last spring frost occurs in May and the first fall frost usually occurs in September (Longley, 1972).

GEOLOGY

BEDROCK GEOLOGY

The bedrock geology of the study area, determined using lithologs, geophysical logs, outcrop data, and information obtained from previous investigations, is represented on the main map, geological side map, and cross sections. Table 1 lists the formations found within the study area.

Bedrock consists of nonmarine lenticular sandstone, shale, and coal beds. The regional strike is approximately N45 W and the dip is to the southwest at 3 to 4 m/km (15 to 20 ft/mi).

The primary geological units of the area are:

Belly River Formation: The Belly River Formation consists of nonmarine bentonitic sandstone, medium to dark gray siltstone, and claystone, with thin beds of dark brown weathering sideritic ironstone and coal (Locker, 1973).

Bearpaw Formation: According to Green (1972), interfingering dark gray marine shales, nonmarine bentonitic beds, and glauconitic sandstones constitute the Bearpaw Formation.

Horseshoe Canyon Formation: The Horseshoe Canyon Formation consists of fine-grained bentonitic sandstones, silty shales, lenticular coal lenses, and numerous bentonitic beds, with abundant siderite and siderite-cemented beds (Green, 1972). One of the most characteristic properties of the Horseshoe Canyon Formation is the discontinuity of beds due to lateral and vertical lithological variation. Both the upper and lower boundaries of the Horseshoe Canyon Formation are poorly defined because the transitions between this formation and the underlying Bearpaw Formation and the overlying Whitemud Formation are gradational.

Wapiti Formation: North of the North Saskatchewan River the Bearpaw Formation is poorly defined. Consequently, the Horseshoe Canyon Formation is combined with the Belly River Formation and termed the Wapiti Formation (Green, 1972).

Whitemud Formation: The Whitemud Formation consists of nonmarine, greenish-gray siltstones and sandstones with gray and green clay interbeds (Irish, 1970). The thickness of the formation in the study area is about 18 m (60 ft). The contact with the overlying Battle Formation is abrupt.

Battle Formation: According to Green (1972) the Battle Formation consists of purplish-black bentonitic mudstone containing siliceous tuff beds. In the study area the thickness of the Battle Formation varies from 15 to 18 m (50 to 60 ft). The upper contact with the Paskapoo Formation is gradational in some places and distinct in others. The lower contact with the Whitemud Formation is well defined.

Paskapoo Formation: The Paskapoo Formation is composed of Upper Cretaceous and Tertiary nonmarine lenticular beds of fine- to medium-grained sandstones which attain thicknesses of 30 m (100 ft) (Green, 1972). Siltstones and claystones are thinner and consist of medium to dark gray rocks with thin sandy intervals (Locker, 1973). Sandstones of the Paskapoo Formation tend to be less bentonitic and "softer" than those of the Horseshoe Canyon Formation.

The Scollard Member of the Paskapoo Formation, which is composed of Upper Cretaceous beds, is about 46 m (150 ft) thick in the study area. Within the Scollard Member are three major coal zones known as Lower Ardley A, Lower Ardley B, and Upper Ardley (Holter, Yurko, and Chu, 1975).

BEDROCK TOPOGRAPHY

A bedrock topography map was constructed utilizing electric logs, lithologs, and seismic shothole data (Ceroici, in preparation, b). In general, the preglacial topography was similar to present topography, but preglacial drainage has been modified somewhat and a thin cover of glacial materials has been deposited.

The preglacial Stony Valley, which is a tributary to the Beverly Valley, trends northeast from the northwestern corner of the study area. The North Saskatchewan River flows in the preglacial valley starting in the southwestern part of the city of Edmonton where the outcrop of the Saskatchewan gravels and sands is evidenced by numerous contact springs and seepages. The largest tributary to the Stony Valley is the New Sarepta Valley (Carlson, 1966), which originates in Tp. 49, R. 22. The Ellerslie Valley (Kathol and McPherson, 1975) is the largest of numerous tributaries to the New Sarepta Valley. The thickness of surficial deposits within the preglacial valleys varies from less than 23 m (75 ft) in the Ellerslie Valley to over 45 m (150 ft) in the Stony Valley.

TABLE 1

Stratigraphic column of formations found in the southwest segment, Edmonton area

PERIOD	FORMATION	
Quaternary	glacial deposits	
Tertiary	Saskatchewan gravels and sands	
	Paskapoo Formation	
Upper Cretaceous	Scollard Member	
	Battle Formation	
	Whitemud Formation	
	Horseshoe Canyon Formation	Wapiti Formation*
	Bearpaw Formation	
	Belly River Formation	
	Lea Park Formation	

*The North Saskatchewan River is the customary, arbitrary boundary between the Wapiti Formation and the Horseshoe Canyon and Belly River Formations.

The highest bedrock elevation (over 900 m, or 2950 ft) is found in the southwestern part of the study area where the bedrock is the resistant Paskapoo Formation. Due to preglacial erosion of the Stony Valley, the lowest bedrock elevation (less than 625 m, or 2050 ft) is found north of Devon.

SURFICIAL GEOLOGY

Till overlies much of the study area in the form of ground moraine and hummocky disintegration moraine. Areas of hummocky disintegration moraine, located primarily in the northeastern part of the map area, are characterized by "knob and kettle" topography. Ground moraine areas are characterized by a rolling topography. In general, the till is a poorly sorted mixture of clay, silt, sand, and gravel containing about 80 percent local bedrock and 20 percent Canadian Shield igneous and metamorphic rocks. Montmorillonite is the dominant clay mineral with lesser amounts of illite and kaolinite (Gravenor and Bayrock, 1961). Several workers have argued for the presence of two different till sheets (Bayrock and Berg, 1969; Gabert, 1968; and Westgate, 1969). As the lithology and hydraulic properties of the two hypothesized till sheets are similar, they will be considered to be a single unit in this report.

Glaciofluvial deposits are widespread over the entire study area. These consist of stratified deposits of clay, silt, sand, and gravel in the form of kames, outwash sands and gravels, and localized lenses within the till. Long and narrow, east-west trending channels are surface expressions of glaciofluvial erosion and deposition.

The preglacial Stony Valley is floored by fine- to medium-grained sands, known as the Saskatchewan gravels and sands, which lie unconformably on the Upper Cretaceous bedrock surface and are overlain by till. Criteria for the identification of the Saskatchewan gravels and sands are given by Stalker (1968). Gabert (1968) encountered 21 m (70 ft) of the sands in a testhole at Lsd. 3, Sec. 27, Tp. 51, R. 26, W. 4th Mer.; this is the greatest thickness of this material yet detected. The Saskatchewan gravels and sands consist of quartzite, which is the dominant component, and lesser amounts of limestone, basic volcanics, arkose, chert and local bedrock (Horberg, 1952).

Most of the glaciolacustrine sediments are found in the north-central part of the study area. The main components are clay, silt, and sand. These deposits attain thicknesses of up to 15 m (50 ft), and were deposited in proglacial Lake Edmonton. Varves are common in the deposits. The lower portion of the sediments, which apparently was deposited in proximity to the glacier margin where ice rafting and slumping of glacial materials was prevalent tends to be sandier than the upper portion (Kathol and McPherson, 1975).

