

ENVIRONMENTAL CONSIDERATIONS

- A. FISH & THE BIOLOGICAL SYSTEM
- B. WILDLIFE
- C. RECREATION
- D. WATER QUALITY
- E. RIVER REGIME
- F. GROUNDWATER

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Fig. 122

*Water Quality Background Data
for Major Formations*

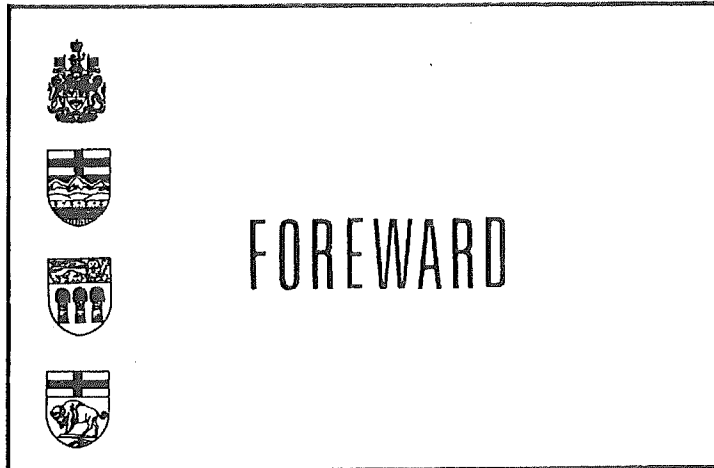
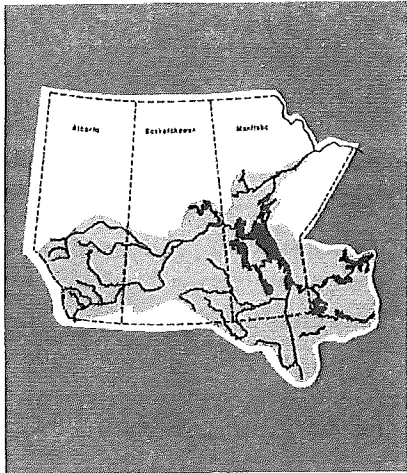
1972

WATER SUPPLY FOR THE SASKATCHEWAN-NELSON BASIN

CANADA ALBERTA SASKATCHEWAN MANITOBA

APPENDIX 7: ENVIRONMENTAL CONSIDERATIONS

- Section A — Fish and the Biological System
- Section B — Wildlife
- Section C — Recreation
- Section D — Water Quality
- Section E — River Regime
- Section F — Groundwater



The Saskatchewan-Nelson Basin Study of water supply could be considered a first step in the joint Interprovincial and Federal-Provincial planning of water resources development. Subsequent steps might include a study of water uses, then a study of the benefits and disbenefits of various hypothetical project combinations selected to supply those uses. The evaluation of benefits and disbenefits may eventually require further basic studies, such as the effects of flow regulation on the river regime and aquatic environment and the relation between river regulation and riparian environments.

Early in the course of the study, the Saskatchewan-Nelson Basin Board decided that some consideration should be given to subjects other than water supply even though no such provision had been made in its terms of reference. Arrangements were made for knowledgeable persons to report on each of eight topics; fish and the biological system, recreation, wildlife, river regime, water quality, groundwater, the effects of diversion on the Churchill River System, and the effects of diversion on the MacKenzie River System. A complete study of each topic was not possible within the framework of the SNBB study, so a general appraisal was made under three headings.

