Report 75-1

HYDROGEOLOGY OF THE WAINWRIGHT AREA, ALBERTA

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HYDROGEOLOGY
OF THE WAINWRIGHT AREA,
ALBERTA

Abstract

The Wainwright map area lies southeast of Edmonton between longitudes 110° and 112° west and latitudes 52° and 53° north. It covers about 6 000 square miles (15 500 km^2), of mostly aspen parkland. Precipitation is about 14 inches (36 cm) annually, while potential evapotranspiration is about 21 inches (54 cm).

Hydrogeological information is abundant for depths less than about 500 feet (152 m). At depths greater than 500 feet (152 m) the hydrologic environment has been inferred from geological information. Geologic units of hydrogeological interest include the glacial drift, preglacial sands and gravels, Horseshoe Canyon Formation, Bearpaw Formation, Belly River Formation, and Lea Park Formation. The last-named four are Late Cretaceous in age.

Groundwater yields are generally between 0 and 25 igpm (about 0 to 100 l/min) with certain areas having much greater yields. Groundwater quality is not exceptionally good; one third to one half of the samples analyzed exceeded provincial standards for total dissolved solids, sulfate, alkalinity, or sodium. Nitrate represents a local pollution problem.

In addition to the groundwater availability map at 1:250 000 scale, maps at 1:1 000 000 scale are presented showing hydrochemistry of bedrock waters for the depth intervals 0 to 150 feet (0 to 46 m) 150 to 350 feet (46 to 107 m), and 350 to 500 feet (107 to 152 m). Hydrochemistry of drift waters from 0 to 150 feet (0 to 46 m) of depth is also presented.

INTRODUCTION

This report and map are part of a program of the Alberta Research Council to produce reconnaissance hydrogeological maps for the entire province under a uniform legend (Badry, 1972). They represent the interpretation by one groundwater hydrologist and one technician of existing hydrogeological data supplemented by one summer of field work.

The area covered by this study is located between longitudes 110° and 112° west and latitudes 52° and 53° north. It encompasses townships 35 through 46 and ranges 1 through 14, west of the fourth meridian, which is an area of about 6 000 square miles (15 500 km^2). Under the National Topographic System the area is designated as map number 73D, Wainwright, Alberta.

The area is dominantly utilized for mixed farming with certain portions suitable only for stock raising due to relatively great local relief and poorly arable soils. Most of the area lies in the aspen parkland. The numerous farms result in much available groundwater information, both in terms of yield and chemistry, for depths less than 500 feet (152 m). At depths greater than 500 feet (152 m) information is quite sparse and is usually related to petroleum activities.

Petroleum production is a major industry of the area. Approximately half of the area contains established petroleum fields.

The work undertaken during one summer of field mapping included collection of about 300 water samples, and carrying out of 55 two-hour pump tests and two 4-day pump tests.

The references section of this paper is intended to be as complete a history as possible of published reports pertaining to the hydrology of the area and adjacent areas. Nielsen ***et al.*** (1972) present a bibliography of published and unpublished groundwater reports for all of Alberta.

Acknowledgments

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O. Tokarsky and Miss Ann Badry reviewed and commented on the report. The help of these former members of the Alberta Research Council is appreciated.

PHYSIOGRAPHY

The land surface in the area generally falls from south to north. High areas, exceeding 2 800 feet (850 m) above sea level, occur in the Neutral Hills in the south-central portion of the area. Much of the rest of the southern one third of the area varies between 2 400 and 2 700 feet (730 to 820 m) above sea level; much of the northern half of the area is below 2 200 feet (670 m).

A large portion of the area is hummocky containing many undrained depressions, and internal drainage is characteristic. Surface water divides shown on the hydrogeological map are only approximate in many areas.

The Battle River has incised a valley several hundred feet deep through the area. This valley is usually fairly narrow in the upstream portions and widens in the downstream reaches. The river drops about 380 feet (about 120 m) while passing through the area. There are no gauging stations on the Battle River in the map area. At Forestburg, just upstream from the west map boundary, the mean discharge was 24 and 163 cfs (0.7 and 4.6 m^3/sec) for 1968 and 1969, respectively, while at Unwin, Saskatchewan, just downstream from the east map boundary, the corresponding discharges were 118 and 368 cfs (3.3 and 10.3 m^3/sec). This indicates a two- to five-fold increase in discharge while passing through the area.

CLIMATE

Climatic averages for the area are presented on the meteorological side map. Mean annual precipitation varies from about 13 inches (33 cm) in the southeast to slightly over 15 inches (38 cm) in the northwest. The average annual temperature is about 36°F (2°C). Potential evapotranspiration (Thornthwaite and Mather, 1957) is about 21 inches (54 cm) per year, while evaporation (Bruce and Weisman, 1967) is slightly less than 35 inches (90 cm) per year.

GEOLOGY

Surficial Geology

Bayrock (1957, 1958, 1967), Gravenor (1956), Gravenor and Bayrock (1955), and Gravenor and Ellwood (1957) have mapped the surficial deposits of the entire area. Although many types occur, the most prevalent are morainal deposits, outwash sand deposits, and lake deposits.

Carlson and Topp (1971) show that about one half of the area is covered with drift less than 50 feet (15 m) thick (Fig. 1) and that surficial deposits up to about 150 feet (46 m) thick cover about one quarter of the area. A major preglacial valley, the Battleford Valley (Christiansen, 1965) [also referred to as the Red Deer Bedrock Channel (Farvolden, 1963) and the Wainwright Valley (Carlson and Topp, 1971)], extending from Chauvin to north of Hardisty, has deposits comprised mostly of sand and gravel which are up to 450 feet (about 140 m) thick in some locales. The exact extent of gravel deposits in this channel is not well known but it is probable that some occur along the thalwegs indicated on the hydrogeological map.

Bedrock Geology

The bedrock units of significant hydrogeological interest are all of Late Cretaceous age; these are the Horseshoe Canyon, Bearpaw, Belly River, and Lea Park Formations. The following descriptions are provided by Green (1972):

Horseshoe Canyon Formation: grey, feldspathic, clayey sandstone; grey bentonitic mudstone and carbonaceous shale; concretionary ironstone beds, scattered coal, and bentonite beds of variable thickness, minor limestone beds; mainly nonmarine

Bearpaw Formation: dark grey blocky shale and silty shale; greenish glauconitic and grey clayey sandstone; thin concretionary ironstone and bentonite beds; marine

Belly River Formation: grey to greenish grey, thick-bedded, feldspathic sandstone; grey clayey siltstone, grey and green mudstone; concretionary ironstone beds; nonmarine

Lea Park Formation: dark grey shale; pale grey, glauconitic, silty shale with ironstone concretions; marine

The Horseshoe Canyon Formation contains a basal sandstone unit which is utilized for water supply in the southwestern portion of the area. Locally, coal beds may be of importance.

The Bearpaw Formation contains three major sandstone members, locally known as the "Bulwark sands." The geological side map shows the subcrop of the upper or first Bulwark sand as well as the subcrop and structural contours on the lower or third Bulwark sand.

The Belly River Formation contains several "zones" within which sandstones are very prevalent. Structure contours and the subcrop of one major sand sequence are presented on the geological side map.

The top of the Lea Park Formation represents a boundary separating comparatively high yielding, good quality aquifers from much lower yielding, poorer quality aquifers.

For more detailed discussion of the stratigraphy of the area the reader is referred to Shaw and Harding (1954) and Nichols and Wyman (1969).

HYDROGEOLOGY

Groundwater Flow

The water levels shown on the main map are dominantly those of the Belly River sand zone depicted on the geological side map and defined above. In those areas where the sand zone does not exist the water levels presented are those from wells of an approximately equivalent depth. Groundwater flow within this zone is basically from southwest to northeast. Locally flow is directed into the Battle River valley and into the preglacial Battleford Valley.

Data seem to indicate that the water table can be approximated by the land surface, and that it is usually within 50 feet (15 m) of the surface.