Recent eolian sand deposits are present in the northwestern corner of the map area and near Millet (Bayrock, 1972). Parabolic and longitudinal dunes, stabilized by vegetation, indicate a prevailing wind direction from the northwest during dune formation. The maximum thickness of the deposits is about 15 m (50 ft).

North Saskatchewan River alluvium consists of clay, silt, sand, and coarse gravels. Downcutting of the river valley and the resulting deposition of alluvium commenced after drainage of proglacial Lake Edmonton. Four postglacial terraces have been recognized in the river valley (Westgate, 1969).

HYDROGEOLOGY

Groundwater availability in the study area is represented on the yield map and the hydrogeological cross sections. The yield map shows the maximum potential yield which can be obtained at any point within the study area to a depth of approximately 100 m (350 ft), regardless of quality. Anticipated yields are based on approximately 250 short-term pump tests and about 15 pump tests 2 hours or more in duration. The actual yield within an area may differ from the predicted yield because of local variations in geology and topography. Where the yield has been estimated from qualitative information it is termed "probable," and where it has been estimated from quantitative information it is termed "possible" (Badry, 1972).

To determine aquifer parameters, the Theis nonequilibrium method (Theis, 1935) was used when observation well data were available, and the Jacob modified nonequilibrium method (Jacob, 1940) was used when pumping well data only were available. Transmissivity is termed "apparent" if it is derived from short pump or bail tests for which only the rate of production and total drawdown at the end of the production period are known (Farvolden, 1961).

The 20-year safe yield was calculated using the equation:

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

where Q_{20} is the sustainable yield in igpm, T = transmissivity (igpd/ft), and H = available drawdown (ft). The accuracy of the safe yield estimate is largely dependent upon the length of the pump test. An arbitrary safety factor of about 0.7 is applied to the safe yields due to boundary conditions and other uncertainties. Sustainable yields which are calculated yields which are calculated using apparent transmissivities are termed "apparent safe yields." When the yield map was compiled, sustainable yields calculated from long-term pump tests were weighted more heavily.

BEDROCK AQUIFERS

Paskapoo Formation

The greater part of the Paskapoo Formation was assigned a yield value between 0.4 and 2 L/sec (5 and 25 igpm). Massive sandstones within the Paskapoo Formation are capable of yielding more than 8 L/sec (100 igpm). The thickest sandstone unit encountered, referred to as the "basal Paskapoo" sandstone, is 18 m (60 ft) thick in a testhole located in Lsd. 8, Sec. 18, Tp. 47, R. 26, W. 4th Mer., for which a transmissivity and hydraulic conductivity of 160 m^2/day (10,700 igpd/ft) and 10^{-2} cm/sec (170 igpd/ft^2), respectively, were calculated from a 4-hour pump test. Near Pigeon Lake at Lsd. 12, Sec. 1, Tp. 47, R. 28, W. 4th Mer., a testhole was completed in a series of sandstones overlying the Upper Ardley coal zone. The transmissivity and sustainable yield were found to be 104 m^2/day (7000 igpd/ft) and 57 L/sec (750 igpm), respectively.

Coal zones within the Scollard Member are generally poor aquifers; however, where the zones are at shallow depth they may be significantly fractured, resulting in higher groundwater potential. They are assigned a yield range between 0.4 and 2 L/sec (5 and 25 igpm).

Battle and Whitemud Formations

None of the wells for which data are available are completed in the Battle and Whitemud Formations; consequently the yields are predicted from qualitative data. The Battle Formation, composed of bentonite and bentonitic shale, has a low permeability and was assigned to a yield category of less than 0.1 L/sec (<1 igpm).

Within the Whitemud Formation are numerous thick sandstones which are evident on electric logs. The resistivity and spontaneous potential deflections on electric logs are similar to those for Paskapoo sandstones, so the Whitemud Formation has been assigned to a yield range of 0.4 to 2 L/sec (5 to 25 igpm).

Horseshoe Canyon Formation

Groundwater availability in the Horseshoe Canyon Formation is extremely variable due to lateral and vertical variations in lithology. Sandstone and coal lenses capable of yielding between 0.1 and 0.4 L/Sec (1 and 5 igpm) are the dominant aquifers throughout most of the formation. In general, the sandstones of the Horseshoe Canyon Formation, owing to their high bentonite content, tend to be less permeable than those of the Paskapoo Formation. Yields from the Horseshoe Canyon Formation are less than 0.1 L/sec (1 igpm) near Nisku due to a higher argillaceous content. A transmissivity and sustainable yield of less than 0.04 m^2/day (2.4 igpd/ft) and less than 0.1 L/sec (1 igpm), respectively, were calculated from a pump test of a well completed within a shale-sandstone succession of the Horseshoe Canyon Formation near Ellerslie.

The "Millet" sandstone, the top of which is located about 46 to 61 m (150 to 200 ft) below the Whitemud Formation, is the most important aquifer within the Horseshoe Canyon Formation. The aquifer, which is capable of yielding from 2 to 8 L/sec (25 to 100 igpm), consists of a succession of sandstones, siltstones, and shales which are laterally and vertically discontinuous. During pump tests in Millet and near Calmar (Stein, 1977) several boundaries were encountered, probably due to the lateral and vertical discontinuity of strata. The regional transmissivity, calculated from the latter part of the time-drawdown curves, was about 60 m^2/day (4020 igpd/ft). In the Millet pump test a shallow aquifer, separated from a deeper aquifer by a 3-m (10-ft) thick claystone-siltstone succession, responded to pumping in the deeper aquifer. The response of the shallow aquifer suggests that the claystone-siltstone succession is either fractured or is an impermeable lens of only limited areal extent. The high yield of the Millet sandstone may be due to significant fracture permeability or perhaps to the localized occurrence of a permeable sandstone facies. Strata adjacent to the Millet sandstone that are less fractured or contain less arenaceous material are assigned a yield one category lower.

The Horseshoe Canyon Formation is noticeably more permeable in both the Millet area and north of Devon than in other parts of the map area. Both areas are overlain by extensive dune fields. According to Stein (1976), higher permeability in bedrock overlain by highly permeable surficial deposits may be due to "the solution of cementing material by persistent and relatively intense groundwater flow caused by high rates of infiltration of precipitation through the surficial deposits."

The basal portion of the Horseshoe Canyon Formation contains numerous coal lenses and seams. In the northeastern corner of the study area some of these coal members subcrop and are significantly fractured, probably due to glacial overriding. Yield from the coal member, which is controlled by the areal distribution and thickness of the coal lenses, varies from 0.1 to 2 L/sec (1 to 25 igpm).

Bearpaw Formation Equivalent

The Bearpaw Formation Equivalent has been assigned a yield range of 0.1 to 0.4 L/sec (1 to 5 igpm). The primary water-bearing units are probably discontinuous sandstone and coal lenses. Water from the formation is saline.

Belly River Formation

Numerous important sandstone aquifers are present within the Belly River Formation northeast of the map area (Stein, 1976). However, in the study area, to the depth considered, the Belly River is a poor aquifer consisting primarily of a sequence of shales so is assigned a yield of less than 0.1 L/sec (<1 igpm).