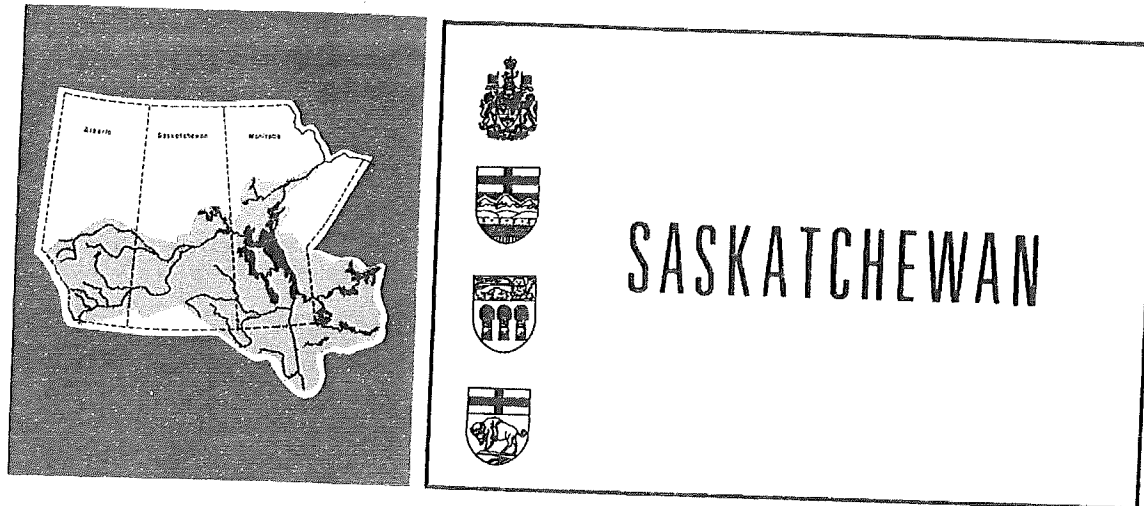
1. What is the situation now - or what is known about the topic or resource - within the basin?
2. What kinds of things would happen as a result of the construction of reservoirs and diversions?

3. What kinds of information and studies are needed so that the effects of future projects can be predicted with confidence?

The report on each topic is reproduced in full in Appendices 7 and 8. This Appendix (7) contains the reports on fish and the biological system, recreation, wildlife, river regime, water quality and groundwater. Appendix 8 contains the two reports on the possible effects of diversion on donor basins, one for the MacKenzie River System and one for the Churchill.

The reports include recommendations made by the various authors for more data and studies. The Board has not attempted to bring these recommendations together to form an integrated study program. In their present form they must be considered as suggestions made by specialists in various fields, with no direct nor implied endorsement by the Board.

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General Geology and Hydrology

Saskatchewan is situated in the northeasterly portion of the western Canada sedimentary basin (Figures 121 and 122). Sedimentary rocks overlap igneous and metamorphic rocks of Precambrian age to the north and dip gently southward toward the Williston Basin in southeastern Saskatchewan and southwestward toward the Cordilleran geosyncline in western Alberta. The geological history of western Canada is described in detail by McCrossan and Glaister (1964). Hitchon (1964, 1969a, b) described regional groundwater flow systems of the western Canada sedimentary basin.

All aquifers in the basin are restricted to the sedimentary rocks overlying the Precambrian igneous and metamorphic rocks. The most continuous and pervious units include the Winnipeg/Deadwood Formations, the Devonian carbonates and the Blairmore/Swan River Groups. These units constitute the major aquifers in the bedrock, and their physical properties govern the overall flow pattern of the western Canada sedimentary basin (Hitchon, 1969b).

The orogenic processes which created the Rocky Mountains in their present configuration uplifted the sedimentary basin above sea level during the latter part of the Cretaceous Period. Integrated surface drainage systems developed on the eastern slopes of the Rocky Mountains, draining in a northeasterly direction, eroding the landscape at successively lower base levels. Fluvial deposits of these early drainage systems are preserved as erosional remnants on the Cypress Hills, Wood Mountain and other smaller upland areas.

CLASSIFICATION OF AQUIFERS

VALLEY AQUIFERS: preglacial and glacial valley aquifers which occur within the Empress Group as narrow, longitudinally-continuous, sand and gravel deposits which typically function as buried sand drains; alluvial fill 50-300 feet thick, typically fine to medium grained, subangular to subrounded sand having a permeability of $2-4 \times 10^{-2}$ cm/sec; coarse sand to well-sorted gravel beds are typically less than 10 feet thick and discontinuous; interbedded with silt, clay, till and collaterally by bedrock aquifers which will contribute significantly to the total productivity of the system; longitudinal continuity may be disrupted by collapse structures, glacial erosion, or by facies changes.

BLANKET SAND AQUIFERS: present within the Empress Group as laterally extensive, continuous, sand aquifers up to 100 feet thick made up principally of fine to medium grained subrounded sand having a permeability of $2-4 \times 10^{-2}$ cm/sec; granular deposits vary laterally to sandy till, pebbly silt and till; underlain and overlain by till and bounded laterally by till or bedrock clay or sand; continuity may be disrupted by facies changes, glacial erosion or collapse structures; may contribute significantly to the yield of adjacent major aquifers; or may be of major significance in their own right.