Areas of major groundwater discharge are limited to certain portions of townships 42 and 43, ranges 1, 2, and 3. Here flowing wells, salt deposits, springs, and very saline lakes are observed. Evidence of major groundwater discharge into the Battle River valley is lacking: large springs are not frequently observed but minor seepage areas are common; surficial salt deposits do occur but they are neither extremely common nor heavy; of the few wells that do exist in the valley most do not flow (see main map). It appears likely that the Battle River valley receives groundwater discharge only from local flow systems, not from regional systems, thus accounting for the general lack of salt deposits and major seepage areas.

The many closed topographic depressions of the area probably result in the development of numerous local groundwater flow systems. It is hypothesized that most of these behave very similarly to the "temporary" sloughs described by Meyboom (1966). He demonstrated that this type of slough is: 1) a recharge area during fall and spring; 2) a discharge area during summer; and 3) hydrologically nonexistent during much of the winter.

Groundwater Yields

Groundwater yields presented on the cross sections represent the probable 20-year safe yields to wells completed by usual present-day techniques. The various colored areas can be considered as hydrogeologic units throughout which conditions are very similar. The value presented on the main map is the sum of all groundwater probabilities occurring in the section to a depth of 500 feet (150 m).

Most groundwater yield information is obtained from water well drillers' reports containing only a static water level and a water level after some stated period of pumping. This type of information allows the calculation of "apparent transmissivity" (Farvolden, 1961) from which an "apparent 20-year safe yield" has been calculated. The approach is parallel to the Jacob method:

$$T_A = 264Q/\Delta s$$

where T_A = apparent transmissivity, Q = pumping rate in igpm, Δs = drawdown in feet per log cycle as inferred from using static water level and the one available pumping water level. Therefore:

$$Q_{A20} = T_A H/2110$$

where Q_{A20} = apparent 20-year safe yield, H = total available drawdown, commonly taken to the top of the open interval of the well.

The results of this approach are probably conservative due to the nature of Δs. Correlation of these values with those from longer production tests (indicated on main map) has produced the final product. Where quantitative information was lacking groundwater yields were inferred from geologic information.

The preglacial Battleford Valley is the major high-yield area of the region. The sands and gravels in this buried valley contain abundant amounts of water. A four-day pump test in the valley south of the town of Wainwright indicated a 20-year safe yield in excess of 1 000 igpm (4 500 l/min).

The high yield area in township 40, ranges 5, 6, and 7, is based on wells at Hughenden and Metiskow and on electrolog correlation of the probable sandstone aquifer. It must be remembered, however, that dissolved gas was abundant in the well at Metiskow and that this factor, which may tend to exaggerate the actual amount of water available, was not taken into consideration in presenting the groundwater probability.

The 25 to 100 igpm (100 to 450 l/min) yield area in the southeast corner of the map area is from sandstone units in the bedrock. These units are encountered at elevations of about 1 900 to 2 000 feet (580 to 610 m) along cross section B-B'.

Over the rest of the map area groundwater yields vary from about 1 to 25 igpm (5 to 100 l/min). The reader is urged to make frequent reference to the cross sections for the vertical distribution of aquifers.

The top of the Lea Park Formation (see geological side map) usually represents the lower limit of useful yields to wells. In most instances drilling into this formation is not warranted. Suitable volumes of water would probably only be obtained from boreholes having a very great open portion.

Groundwater Chemistry

Table 1 presents a summary of chemical constituents from groundwater in the area. A significant number of water analyses have values for these constituents in excess of the Alberta standard (Table 1). Nonetheless, most analyses represent water which is or will be used for domestic purposes.

The four hydrochemical side maps present the chemistry of waters from drift and bedrock for various depth intervals in percent of total cations or anions. The calculation of epm was based on procedures outlined by Le Breton and Vanden-Berg (1965). The reader should make use of the drift thickness map (Fig. 1) to determine whether a well at a particular location will be completed in drift or bedrock.

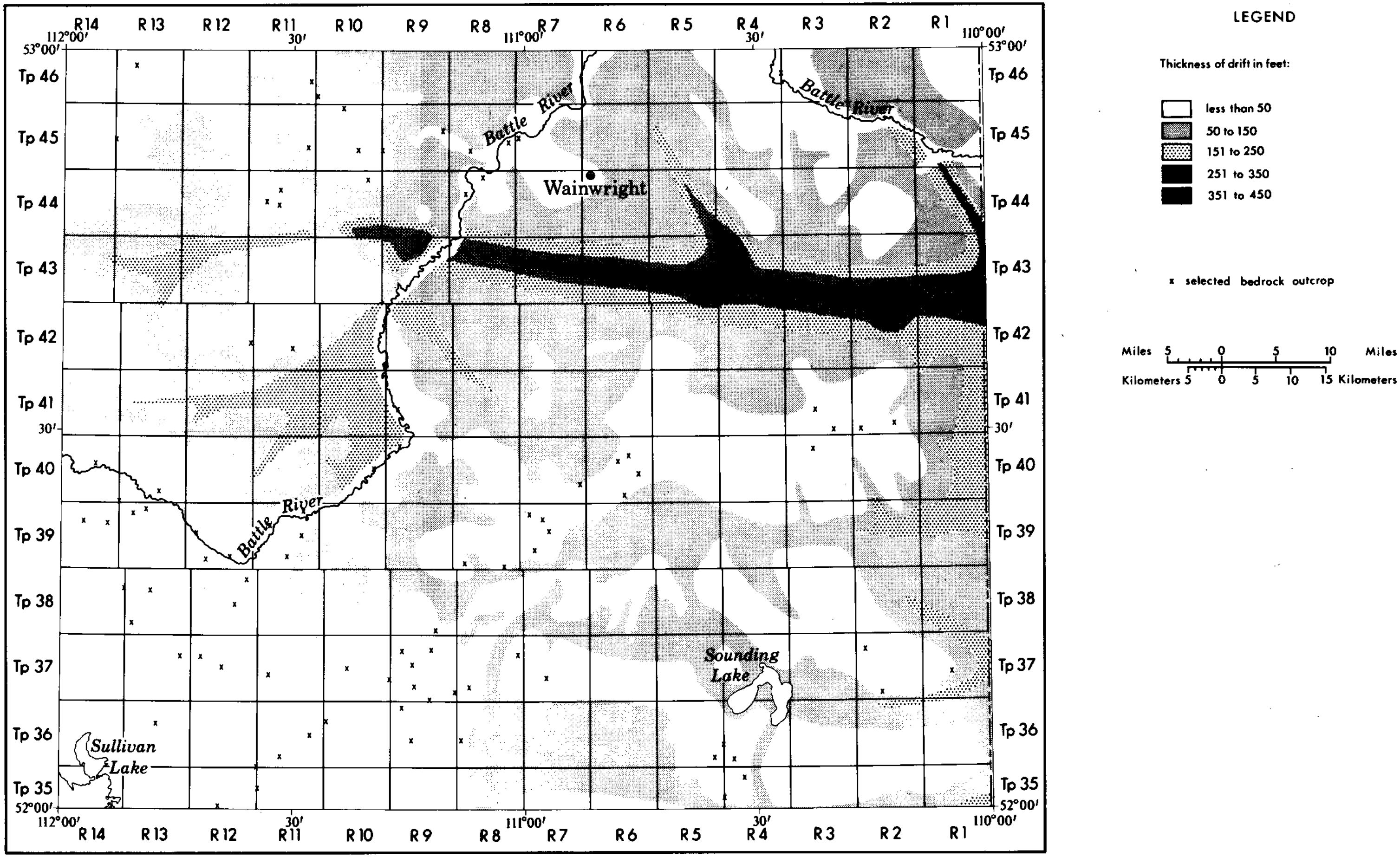


Figure 1. Drift thickness in Wainwright map area

Table 1. Comparison of Alberta Drinking Water Standards to Water Analyses from Wainwright Area

Constituent	Alberta Standard*	Number of Analyses Exceeding Standard	Number of Analyses	Percent of Analyses Exceeding Standard
Total dissolved solids	1 000	679	1 452	46
Hardness	500	192	1 452	13
Sulfate	250	546	1 452	37
Chloride	250	119	1 452	8
Alkalinity	500	631	1 452	43
Nitrate	45	138	1 411	9
Fluoride	1.5	32	641	4
Calcium	200	17	529	3
Magnesium	150	0	526	0
Sodium	300	131	241	54

*Canada Department of National Health and Welfare (1969).