SASKATCHEWAN GRAVELS AND SANDS

The Saskatchewan gravels and sands within the Stony Valley, which are assigned to a yield range of 2 to 7.6 L/sec (25 to 100 igpm), are the most important aquifer in the surficial deposits. Yield from the Saskatchewan gravels and sands varies locally depending on the available drawdown and the saturated thickness. A pump test by Gabert (1968) in Lsd. 13, Sec. 36, Tp. 51, R. 26, W. 4th Mer. of a well completed within the deposits revealed a transmissivity and sustainable yield of 104 m^2/day (6955 igpd/ft) and 6 L/sec (82 igpm), respectively. The preglacial sands are recharged where the preglacial valley crosses the North Saskatchewan River southwest of Edmonton, so yields may be higher upstream, although no pump test data are available.

Preglacial terraces on the flanks of the Stony Valley tend to be less productive than deposits of Saskatchewan gravels and sands, because the terraces are thinner. Glacial reworking of the terrace deposits may have significantly decreased their permeability by introducing more fine-grained sediments.

Tributaries to the Stony Valley such as the New Sarepta and Ellerslie valleys are assigned a yield range of 0.4 to 1.8 L/sec (5 to 25 igpm). The yield from deposits in the tributaries is considerably less than that expected in the major valley because the deposits are thinner and less permeable so the available drawdown is less. In small tributaries filled entirely with till the yield ranges from less than 0.1 to 0.4 L/sec (<1 to 5 igpm).

SURFICIAL DEPOSIT AQUIFERS

Eolian deposits, which attain thicknesses of up to 9 m (30 ft) (Gabert, 1968) in the northwestern part of the study area and near Millet are an important aquifer. Groundwater availability is dependent primarily upon the saturated thickness. Accurate aquifer parameters, derived from good pump test data, are not available for eolian deposits. Numerous short-term pump or bail tests suggest, however, that apparent transmissivity values range from 0.7 to 3 m^3/day (47 to 200 igpd/ft).

Till is widespread over the study area and generally has poor groundwater potential. Yield from till is dependent upon the thickness, topographic location, degree of fracturing, and the frequency and distribution of sand and gravel lenses. A yield range of 0.1 to 0.4 L/sec (1 to 5 igpm) can be expected where the till is over 15 m (50 ft) thick, is significantly fractured, or contains numerous sand lenses. Less than 0.1 L/sec (<1 igpm) is to be expected where the till is thin and has primarily a clay matrix.

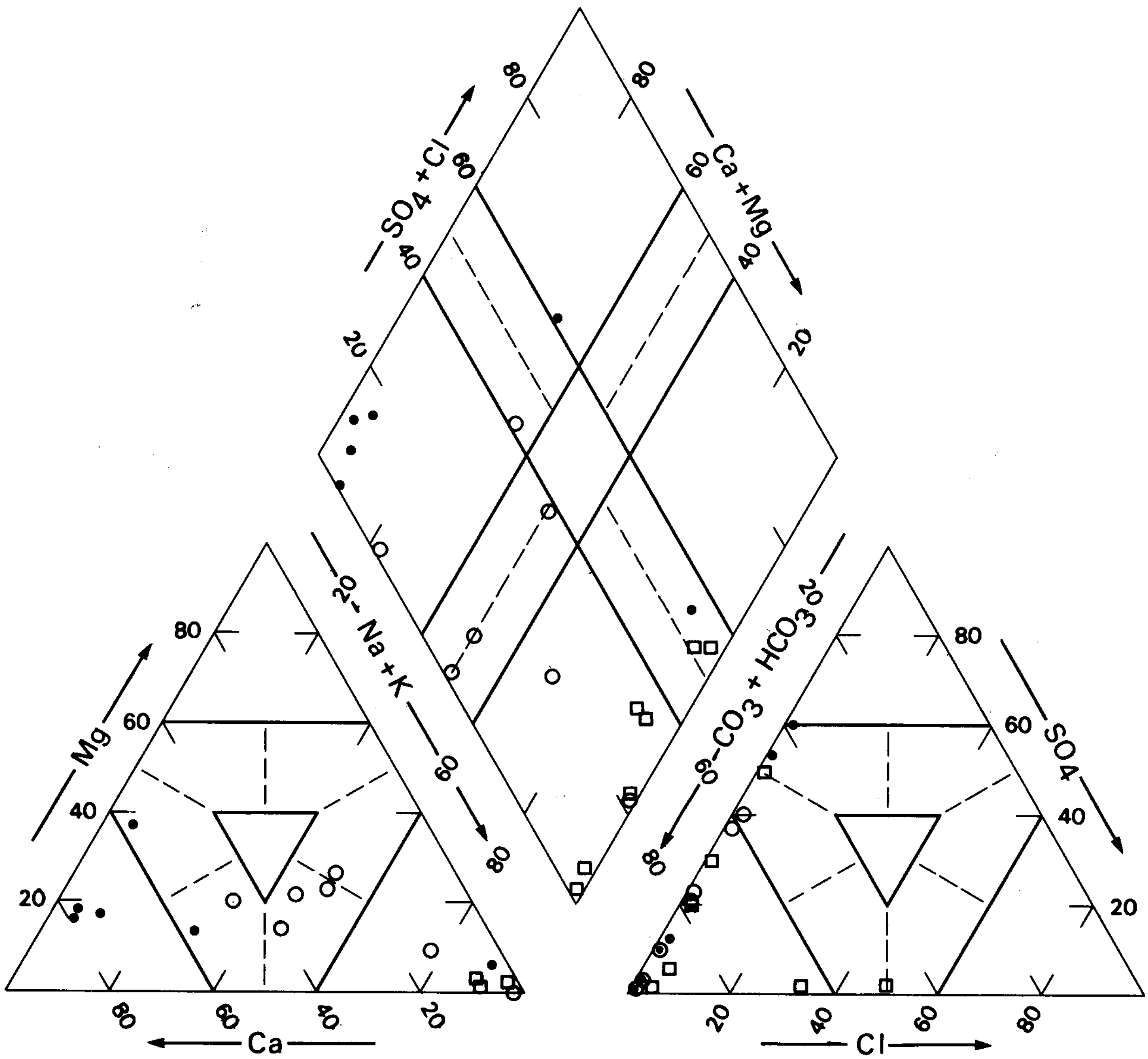
Glaciofluvial deposits, consisting of clay, silt, sand, and gravel, are scattered over the study area. In the southern part of the study area numerous east-west trending channels indicate the presence of glaciofluvial deposits. Some channels have a thin layer of sand and fine gravel, usually less than 3 m (10 ft) thick. West of Millet, glaciofluvial deposits are commonly overlain by eolian deposits (Bayrock, 1972). Since the eolian sands are highly permeable, infiltrating groundwater effectively recharges the glaciofluvial deposits, thereby increasing the possible yield ranges of 0.1 to 0.4 L/sec (1 to 5 igpm), to 0.4 to 2 L/sec (5 to 25 igpm). In areas where glaciofluvial deposits consist predominantly of gravels, as do some of the deposits in the vicinity of Millet, the transmissivity may be as high as 300 m^2/day (20,100 igpd/ft). The yield is low, however, due to the limited areal extent of the deposits. Glaciofluvial deposits also occur as localized lenses within till. Yield from the lenses is largely determined by the amount of groundwater moving into the lens from the surrounding till and by the thickness and areal extent of the lens.