INTER-TILL AQUIFERS: stratified drift, discontinuously preserved on the continuous interface between the deposits of successive glaciations; typically variable, laterally and vertically from thick well-sorted to poorly-sorted gravel deposits of very limited areal extent to thinner more-continuous sand, subangular to subrounded and having a permeability of $2-4 \times 10^{-2}$ cm/sec; granular deposits vary laterally to sandy till, pebbly silt and till; underlain and overlain by till and bounded laterally by till or bedrock clay or sand; continuity may be disrupted by facies changes, glacial erosion, or collapse structures.

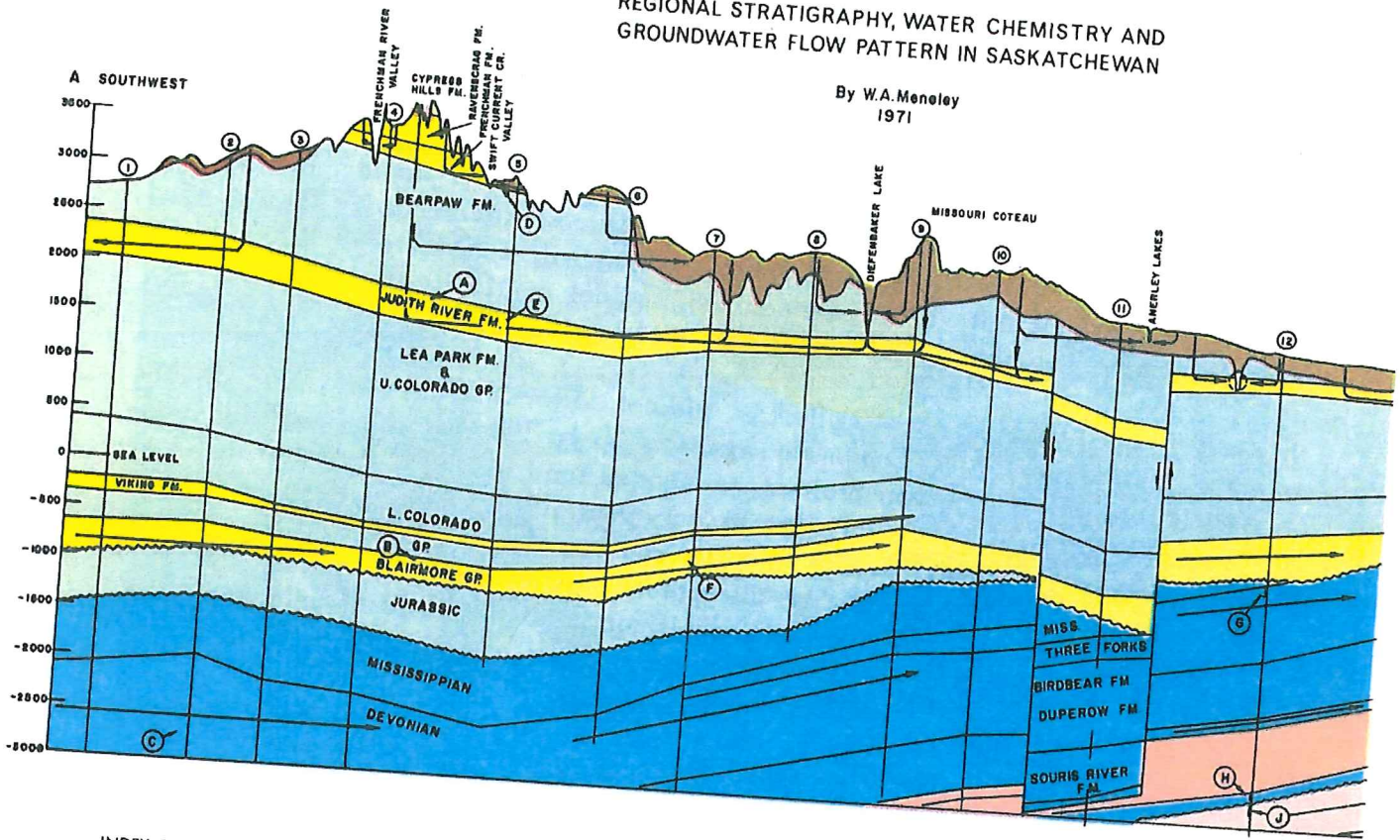
BEDROCK AQUIFERS (Major): include the Blairmore-Swan River Group and the Winnipeg and Deadwood Formations in north-central Saskatchewan; 300-800 feet thick, mainly fine to medium grained subrounded quartz sand, unconsolidated, permeability probably $1-5 \times 10^{-2}$ cm/sec; very continuous and uniform over large areas; underlain by carbonate aquifer or Winnipeg-Deadwood Formations and overlain by bedrock clay sandy till, or sand; southern boundary is a fresh water/saline water boundary which lies up-gradient from the fresh water zone.