Drift waters from 0 to 150 feet (0 to 46 m) deep

Anions in this interval tend to be bicarbonate plus carbonate with large areas over which no one ion dominates. The bicarbonate plus carbonate facies tends to occur in the central part of the area where total dissolved solids are below 1 000 ppm.

The cations of this upper portion of the drift tend to be calcium plus magnesium. Major areas of sodium plus potassium domination occur in the south and east where the drift cover is thin.

The pattern of total dissolved solids reflects drift thickness somewhat (Fig. 1). In areas where drift is thin the total dissolved solids content of the drift waters tends to rise. This is probably due to the large proportion of bedrock material in the thin drift. At the scale of presentation virtually all water could be expected to have total dissolved solids in excess of 500 ppm; however, lesser values are observed locally.

Drift waters from 150 to 350 feet (46 to 107 m) deep

Figure 2 shows a modified version of a hydrochemical side map for water in the Battleford Valley. Water here tends to be of generally good quality in spite of the depth.

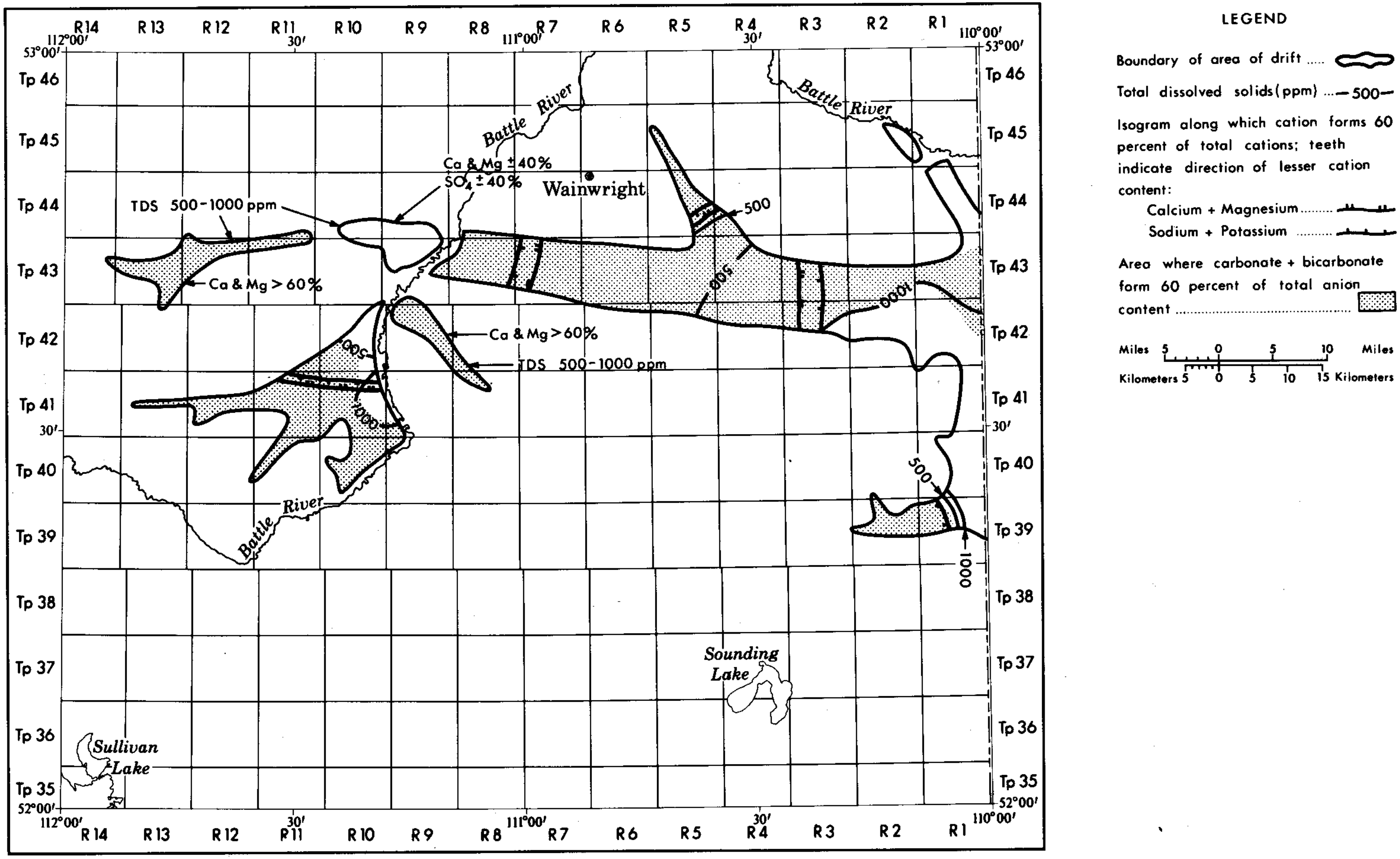


Figure 2. Hydrochemistry of drift waters from 150-350 foot depth

Calcium and magnesium tend to dominate the cations in the western reaches of the channel while sodium and potassium are more abundant to the east. The dominant anions are carbonate and bicarbonate. Total dissolved solids content tends to be fairly low, and is less than 500 ppm in several areas. The areas of low TDS reflect the rapid infiltration in areas of very sandy drift.

Bedrock waters from 0 to 150 feet (0 to 46 m) deep

The chemistry of waters in this interval is substantially different from the waters in the drift for the same interval.

Sodium plus potassium tend to dominate the cations around the outer perimeter of the area while calcium plus magnesium are dominant in the central and northern portions. This reflects the drift thickness pattern of the area; there is more drift material (with calcium-magnesium water) in the central portion of the area than around the outer edges. It also indicates downward moving groundwater. This pool of calcium-magnesium rich water exerts its influence to a greater depth than in areas of thinner drift.

Bicarbonate plus carbonate dominates the anions of waters in this depth interval. Sulfate anions are dominant in several areas, particularly where the Bearpaw Formation outcrops in the southwest.

An area in which chloride ion dominates the anions is shown. This area coincides quite closely with a closed water-table contour area shown on the main map. The lack of significant areas of chloride ion substantiates the observation (Groundwater Flow) that regional discharge areas are lacking.

The total dissolved solids content shows a similar pattern to that of the cations; it tends to be lower in the central portion of the area and higher around the edges. This is similar to the total disssolved solids pattern for drift waters in the same interval and in fact reflects the recharge of this low TDS water into the bedrock.

The TDS content of this interval is quite variable but can be expected to virtually always be above 1 000 ppm.

The fluoride content of waters in this depth interval is low. In most cases the fluoride level is less than 0.5 ppm in areas where a significant drift cover overlies the bedrock. Where the drift cover is thin the fluoride content increases slightly but remains, however, less than 1.0 ppm.

Bedrock waters from 150 to 350 feet (46 to 107 m) deep

The dominant anions continue to be bicarbonate plus carbonate. The pattern for these constituents is much more uniform than in the overlying interval and reflects the greater continuity of these deeper bedrock units and the lessening of influences of local flow systems.

Chloride continues to dominate the anions in a small area near Hardisty. This ion also is dominant in the northwest area. The discharge area in township 42, ranges 1 and 2, shows some minor areas of chloride dominance.

The major cations are sodium and potassium. Calcium and magnesium appear as dominant ions in areas where drift is thick and probably reflect rapid recharge from these overlying aquifers.