The Recent alluvium, composed of clay, silt, sand, and gravel, present in the North Saskatchewan River valley, is capable of yielding 7.6 to 38 L/sec (100 to 500 igpm). Yields of over 38 L/sec (500 igpm) can be obtained if water is removed from the river by induced infiltration. Yields tend to be lower in the terrace deposits flanking the river valley, because the terraces are at higher elevations and consequently their zone of saturation is thinner.

GROUNDWATER FLOW DISTRIBUTION

Direction of groundwater flow was determined utilizing surface topography, groundwater discharge features such as flowing wells, springs, and seeps, and about 600 non-pumping water levels from water wells. Non-pumping water level contours are shown on the main map and equipotential lines are shown on the cross sections. Owing to inaccuracies involved in water level measurement, and to seasonal variations of the water levels, the contours are approximate.

PERCENT OF TOTAL EQUIVALENTS PER MILLION



Legend

Source of groundwater
- ● surficial deposits
- ○ Saskatchewan gravels and sands
- □ Bedrock

FIGURE 1. Piper diagram showing the chemical character of groundwater

The dune field in the northwestern corner of the study area is a recharge area from which groundwater moves east and south towards the Stony Valley and North Saskatchewan River. Within the dune fields numerous local flow systems are developed. Surface water bodies occurring in the dune field are "outcrops" of the water table.

In the hummocky disintegration moraine plateau located in the northeastern part of the study area, groundwater moves westward toward the Stony Valley and North Saskatchewan River. As in the dune fields, local flow systems are prevalent. Recharge occurs at local topographic highs and discharge occurs in the adjacent topographic lows.

The Stony Valley has the lowest potential in the study area and acts as a "line" sink, inducing flow toward itself from all directions. Gabert (1968) found that along the course of the valley, from southwest to northeast, there is a drop in the natural fluid potential resulting in a dominant groundwater flow toward the northeast.

The major flowing artesian areas within the study area lie in topographic lows along three bands which coincide with the regional geologic strike. The three bands lie approximately over the subcrop of three highly permeable bedrock aquifers:

(1) an unnamed sandstone in the upper part of the Paskapoo Formation;

(2) the "basal Paskapoo" sandstone overlying the Lower Ardley "A" Coal Zone;

(3) the "Millet" sandstone within the Horseshoe Canyon Formation.

In general, the flowing artesian areas associated with the "Millet" sandstone are permanent, while those artesian areas associated with Paskapoo sandstones tend to be intermittent. Localized flowing artesian areas, occurring primarily in the southern portion of the study area, are low flow, temporary discharge features associated with local or intermediate flow systems.

Ceroici (in preparation, a) used a two-dimensional finite element mathematical model to generate theoretical groundwater flow along a section within the study area. The simulation suggested that:

(1) The major recharge area is the unnamed topographic high adjacent to Pigeon Lake. Water moves downward to recharge bedrock aquifers, then laterally southwest to discharge at Pigeon Lake, and northeast to discharge in the numerous outwash lakes (Wizard Lake, Long Lake) and North Saskatchewan River.

(2) About 80 percent of the groundwater flow is concentrated in the strata overlying the Horseshoe Canyon Formation.

(3) The hummocky water table, located in the region of glacial outwash lakes, generates numerous local flow systems which are enveloped by a larger intermediate flow system.

(4) Most of the flow is concentrated in the highly permeable sandstone units of the Paskapoo Formation.

(5) Groundwater flow is essentially vertical through the Battle Formation owing to low permeability.

(6) In areas where the regional water table slope is shallow, groundwater flow is essentially parallel to the water table.

(7) Major topographic lows in the study area, such as the North Saskatchewan River, are major discharge areas. Local topographic depressions tend to be discharge points for local and intermediate flow systems.

Most of the springs within the study area are low-flow contact springs issuing from drift-bedrock contacts in the outwash channels and North Saskatchewan River. Springs and seepages issuing from the contact between the Saskatchewan gravels and sands and bedrock at the "Big Bend" (Lsd. 3, Sec. 16, Tp. 25, R. 52, W. 4th Mer.) are evidenced by increased vegetation and the precipitation of ferric hydroxide.

HYDROCHEMISTRY

The areal distribution of chemical constituents is presented on the chemical side maps, and vertical variations are shown on the hydrogeological cross sections. Chemical character of groundwater is illustrated graphically in figure 1 using a method devised by Piper (1944).

In most cases calcium plus magnesium (Ca + Mg) constitute over 60 percent of the total cations in the surficial deposits and sodium plus potassium (Na + K) always predominate in bedrock waters. Cation concentration variations in waters from surficial deposits are due to local lithologic variations within the drift. In general, the major cations in groundwater from the dune fields and the upper part of the Saskatchewan gravels and sands are Ca + Mg, while in groundwaters from the till, which is composed partly of local bedrock having a high montmorillonite content, Na + K may constitute over 60 percent of the total cations.

Chloride (Cl) concentrations are generally less than 50 mg/L in both the surficial deposits and the bedrock. High chloride concentrations are found locally in groundwater from the bedrock in the northeastern corner of the study area. The high chloride concentrations are probably derived from poorly permeable marine strata within the Horseshoe Canyon and possibly the Bearpaw Formation. Because the area lacks significant relief there is little potential difference, resulting in slow groundwater movement which precludes flushing of bedrock sediments.

Sulfate (SO_4) concentrations in bedrock groundwaters vary from 0 to over 200 mg/L with an average of about 100 mg/L. In drift waters the concentration varies from 0 to over 10,000 mg/L with an average of about 150 mg/L. The highest sulfate ion concentrations are found primarily in the northeastern corner of the study area, owing to the abundance of gypsum within the drift and in coal lenses in the Horseshoe Canyon Formation coaly member which subcrops in the area.

Bicarbonate plus carbonate ion ($HCO_3 + CO_3$) concentrations comprise over 80 percent of the total cations in the upland areas, but the proportion of these ions decreases toward the lowland areas. In general, a high $HCO_3 + CO_3$ concentration indicates that the groundwater has had short subsurface residence time.

The highest total dissolved solids concentrations are found in the northeastern part of the study area, and are usually associated with $(Ca + Mg)/SO_4$ type water from the drift or Na/Cl type water from the bedrock. In the remainder of the study area, to the depths considered, the total dissolved solids concentrations are usually less than 2500 mg/L. Since the Paskapoo Formation contains only minor amounts of soluble salts and is often subject to high relief, and consequently frequent flushing, groundwaters from these strata usually have total dissolved solids concentrations less than 1500 mg/L. Groundwaters from the surficial deposits in upland areas such as the dune fields often have total dissolved solids concentrations of less than 500 mg/L due to the high permeability of the deposits and frequent flushing. In general, total dissolved solids concentrations of less than 2000 mg/L are associated with $(Ca + Mg)/HCO_3$ or $(Na + K)/HCO_3$ type waters.

Nitrate (NO_3) concentrations are almost negligible in bedrock groundwaters; however, they often exceed 20 mg/L in drift waters. Since background nitrate levels are low, a well is termed contaminated when nitrate concentrations are over 10 mg/L. Almost half of the wells completed in the drift show signs of nitrate contamination, probably due to poor well construction and nearness of wells to decaying vegetable matter, barns, and so on.