CARBONATE AQUIFERS: dolomite and dolomitic limestone, jointed, jointed, with variable solution enlargement on joints; probably similar in characteristics to the carbonate aquifer in the Winnipeg area and the Grand Rapids area; very little known about this aquifer in Saskatchewan as yet.

'Compiled by W. A. Meneley, Geology Division, Saskatchewan Research Council'

REGIONAL STRATIGRAPHY, WATER CHEMISTRY AND GROUNDWATER FLOW PATTERN IN SASKATCHEWAN

By W.A. Meneley
1971

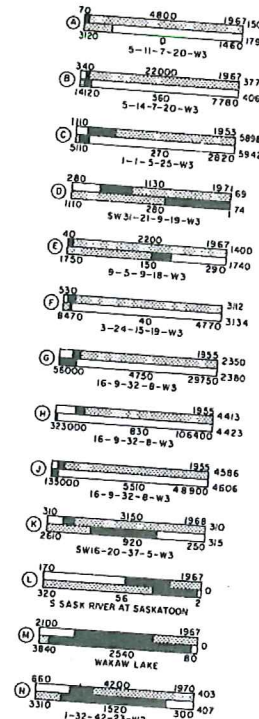


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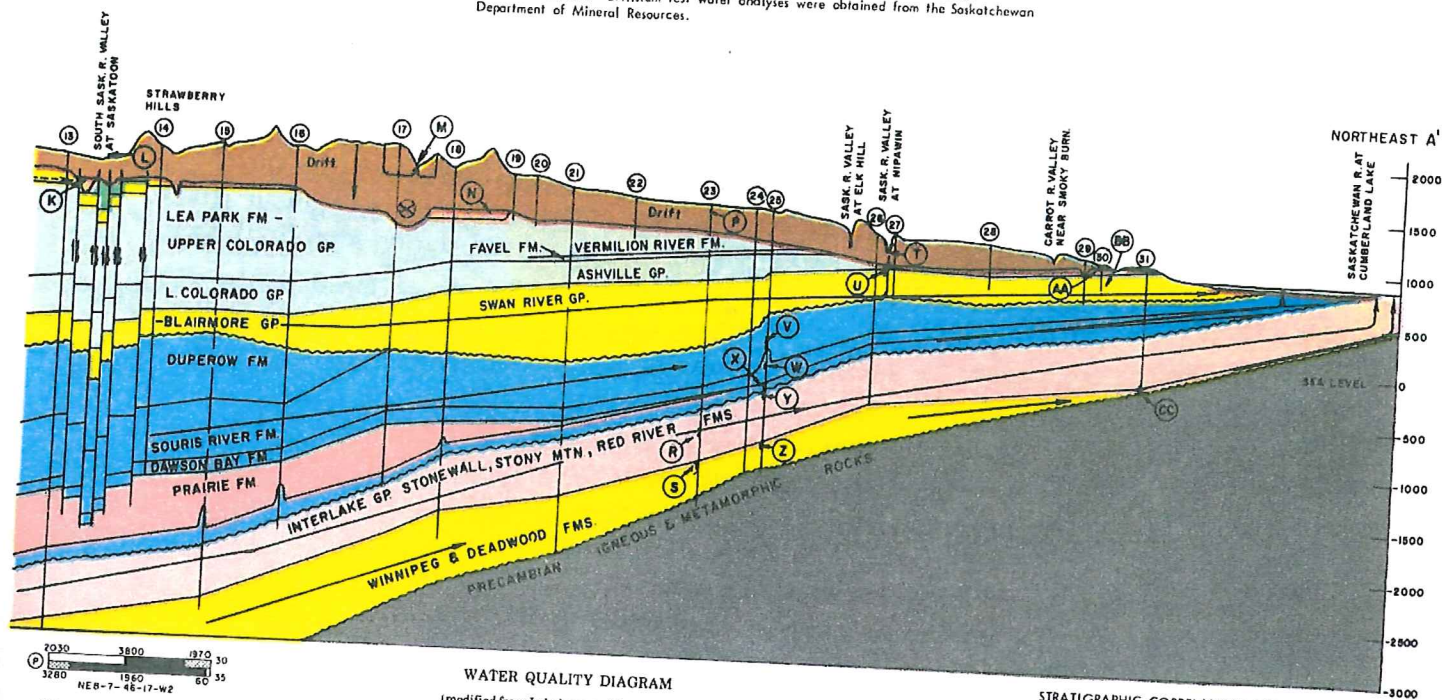
GENERALIZED LITHOLOGY