As in the previously mentioned depth intervals total dissolved solids concentration tends to be lowest in the central portion of the map area. This again reflects the great depth of influence of the low TDS drift waters. The previously mentioned discharge area is reflected by a small 1 500 ppm closed contour in township 42, range 2.

In general, one can expect TDS in waters from this interval to exceed 1 000 ppm.

The fluoride side map indicates the fluoride content of waters obtained from wells 150 to 350 feet (46 to 107 m) deep which terminate in bedrock. The average values in this interval are substantially higher than in the bedrock above although still below recommended health standards for most of the area. The areas of low fluoride content continue to generally correspond with areas of thick overlying drift. The presence of the more shaly Bearpaw and Horseshoe Canyon Formations produces higher fluoride values to the western edge of the area.

Bedrock waters from 350 to 500 feet (107 to 152 m) deep

The dominant anions are virtually always bicarbonate plus carbonate. Chloride ions become more prevalent, especially in the western and northeastern sectors. This may be due in large part to the presence of marine deposits (Bearpaw and Lea Park) at this depth in these areas.

Cations are mostly sodium plus potassium; only one small area in the southeast has sodium plus potassium values of less than sixty percent.

Total dissolved solids continue to show a low-value area in the central portions of the area with higher values elsewhere. Thus the effects of water recharging in this area are reflected to great depth.

Fluoride values in the bedrock at depths of 350 to 500 feet (107 to 152 m) are also indicated on the fluoride side map. The values in this depth range are substantially higher than in the overlying bedrock interval. The area of low fluoride values just north of the center of the map continues to correspond to the location of thick drift. Fluoride values rise rapidly to the east reflecting a local high in the Lea Park Formation. High fluoride values to the northwest reflect the influence of the Bearpaw Formation.

Nitrate pollution

Nitrate pollution of shallow wells has been noted to be a significant problem in the Wainwright area. Of 590 water analyses from wells less than 100 feet (30 m) deep, 130 (22%) exhibited nitrate values in excess of 45 ppm (the Provincial Health limit). In addition, 69 (12%) of the water analyses of these 590 wells showed values in excess of 20 ppm but less than 45 ppm, indicating a significant degree of contamination.

Nitrate contamination results from poor well completion or poor location or both, and can commonly be traced to sites of concentrated animal waste (barn-yards, feedlots, corrals) or human waste (privies, sewage lagoons, leach fields).

To date the towns of Hayter, Czar, Metiskow, Sedgewick, and Killam have large numbers of water analyses from shallow wells [less than 100 feet (30 m) deep] which show nitrates in excess of provincial standards. Sedgewick also has a large number of water analyses from shallow wells which have nitrate levels between 20 and 45 ppm. The local contamination at Sedgewick and Killam is of concern as these towns are located over bedrock channels which contain major groundwater aquifers (see main map).

CONCLUSIONS

Groundwater yields to wells in the Wainwright area can generally be expected to be in the range of 1 to 25 igpm (5 to 100 l/min). Higher yields are available in many areas. For practical purposes the Lea Park Formation represents the lower limit of abundant, potable water supplies.

The general quality of groundwater in the area is not exceptionally good with respect to potability. A large percentage of analyses have total dissolved solids, sulfate, alkalinity, and sodium in excess of provincial standards. Nitrate pollution is definitely a problem in many localized areas.

Except for very localized situations the entire area appears to lie in a regional recharge area. The only major discharge area [about 50 square miles (130 km^2)] is located just west of Chauvin. The Battle River valley does not appear to be a major discharge area.

REFERENCES

Badry, A. (1972): A legend and guide for the preparation and use of the Alberta Hydrogeological Information and Reconnaissance Map Series; Res. Coun. Alberta Rept. 72-12, 96 pages.

Bayrock, L. A. (1955): Glacial geology of an area in east-central Alberta; Res. Coun. Alberta Prelim. Rept. 55-1, 46 pages.

__________ (1957): Glacial geology, Galahad-Hardisty district, Alberta; Res. Coun. Alberta Prelim. Rept. 57-3, 35 pages.

__________ (1958): Glacial geology, Alliance-Brownfield district, Alberta; Res. Coun. Alberta Prelim. Rept. 57-2, 56 pages.

__________ (1962): Heavy minerals in till of central Alberta; Jour. Alberta Soc. Petroleum Geol., Vol. 10, No. 4, p. 171-184.

__________ (1967): Surficial geology of the Wainwright area (east half), Alberta; Res. Coun. Alberta Rept. 67-4, 10 pages.

Bayrock, L. A. and S. Pawluk (1967): Trace elements in tills of Alberta; Can. Jour. Earth Sci., Vol. 4, p. 597-607.

Bird, R. D. (1961): Ecology of the aspen parkland; Can. Dept. Agriculture, Res. Branch, Publ. 1066, 155 pages.

Bruce, J. P. and B. Weisman (1967): Provisional evaporation maps of Canada; Canada Dept. Transport, Met. Branch, 21 pages.

Byrne, P. J. S. and R. N. Farvolden (1959): The clay mineralogy and chemistry of the Bearpaw Formation of Southern Alberta; Res. Coun. Alberta Bull. 4, 44 pages.

Canada Department of Energy, Mines and Resources (1971): Surface water data — Alberta; Water Surv. Canada, Inland Waters Branch, Ottawa, 178 pages.

Canada Department of National Health and Welfare (1969): Canadian drinking water standards and objectives, prepared by the Joint Committee on Drinking Water Standards of the Advisory Committee on Public Health Engineering and the Canadian Public Health Assoc., 39 pages.

Canada Department of Transport (1967): Temperature and precipitation tables for Prairie Provinces, Vol. III, 56 pages.

Carlson, V. A. and L. M. Topp (1971): Bedrock topography of the Wainwright map area, NTS 73D, Alberta; Res. Coun. Alberta map.

Christiansen, E. A. (1965): Geology and groundwater resources of the Battleford area (73C), Saskatchewan; Saskatchewan Res. Coun., Geol. Div., Map No. 4.

Farvolden, R. N. (1961): Groundwater resources, Pembina area, Alberta; Res. Coun. Alberta Prelim. Rept. 61-4, 26 pages.

__________ (1963): Bedrock channels of Southern Alberta; *in* R. N. Farvolden, W. A. Meneley, E. G. Le Breton, D. H. Lennox, and P. Meyboom, Early contributions to the groundwater hydrology of Alberta; Res. Coun. Alberta Bull. 12, p. 63-75.

Given, M. M. and J. H. Wall (1971): Microfauna from the Upper Cretaceous Bearpaw Formation of south-central Alberta; Bull. Can. Petroleum Geol., Vol. 19, No. 2, p. 502-544.

Govett, G. J. S. (1958): Sodium sulfate deposits in Alberta; Res. Coun. Alberta Prelim. Rept. 58-5, 34 pages.

Gravenor, C. P. (1956): Glacial geology, Castor district, Alberta; Res. Coun. Alberta Prelim. Rept. 56-2, 23 pages.

Gravenor, C. P. and L. A. Bayrock (1955): Glacial geology, Coronation district, Alberta; Res. Coun. Alberta Prelim. Rept. 55-1, 38 pages.

Gravenor, C. P. and R. B. Ellwood (1957): Glacial geology, Sedgewick district, Alberta; Res. Coun. Alberta Prelim. Rept. 57-1, 43 pages.

Green, R. (1972): Geological map of Alberta; Res. Coun. Alberta Map 35, Scale 1 inch to 20 miles.

Hume, G. S. (1926): Oil and gas prospects of the Wainwright-Vermilion area, Alberta; Canada Dept. Mines and Geol. Surv. Summary Rept. 1924, Part B, p. 1-22.

Hume, G. S. and C. O. Hage (1947): Groundwater resources of townships 35 to 38, ranges 1 to 4, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 265.

__________ (1947): Groundwater resources of townships 35 to 38, ranges 5 to 8, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 266, 15 pages.

__________ (1947): Groundwater resources of townships 35 to 38, ranges 9 to 12, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 267, 15 pages.