In bedrock waters iron is present in low concentrations, usually less than 0.5 mg/L. However, groundwaters from surficial deposits often contain over 5 mg/L iron. The highest iron concentrations are in waters from the dune fields and Saskatchewan gravels and sands. Occasionally waters in sand lenses within till may have a high iron content owing to the presence of ferromagnesian minerals derived from igneous rocks.

Fluoride concentrations are generally less than 0.5 mg/L in drift waters; however, they may be over 1.5 mg/L in bedrock waters.

CONCLUSIONS

The Paskapoo Formation, which is capable of yielding up to 38 L/sec (500 igpm), is the best bedrock aquifer in the study area. In general, the Horseshoe Canyon Formation is a poor aquifer except for the "Millet" sandstone which yields up to 7.6 L/sec (100 igpm) and the coaly member which is capable of yielding up to 2 L/sec (25 igpm). The Whitemud, Battle, and Belly River Formations are poor to moderate aquifers. The best aquifer (within the surficial deposits) is the coarse sand in the Stony Valley, which is capable of yielding up to 7.6 L/sec (100 igpm).

The general direction of groundwater flow is toward the Stony Valley and North Saskatchewan River, which act as line sinks, inducing flow toward themselves from all directions. All of the major flowing artesian areas are in the southwestern part of the study area where large permeability contrasts and significant relief generate significant potential differences.

Calcium-magnesium bicarbonate type water predominates in the surficial deposits and sodium bicarbonate type water predominates in the bedrock. Waters which have bicarbonate as the major anion are usually associated with a total dissolved solids concentration varying from 500 to 2000 mg/L. Locally, in the northeastern part of the study area, chloride or sulfate are the major anion and the total dissolved solids concentration is as high as 5000 mg/L. Nitrate contamination is evident in almost half of the wells completed in the drift.

APPENDIX. AQUIFER TESTS AND TEST DRILLING

1.	Location:	Lsd. 9, Sec. 26, Tp. 47, R. 25, W. 4
	Owner:	Alberta Research Council
	Contractor:	H.W. Warnke Drilling, Wetaskiwin
	Depth of well:	122 m (400 ft)

Lithological log (ft):

0-8	clay, brown
8-15	sand and gravel
15-45	clay, brown
45-67	sand, fine-grained
67-93	clay, blue
93-113	shale, gray
113-114	coal
114-147	shale, gray
147-153	sandstone, fine-grained
153-167	shale, gray
167-174	sandstone
174-192	shale, blue
192-193	rock
193-205	shale, blue, rocky
205-210	sandstone, fine-grained
210-233	shale, blue
233-236	shale, gray; minor sandstone, fine-grained
236-248	shale, blue
248-256	shale, gray-brown
256-325	shale, blue
325-330	sandstone, coarse-grained
330-346	shale, blue
346-350	shale, gray; sandstone, fine-grained
350-365	shale, gray-brown
365-370	shale, brown
370-400	shale, gray-brown

Tests: pumping: 180 min
rate: 1.2 L/sec (16 igpm)

Aquifer parameters: transmissivity (T): 21 m^2/day
(1400 igpd/ft)
20-year safe yield (Q_{20}): 7 L/sec
(87 igpm)

2. Location: Lsd. 8, Sec. 18, Tp. 47, R. 26, W. 4
Owner: Alberta Research Council
Contractor: H.W. Warnke Drilling, Wetaskiwin
Depth of well: 46 m (150 ft)

Lithological log (ft):

0-25	clay, brown
25-40	clay, blue; sand, medium-grained
40-46	shale, gray
84-136	sandstone, light gray, medium- to coarse-grained
136-137	coal
137-139	shale, carbonaceous
139-143	coal
143-150	shale, greenish-gray

Tests: pumping: 480 min
rate: 4.5 L/sec (60 igpm)

Aquifer parameters: transmissivity (T): 152 m^2/day
(10,200 igpd/ft)
20-year safe yield (Q_{20}): 28 L/sec
(370 igpm)

3. Location: Lsd. 3, Sec. 16, Tp. 47, R. 27, W. 4
Owner: Alberta Research Council
Contractor: Garritty and Baker Drilling Ltd., Edmonton
Depth of well: 87 m (285 ft)

Lithological log (ft):

0-14	till, brown
14-36	till, gray
36-37	sand, fine-grained, gray
37-57	till, gray
57-94	clay, gray, minor coal
94-104	shale, green
104-110	siltstone, light gray
110-134	shale, gray; siltstone, light gray
134-180	shale, green
180-220	sandstone, fine-grained, light gray; siltstone, light gray
220-233	coal
233-254	shale, gray
254-256	coal
256-270	shale, gray
270-285	shale, gray; siltstone, light gray

Tests: not tested

4. Location: Lsd. 1, Sec. 3, Tp. 48, R. 24, W. 4
Owner: Alberta Research Council
Contractor: H.W. Warnke Drilling, Wetaskiwin
Depth of well: 122 m (400 ft)

Lithological log (ft):

0-25	sand, fine-grained, silty
25-32	clay, silty
32-42	till
42-44	gravel
44-52	till
52-70	shale, grayish-green; siltstone, light gray
70-82	shale, greenish-gray
82-85	sandstone, fine-grained
85-95	shale, greenish-gray
95-96	sandstone, fine-grained
96-100	shale, greenish-gray
100-110	shale, light gray; siltstone

110-117	sandstone, fine-grained, clayey, gray
117-130	shale, greenish-gray
130-136	shale, light gray
136-140	sandstone, light gray; siltstone, light gray
140-160	shale, greenish-gray; sandstone, fine- to medium-grained, light gray
160-163	shale, light greenish-gray
163-164	sandstone, fine- to medium-grained, gray
164-176	shale, greenish-gray
176-200	shale, greenish-gray; sandstone, fine-grained
200-237	shale, rocky, blue
237-239	sandstone, rock
239-241	shale, blue
241-243	sandstone, light gray
243-257	shale, gray-green
257-259	sandstone, light gray
259-306	shale, greenish-gray
306-308	sandstone, light gray
308-315	shale, gray
315-335	shale, brown with coal
335-348	shale, blue-gray
348-351	sandstone, light gray
351-400	shale, gray

Tests: pumping: 240 min
rate: 2 L/sec (24 igpm)
remark: pumping test was also conducted when testhole was 61 m (200 ft) deep

Aquifer parameters: transmissivity (T): 14 m^2/day (967 igpd/ft)
20-year safe yield (Q_{20}): 3 L/sec (40 igpm)

5. Location: Lsd. 12, Sec. 1, Tp. 47, R. 28, W. 4
Owner: Alberta Research Council
Contractor: H.W. Warnke Drilling, Wetaskiwin
Depth of well: 116 m (380 ft)

Lithological log (ft):

0-16	clay, brown
16-18	sand, fine-grained
18-42	clay, gray
42-49	clay, blue
49-73	shale, green-gray
73-93	sandstone, fine-grained
93-123	shale, gray
123-202	sandstone, fine-grained
202-214	shale, brown
214-227	shale, gray
227-247	shale, green
247-264	shale, silty, gray
264-267	shale, green
267-316	sandstone, fine-grained
316-318	coal
318-319	shale, brown
319-337	coal
337-358	shale, gray-green
358-364	coal
364-380	shale, gray