- DRIFT:** silt, interbedded with fine to medium grained, sub-angular to subrounded sand, gravel, silt, silty clay and clay; includes sand and gravel deposits of the Empress Group where it is undifferentiated.
- SAND AND GRAVEL:** fine to medium grained, subrounded quartz and chert sand, well rounded black, red, and brown chert, quartzite and argillite sand and gravel, interbedded with calcareous and noncalcareous silt and silty clay, and marl.
- SAND:** very fine to coarse grained friable to cohesive sand, locally cemented with calcium carbonate, interbedded with silt, silty clay, and clay. The Ravenscrag Formation and the Blairmore-Swan River Group include beds of carbonaceous clay and lignite.
- SILTY CLAY:** noncalcareous, bentonitic silty clay interbedded with very fine to medium grained, greenish-gray, friable to cohesive sand, thin bentonite beds.
- SHALE:** noncalcareous and calcareous clay and silty clay of the Lea Park Formation and Colorado Group and interbedded shale, limestone sandstone, chert, dolomite and anhydrite of the Vanguard, Shaunavon, Gravelbourg and Watrous Formations.
- CARBONATES AND EVAPORITES:** predominately dolomite, limestone and anhydrite, with beds of bituminous shale, calcareous shale and siltstone.
- EVAPORITES:** predominately halite, anhydrite, sylvite, carnallite, dolomite.
- CARBONATES:** dense lithographic dolomite with minor dolomitic limestone.
- IGNEOUS AND METAMORPHIC ROCKS:** includes granitic, gneissic, volcanic, plutonic and metasedimentary rocks of the Precambrian Shield.



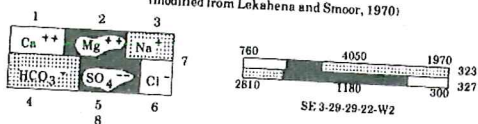
SOURCES OF INFORMATION

Geology compiled by W.A. Meneley from information from Whitaker and Pearson (1971), Whitaker and Christiansen (1971), Christiansen (1968), McCrasson and Gloister (1964), and the Saskatchewan Department of Mineral Resources Schedules of Wells. Water samples, analyzed by the Chemistry Division, Saskatchewan Research Council, were obtained in part from published sources (Rutherford, 1967, 1970) and from the open-file records in the Geology Division, Saskatchewan Research Council. Drillstem test water analyses were obtained from the Saskatchewan Department of Mineral Resources.



WATER QUALITY DIAGRAM

(modified from Lekahena and Smoor, 1970)



Bar graph of major ions based on percentage of total milligram equivalents per liter.

1. Total hardness, parts per million as CaCO₃.
2. Specific conductivity, micromhos/cm at 25°C.
3. Year of analysis.
4. Total ionic concentration, parts per million, computed by summation of the constituents determined without correcting for the reduction of bicarbonate to carbonate. (Item 1970 is 220).
5. Sulphate concentration, parts per million.
6. Chloride concentration, parts per million.
7. Top and base of inlet section of well, feet; O=surface water analysis; n=10, indicates that the analysis represents the arithmetic mean of the analysis of 10 samples.
8. Land location of water sample.