______________ (1947): Groundwater resources of townships 39 to 42, ranges 1 to 4, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 268, 17 pages.

Hume, G. S., A. MacS. Stalker and H. W. Tipper (1948): Groundwater resources of townships 35 to 38, ranges 13 to 16, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 295, 12 pages.

Hume, G. S. and P. S. Warren (1947): Groundwater resources of townships 43 to 46, ranges 13 to 16, west 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 274, 17 pages.

Irish, E. J. W. (1970): The Edmonton Group of south-central Alberta; Bull. Can. Petroleum Geol., Vol. 18, p. 125-155.

Langbein, W. B. (1961): Salinity and hydrology of closed lakes; U.S. Geol. Surv. Prof. Paper 412, 20 pages.

Le Breton, E. G. (1963): Groundwater geology and hydrology of east-central Alberta; Res. Coun. Alberta Bull. 13, 64 pages.

Le Breton, E. G. and J. F. Jones (1963): A regional picture of the groundwater chemistry in particular aquifers of the Western Plains; *in* Proc. Hydrology Symp. No. 3 – Groundwater, Nat. Res. Coun. Can., p. 207-245.

Le Breton, E. G. and A. Vanden Berg (1965): Chemical analyses of groundwaters of east-central Alberta; Res. Coun. Alberta Prelim. Rept. 65-5, 24 pages.

Longley, R. W. (1968): Climatic maps for Alberta; Univ. Alberta, 8 pages.

Meyboom, P. (1966): Unsteady groundwater flow near a willow ring in hummocky moraine; Jour. Hydrol., Vol. 4, p. 38-62.

______________ (1967): Interior plains hydrogeological region; *in* I. C. Brown, editor, Groundwater in Canada, Geol. Surv. Can. Geol. Rept. No. 24, p. 131-158.

Nichols, R. A. H. and J. M. Wyman (1969): Interdigitation versus arbitrary cutoff: resolution of an Upper Cretaceous stratigraphic problem, western Saskatchewan; Bull. Am. Assoc. Petroleum Geol., Vol. 53, No. 9, p. 1880-1893.

Nielsen, G. L., D. A. Hackbarth and S. Bainey (1972): Bibliography of groundwater studies in Alberta, 1912-1971; Alberta Environment, Water Resources Division, Soils, Geology and Groundwater Branch.

Pawluk, S. and L. A. Bayrock (1969): Some characteristics and physical properties of Alberta tills; Res. Council Alberta Bull. 26, 72 pages.

Potter, J. G. (1965): Snow cover; Climatological Studies No. 3, Canada Dept. Transport, Met. Branch, 69 pages.

Rutherford, R. L., B. A. Latour, A. MacS. Stalker and H. W. Tipper (1948): Groundwater resources of townships 39 to 42, ranges 13 to 16, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 294, 13 pages.

Shaw, E. W. and S. R. L. Harding (1954): Lea Park and Belly River Formations of east-central Alberta; *in* Ralph Leslie Rutherford Memorial Volume, Symposium on Western Canada Sedimentary Basin, Bull. Am. Assoc. Petroleum Geol., Tulsa, p. 197-308.

Stalker, A. MacS. (1953): Groundwater resources of townships 35 to 38, ranges 1 to 4, west of 4th meridian, Alberta; Geol. Surv. Canada Water Supply Paper 317.

Thornthwaite, C. W. and J. R. Mather (1957): Instructions and tables for computing potential evapotranspiration and the water balance; Drexel Inst. Tech. Laboratory of Climatology, Publications in Climatology, Vol. 10, No. 3, p. 181-289.

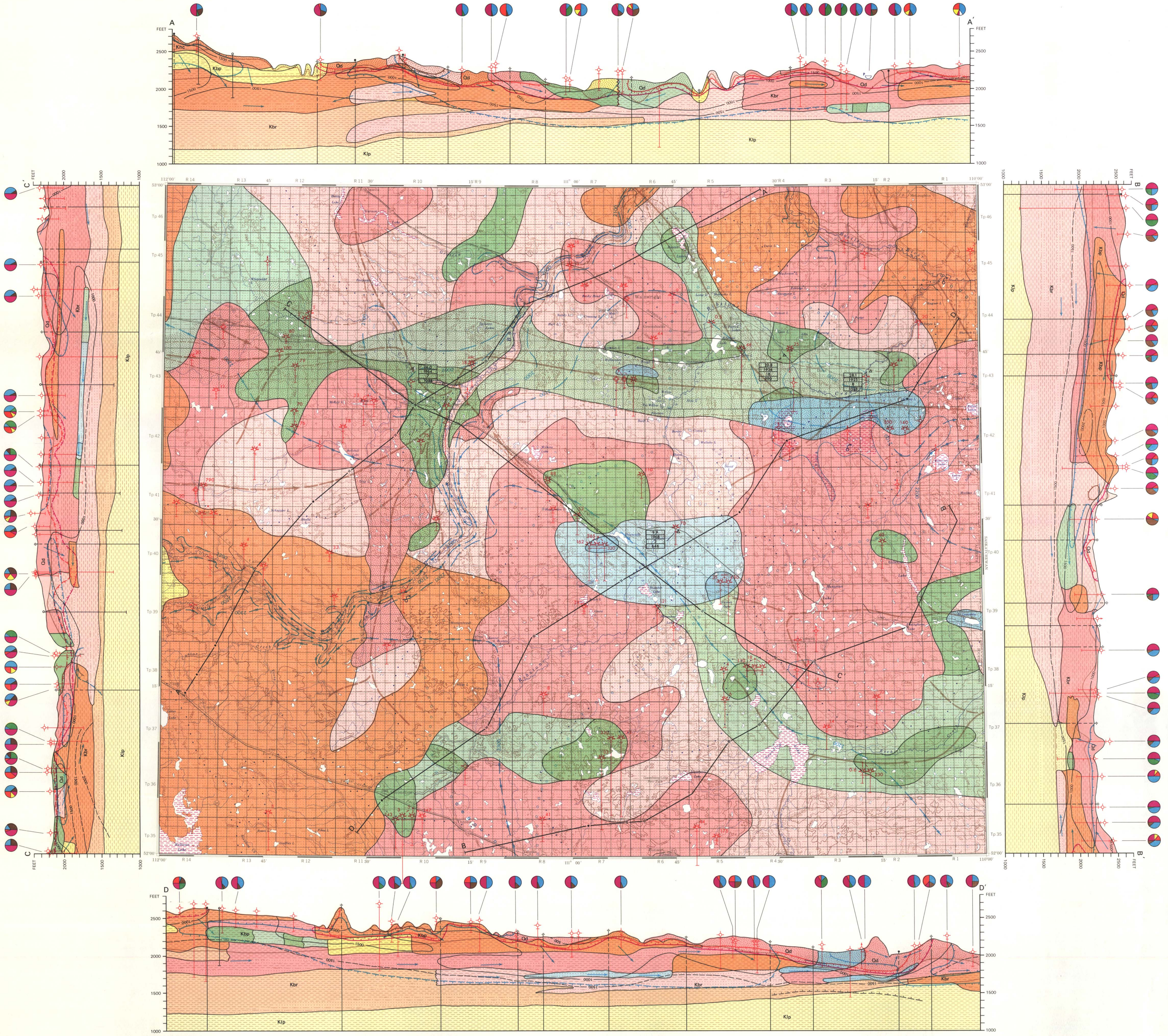
Warren, P. S. and G. S. Hume (1947): Groundwater resources of townships 43 to 46, ranges 1 to 4, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 271, 17 pages.

Warren, P. S., R. L. Rutherford and G. S. Hume (1947): Groundwater resources of townships 43 to 46, ranges 13 to 16, west of 4th meridian, Alberta; Geol. Surv. Can. Water Supply Paper 274, 17 pages.

Wyatt, F. A., J. D. Newton, W. E. Bowser and W. Odynsky (1938): Soil survey of Sullivan Lake sheet; Univ. Alberta Bull. 31, 102 pages.