Tests: pumping: 180 min
rate: 3 L/sec (40 igpm)
remark: 4-1/2 hour pump test was also conducted on a shallow sandstone aquifer

Aquifer parameters: transmissivity (T): 107 m^2/day (7204 igpd/ft)
20-year safe yield (Q_{20}): 57 L/sec (750 igpm)

6. Location: Lsd. 15, Sec. 33, Tp. 47, R. 27, W. 4
Owner: Alberta Research Council
Contractor: H.W. Warnke Drilling, Wetaskiwin
Depth of well: 122 m (400 ft)

Lithological log (ft):

0-15	clay, brown
15-33	clay, blue
33-103	shale, gray; minor coal
103-124	sandstone, fine-grained
124-146	shale, gray
146-165	sandstone, gray
169-174	shale, argillaceous
174-187	coal
187-213	shale, light gray
213-217	coal
217-305	shale, gray
305-316	coal
316-370	shale, gray; minor sandstone, light gray
370-394	shale, brown
394-400	shale, green with bentonitic layers

Tests: not tested

7. Location: Lsd. 3, Sec. 29, Tp. 51, R. 24, W. 4
Owner: Alberta Research Council
Contractor: Garritty and Baker Drilling Ltd., Edmonton
Depth of well: 66 m (218 ft)

Lithological log (ft):

0-14	clay, brown-gray
14-23	clay, gray
23-46	till, coal fragments, stony, gray
46-48	till, stony, gray
48-50	sand, medium-coarse grained
50-53	till, stony, gray
53-63	sandstone, light gray
63-71	shale, green
71-72	siltstone, brown
72-87	sandstone, light gray
87-88	shale, light brown
88-95	sandstone, shale interbeds, light gray
95-129	sandstone, light gray
129-136	siltstone, brown
136-147	sandstone, light gray
147-176	siltstone, light gray with gray shale interbeds
176-184	sandstone, light gray
184-218	siltstone, light gray with brown shale interbeds

Tests: pumping: 60 min
rate: 0.06 L/sec (0.8 igpm)
remark: pumping water level reached pump in one hour

Aquifer parameters: transmissivity (T): 0.04 m^2/day (2.6 igpd/ft)
20-year safe yield (Q_{20}): 0.008 L/sec (0.1 igpm)

8. Location: Lsd. 3, Sec. 29, Tp. 51, R. 24, W. 4
Owner: Alberta Research Council
Contractor: Garritty and Baker Drilling Ltd., Edmonton
Depth of well: 18 m (58 ft)

Lithological log (ft):

0-14	clay, brown-gray
14-34	till, clay interbeds, gray
34-46	sand, poorly sorted, coal chips and till interbeds
46-53	till, gray
53-58	sandstone, light gray

Tests: pumping: 60 min
rate: 0.06 L/sec (0.8 igpm)
remark: pumping water level reached pump in one hour

Aquifer parameters: transmissivity (T): 0.13 m^2/day (8.6 igpd/ft)
20-year safe yield (Q_{20}): 0.01 L/sec (0.12 igpm)

9. Location: Lsd. 16, Sec. 2, Tp. 48, R. 28, W. 4
Owner: Alberta Research Council
Contractor: Garritty and Baker Drilling Ltd., Edmonton
Depth of well: 64 m (215 ft)

Lithological log (ft):

0-14	till, brown, stony, traces of coal, oxidized
14-31	till, medium gray, stony
31-42	shale, green-gray
42-47	shale
47-54	siltstone, medium gray
54-62	shale, light to medium gray
62-73	sandstone, light gray; minor shale, medium gray
73-89	siltstone, light gray
89-98	shale, medium gray; siltstone, light gray
98-115	sandstone, light gray
115-137	shale, light gray
137-156	shale, medium gray
156-167	sandstone, light gray
167-182	shale, medium gray; shale, dark gray, carbonaceous
182-206	coal; shale, dark gray, carbonaceous
207-215	shale, green; siltstone, light gray

Tests: pumping: 1440 min
rate: 0.3 L/sec (4.2 igpm)

Aquifer parameters: transmissivity (T): 8.7 m^2/day (580 igpd/ft)
20-year safe yield (Q_{20}): 1.1 L/sec (15 igpd/ft)