------------------ (1944): Soil survey of the Wainwright and Vermilion sheets; Univ. Alberta Bull. 42, 122 pages.

Alberta RESEARCH COUNCIL



MAIN MAP LEGEND

Topography

Surface contours and elevation in feet (interval 100 feet) — 2000

Geology

Geological boundary

Thalweg of buried valley

Boundary of area of approximate subcrop of Belly River Formation

QUATERNARY

Qd	Unconsolidated deposits

CRETACEOUS

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

Lithology

Sand and gravel

Sand

Silt and Clay

Sandstone

Shale

Hydrography

Lake or slough, perennial

Stream, perennial

Surface water divide

Natural pond or water hole (no surface outlet) — P

Area of noticeable salt precipitates

Hydrometry

Stream gauging station

Average annual discharge in cubic feet per second	9.9
Year of commencement of observations	1968
Number of years averaged for average annual discharge figure	3
Drainage area in square miles	646

Hydrogeology

Spring, flow rate unknown

Approximate water level contour of Belly River Formation — Upward flow, 2300, Downward flow

Direction of groundwater flow

Groundwater divide

Boundary of area of artesian flow

Groundwater Probability†

Range of average expected yield of wells (in imperial gallons per minute)

Probable: estimated from quantitative information (pump tests, bail tests, etc.)
Possible: estimated from qualitative information (flow regime, lithology, etc.)

100-500
25-100
5-25
1-5
<1

Yield boundary

†The indicated average expected yields to wells are predictions based on the best data available 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

Observation well with an automatic recorder

Location of Alberta Research Council test well — ARC

Oil well*

Gas well*

Abandoned well* drilled for oil or gas

Structure testhole*

Line of hydrogeological profile — A A'

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

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:
defined — 500 —
approximate -- 500 --

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

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

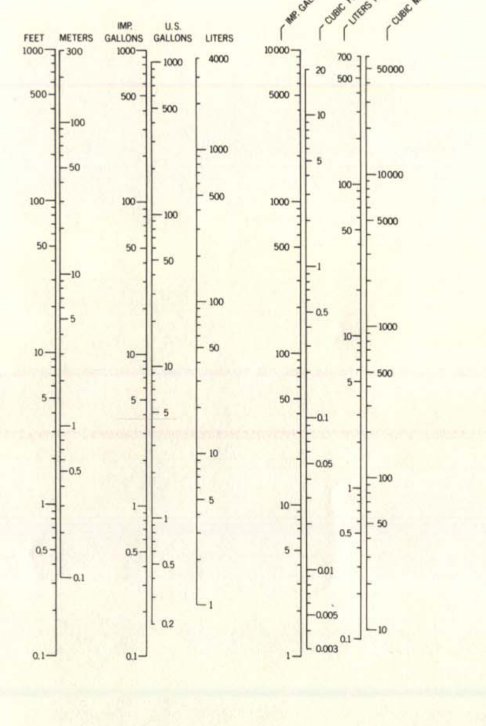
Isogram along which sulfate constitutes 60 percent of total anions;* teeth indicate direction of lesser sulfate content
defined
approximate

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

*determined on equivalents per million basis

CONVERSION TABLE

LOGARITHMIC SCALE



SCALE 1:250,000

Miles 5 0 5 10 15 20 Miles
Kilometers 5 0 5 10 15 20 25 30 Kilometers

All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 40X.

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

Map to accompany Report 75-1

Hydrogeology by D. A. Hackbarth.

Drawn by R. W. Swenson and J. H. Dey.

Cartographic editing by A. R. Campbell.

HYDROGEOLOGICAL MAP WAINWRIGHT ALBERTA

NTS 73D

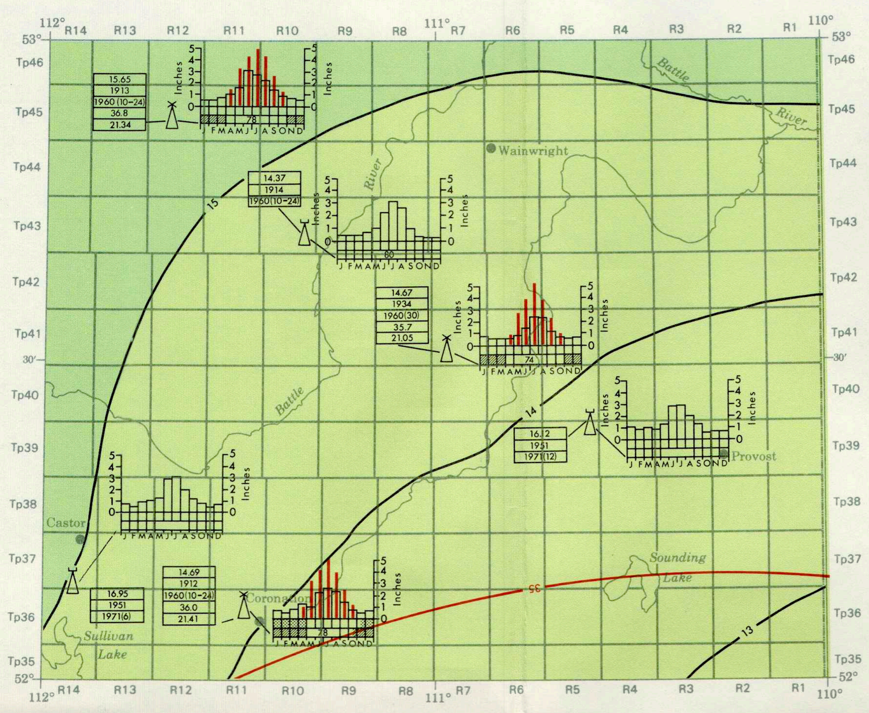
Sheet 1 of 2

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

Published 1975

Alberta RESEARCH COUNCIL

METEOROLOGY



LEGEND

Isohyet, mean annual precipitation in inches 14

Annual average evaporation in inches 35

Mean annual precipitation in inches:
- less than 15"
- 15-20"

Meteorological station ....

Standard rain gauge ....

Precipitation data:
- Mean annual precipitation in inches 14.67
- Year of commencement of observations 1934
- Last year in averages and number of years in average .... 1960(30)
- Average annual temperature 35.7
- Thornthwaite Potential Evapotranspiration in inches 21.05
- Mean monthly potential evapotranspiration
- Mean monthly precipitation
- Period when surface is usually snow covered
- Period with mean daily temperatures below freezing
- Figure indicates percentage of mean annual precipitation falling as rain 74

J F M A M J J A S O N D
Months of the year
Inches 0 1 2 3 4 5

Sources of data:

Climatic Maps of Alberta (Longley, 1968); Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance (Thornthwaite and Mather, 1957); Provisional Evaporation Maps of Canada (Bruce and Weisman, 1967); Temperature and Precipitation Tables for the Prairie Provinces (Canada Department of Transport, 1967).

LEGEND

Khc Horseshoe Canyon Formation: *sandstone, bentonitic mudstone, shale, ironstone beds, coal*

Kbp Bearpaw Formation: *shale, sandstone, thin ironstone and bentonitic beds*

Kbr Belly River Formation: *sandstone, siltstone, mudstone, ironstone beds*

Rock unit, formation boundary:
- defined ....
- approximate ....

Boundary of area of subcrop of uppermost of three major sandstone zones (first Bulwark within the Bearpaw Formation) ....

Structure contour on lowest of three major sandstone zones within the Bearpaw Formation 2400

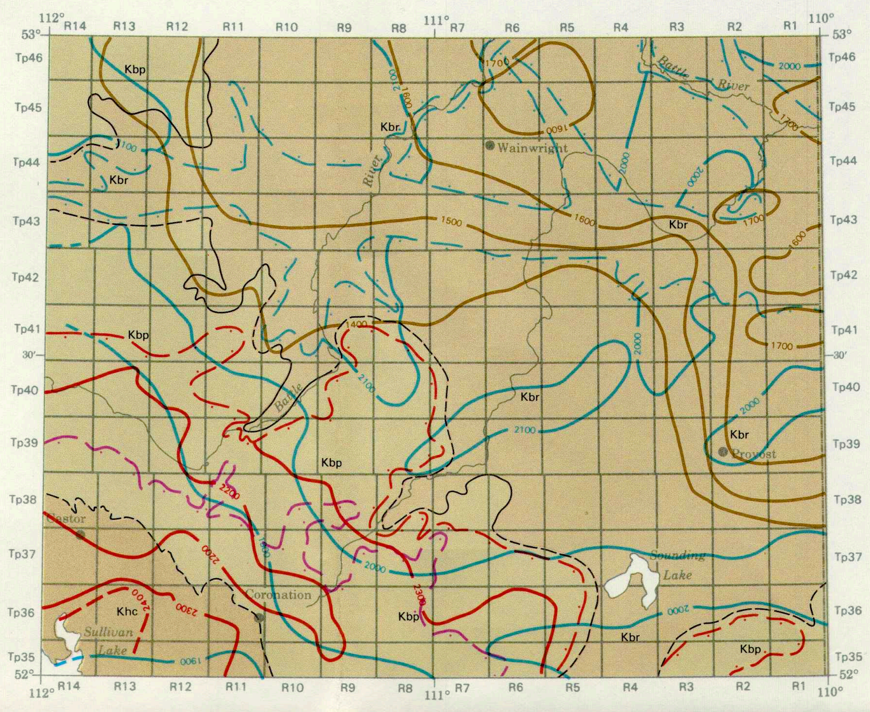
Boundary of area of subcrop of lowest of three major sandstone zones with the Bearpaw Formation ....

Structure contour on top of a major sandstone zone within the Belly River Formation 2000

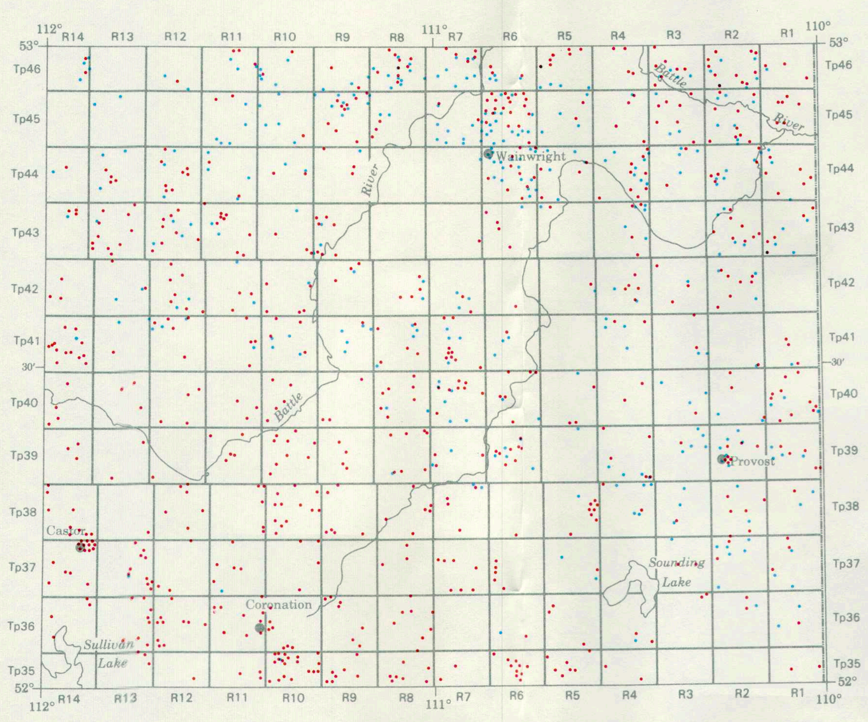
Boundary of area of subcrop of a major sandstone zone within the Belly River Formation ....

Structure contour on the top of the Lea Park Formation (only values above 1,400 ft. are contoured) 1600

GEOLOGY



DATA DENSITY



LEGEND

Data control point marking location of a well with water level information only ....

Data control point marking location of a well with yield information (i.e. production tests) ....

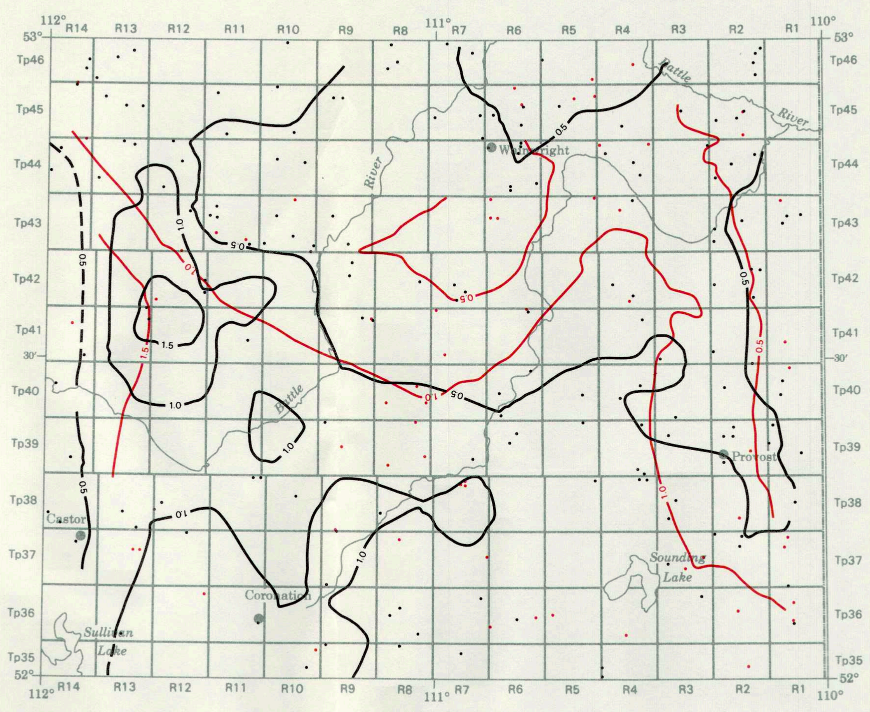
LEGEND

Fluoride content in parts per million in bedrock waters from 150-350 foot depths 1.5

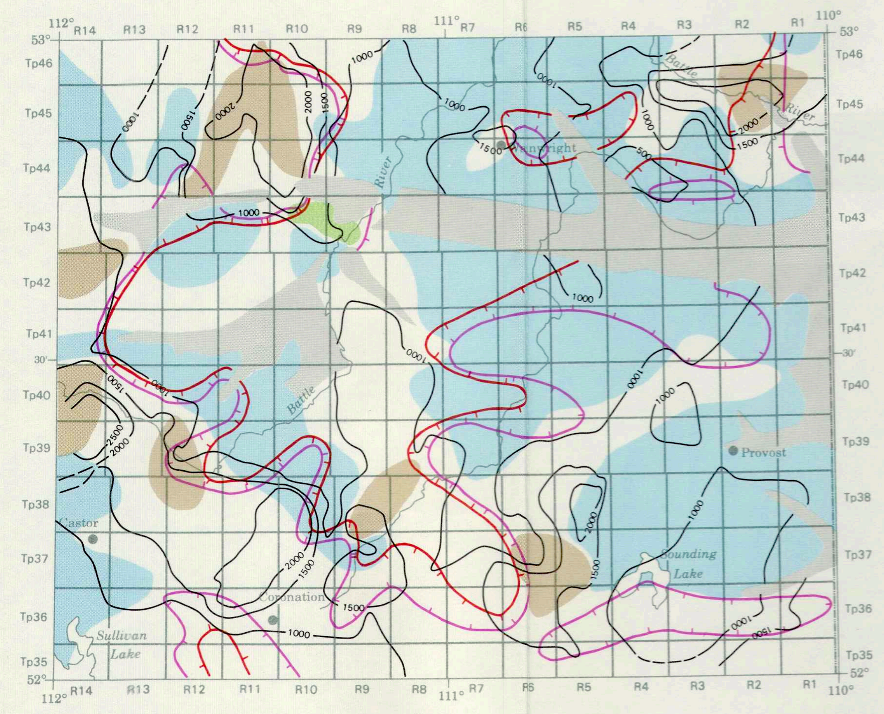
Fluoride content in parts per million in bedrock waters from 350-500 foot depths 1.5

Data control point marking the location of a well with a chemical analysis:
- in bedrock waters from 150-350 foot depths ....
- in bedrock waters from 350-500 foot depths ....