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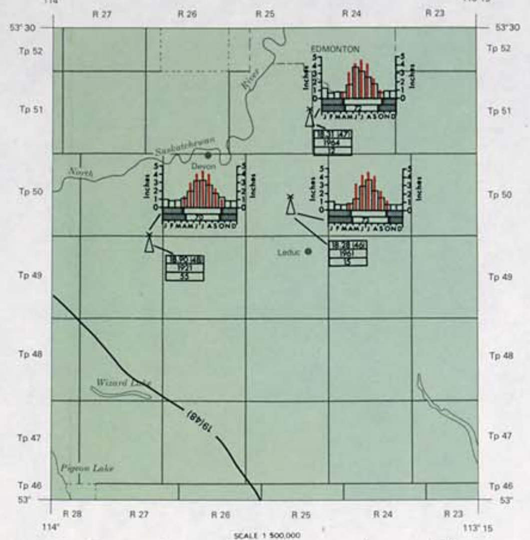
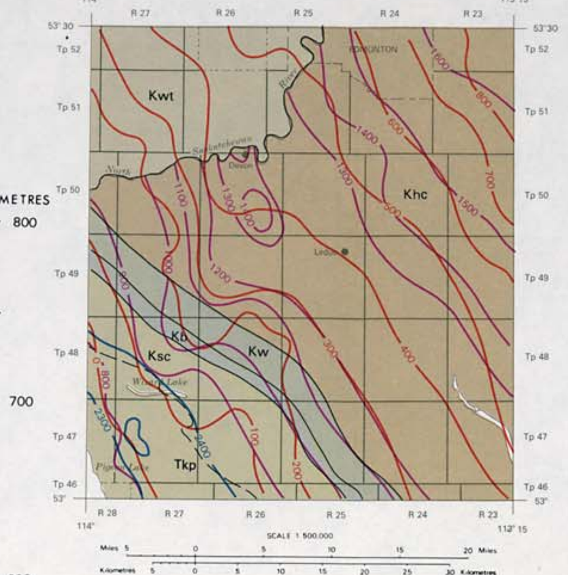
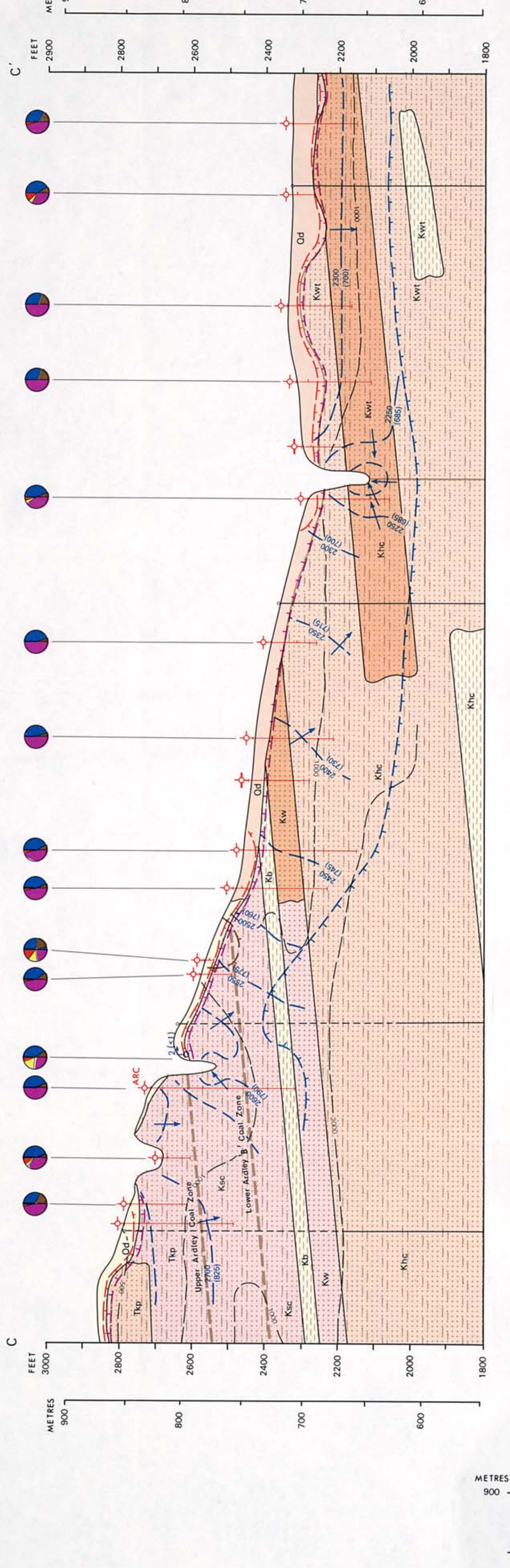
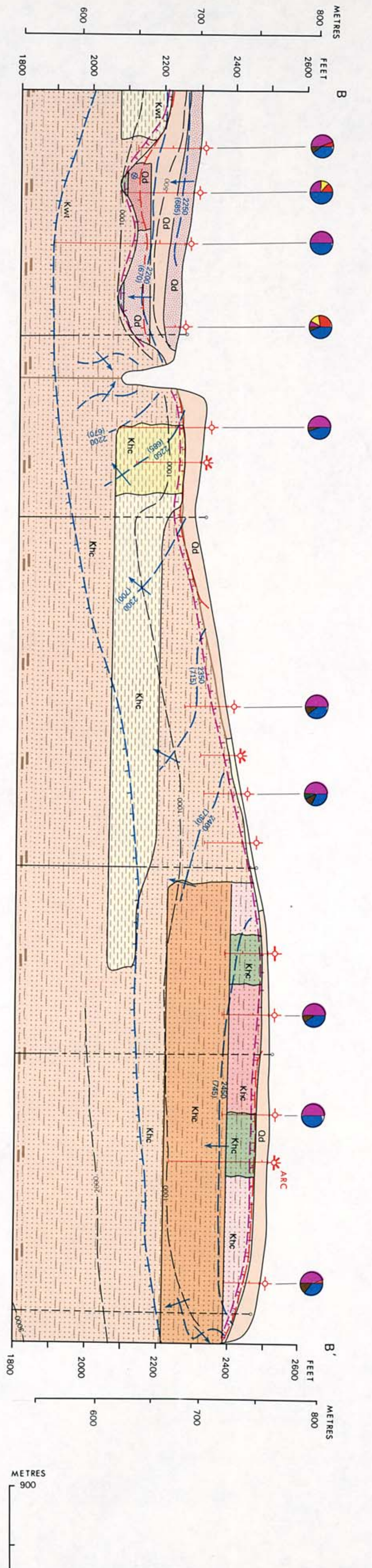
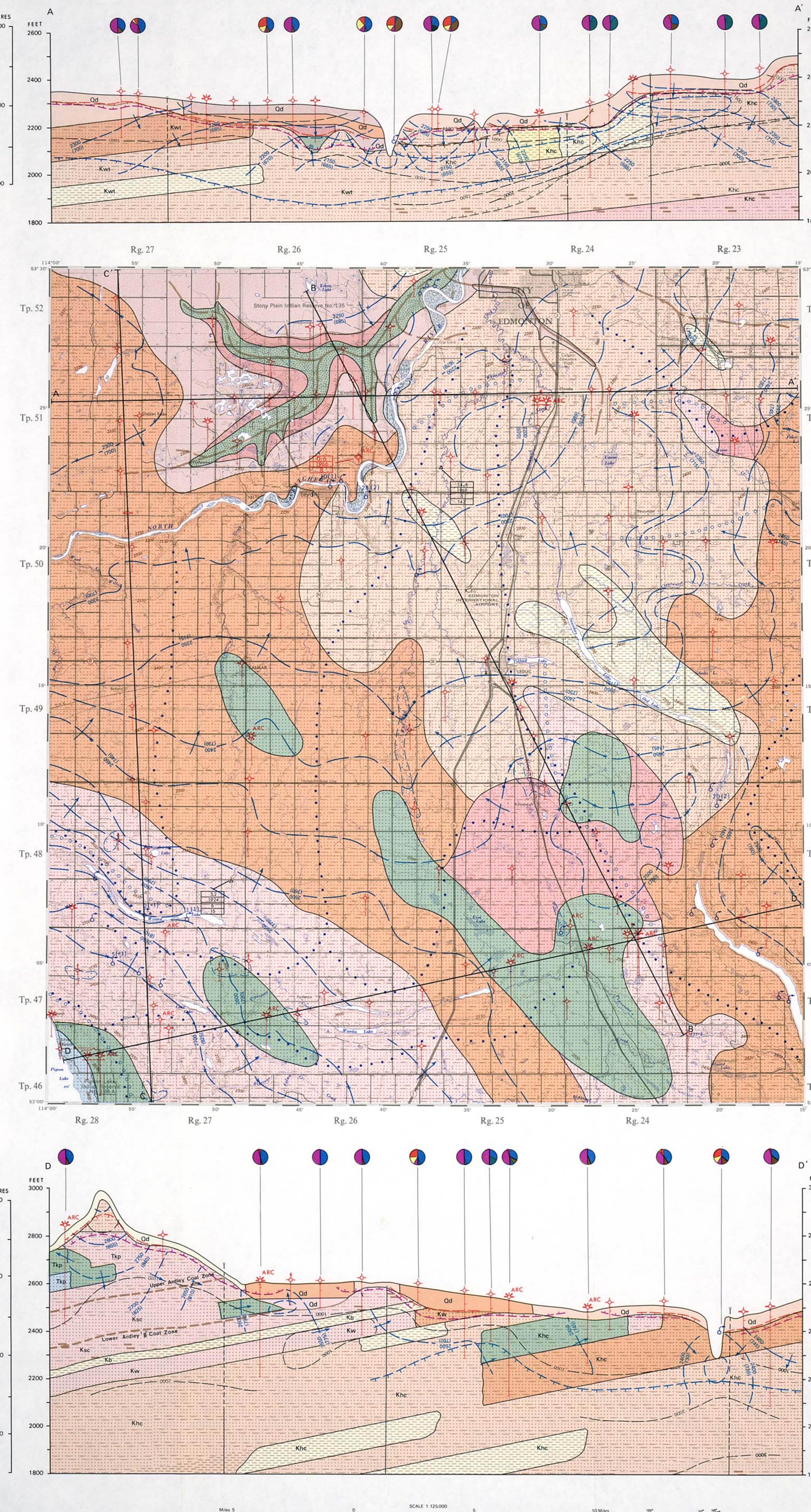
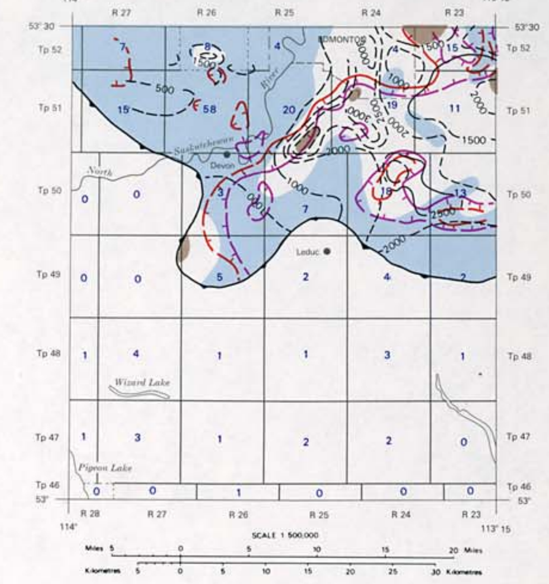