FLUORIDE



HYDROCHEMISTRY: BEDROCK 0-150 FEET



HYDROCHEMISTRY

LEGEND

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* ....

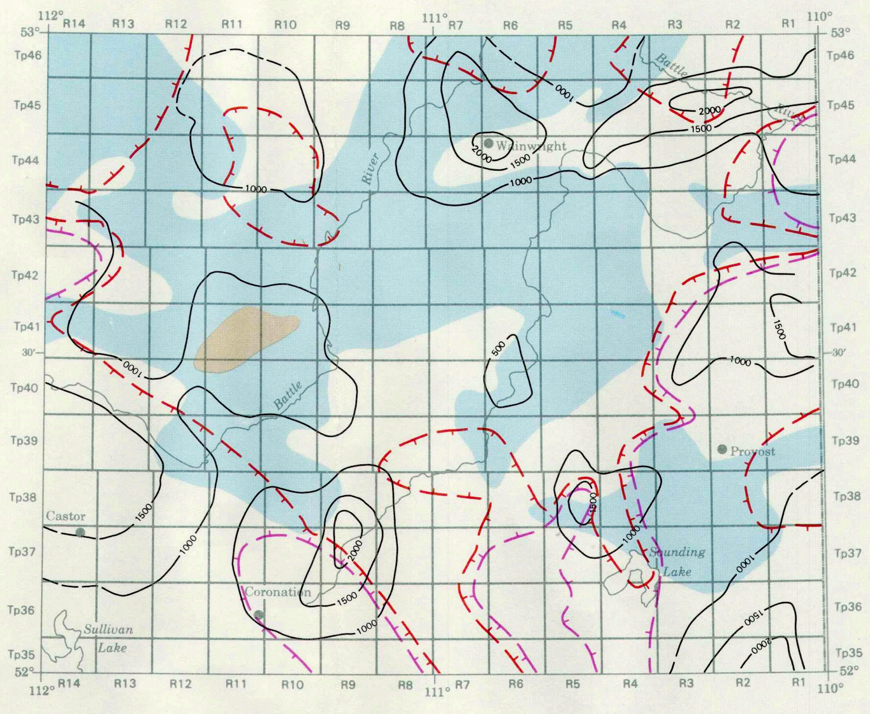
Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content:
- defined ....
- approximate ....

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

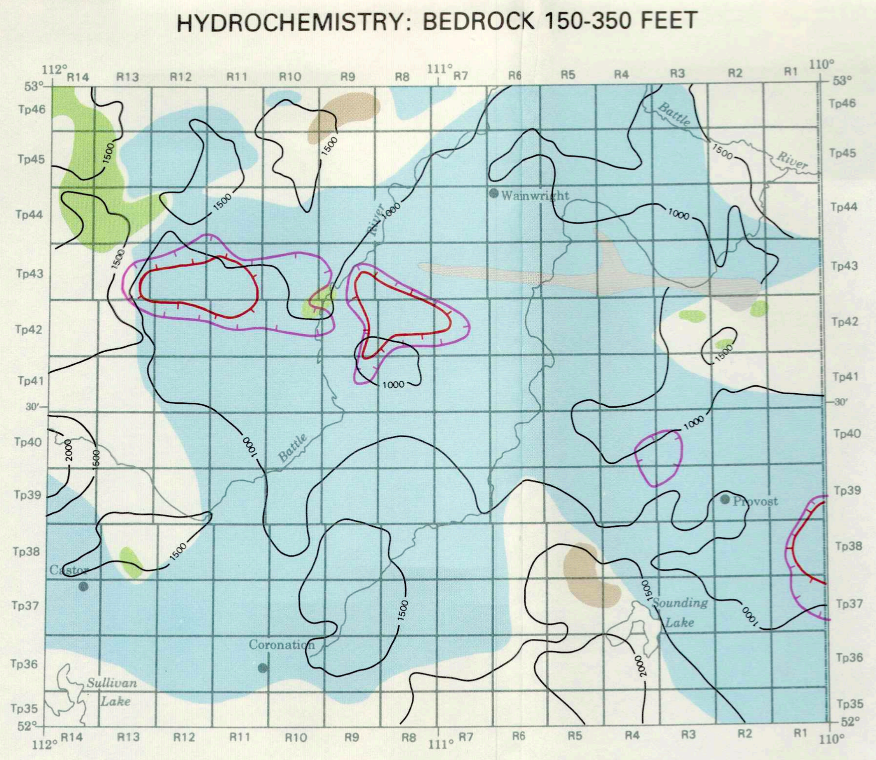
Area where depth to bedrock exceeds maximum depth indicated on map ....

*determined on equivalents per million basis

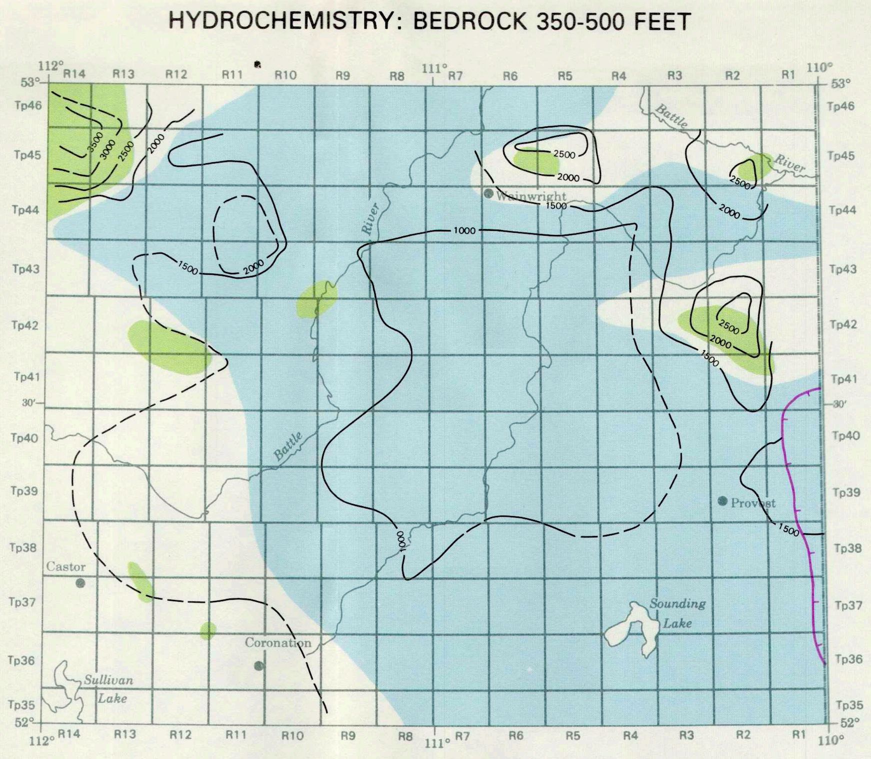
HYDROCHEMISTRY: DRIFT 0-150 FEET



HYDROCHEMISTRY: BEDROCK 150-350 FEET



HYDROCHEMISTRY: BEDROCK 350-500 FEET



SCALE 1:1,000,000

Miles 5 0 10 20 Miles

Kilometers 5 0 10 20 30 Kilometers

HYDROGEOLOGICAL MAP WAINWRIGHT ALBERTA

NTS 73D