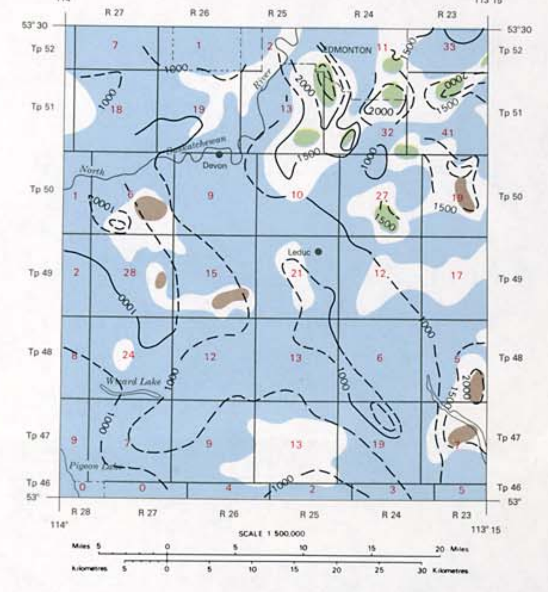


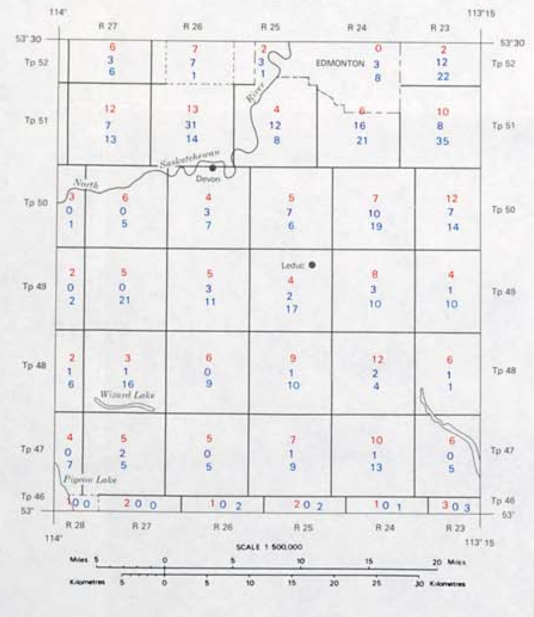










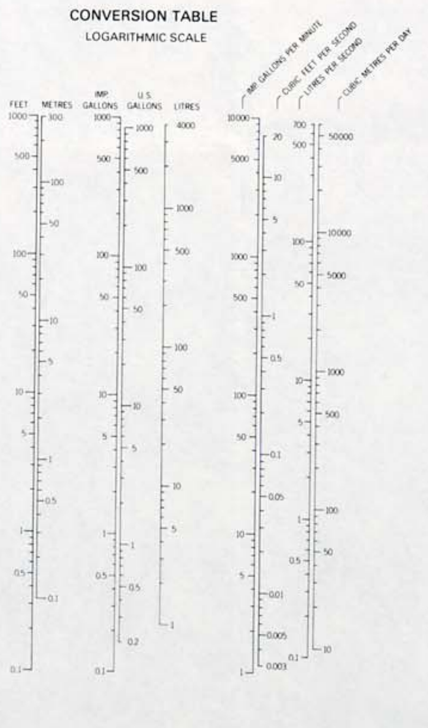


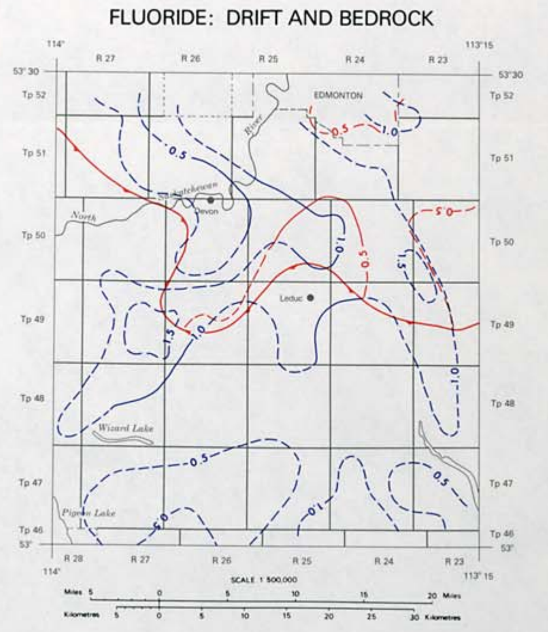
LEGEND

Number of data control points used to determine yield values and apparent transmissivities 12

Number of data control points in each township and range used to determine water levels in the drift 10

Number of data control points in each township and range used to determine water levels in the bedrock 35





LEGEND

Total fluoride content in the drift, in parts per million:
defined 0.5
approximate 1.5
Total fluoride content in the bedrock, in parts per million
defined 0.5
approximate 1.5
Area of no data ....

SCALE 1:125,000

Miles 5 0 5 10 Miles

Kilometres 5 0 5 10 Kilometres

All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 50X.

An expanded legend and explanatory notes (Report 72-12) for use with this hydrogeological map series is available from Publications, Alberta Research Council, 11315 - 87 Avenue, Edmonton, Canada T6G 2C2.

Map to accompany Report 78-5.

Hydrogeology by W.J. Ceroici.

Drafted by J.K. Matthie.

Cartographic editing by A.R. Campbell.

HYDROGEOLOGICAL MAP EDMONTON AREA (SOUTHWEST SEGMENT) ALBERTA

NTS 83H-SW

Base map provided by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa; modified by Surveys Branch, Alberta Transportation, Edmonton

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