EXPLANATION OF MAP SYMBOLS

- ⊗ Direction of groundwater movement based on gravitational flow considerations
- ⑩ Testhole log index number
- | Drillstem test interval

STRATIGRAPHIC CORRELATION GRAPH

AGE	ROCK UNITS	
	Southwestern Sask.	Northeastern Sask.
QUATERNARY	Saskatoon Gp. Sutherland Gp. Empress Gp.	
TERTIARY	Wood Mountain Fm. Cypress Hills Fm. Swift Current Cr. Fm. Ravenscrag Fm. Frenchman Fm. Bearpaw Fm. Judith River Fm.	Riding Mountain Fm.
CRETACEOUS	Lea Park Fm.	Vermilion River Fm. Favel Fm. Ashville Gp.
JURASSIC	Blairmore Gp. Vanguard Fm. Shanavon Fm. Gravelbourg Fm. Walrus Fm.	Swan River Gp.
MISSISSIPPIAN	Kibbey Fm. Paplar Fm. Ratcliffe Fm. Midale Fm. Frobisher-Alida Fms. Tilson Fm. Souris Valley Fm. Bakken Fm.	
DEVONIAN		Three Forks Fm. Birdbear Fm. Duparow Fm. Souris River Fm. Dawson Bay Fm. Prairie Fm. Winnepogosis Fm. Ashern Fm.
SILURIAN		Interlake Gp.
ORDOVICIAN		Stonewall Fm. Stony Mountain Fm. Red River Fm. Winnipeg Fm.
CAMBRIAN		Deadwood Fm.
PRECAMBRIAN		

Figure 122: Stratigraphy, Chemistry, Flow Pattern - Saskatchewan

Concomitantly the gravitational groundwater flow system described by Hitchon (1969a, b) developed in a northeasterly direction - in the direction of the regional topographic slope. The configuration of the Saskatchewan-Nelson Basin (both the surface and subsurface components) was therefore established prior to continental glaciation of western Canada.

Recurrent continental glaciation by ice sheets centered approximately in the Hudson Bay area destroyed the pre-existing drainage system by glacial erosion and by deposition of more than 1,000 feet of drift over parts of Saskatchewan (e.g. Touchwood Hills, Christiansen, 1970b). Although the general boundaries of the basin have remained unchanged, the valleys in which the present rivers flow through Saskatchewan were formed during the final deglaciation of western Canada.

As the last continental glacier wasted and retreated down the continental slope toward the northeast, the valleys of the North and South Saskatchewan Rivers, Battle River, Qu'Appelle River, Souris River, and Assiniboine River were eroded sequentially as meltwater channels which drained into a continuous sequence of ice-marginal lakes at successively lower elevations. The larger valleys such as those of the Saskatchewan and Qu'Appelle Rivers carried runoff from the eastern slopes of the Rocky Mountains as well as locally produced glacial meltwater. Successive reaches of these streams thus developed as discrete elements, shaped by the transient hydrologic regime at that particular time, with downcutting limited only by the temporary base level control of the glacial lakes. This hydrologic regime was characterized by much higher flow during the climax of deglaciation. Furthermore, isostatic rebound of western Canada during deglaciation uplifted Hudson Bay relative to the headwaters of the basin, thereby reducing the longitudinal gradients of the trunk streams. These factors have produced the present situation in Saskatchewan characterized by underfit streams flowing through overdeepened and alluviated valleys incised far below the general level of the plains. These glacially formed valleys are superimposed upon the basin inherited from an earlier hydrologic regime. In Saskatchewan where the effects of glaciation are most pronounced, the major streams are almost devoid of tributaries and function mainly as conductors transmitting water from the headwaters region across the plains. The basin in Saskatchewan thus exists functionally as two parts - the trunk streams and the rest of the basin area. Major aquifers in Saskatchewan possess greater continuity than the surface drainage system of the basin area. The water supply of the trunk streams is derived from precipitation in the headwaters areas whereas the water supply for most of the basin in Saskatchewan is dependent upon local precipitation. The coupling between these two components is effected

through the groundwater flow system, that is, through aquifers and aquifer systems.

Aquifers and Aquifer Systems

Criteria for Identification of High-Yield Aquifers: An aquifer is defined as a zone in which wells can be constructed which will yield water at a rate sufficient for the intended need. In this study a high-yield aquifer is defined as one in which wells yielding at least 1 cfs (375 igpm) can be completed and produced continuously without depleting the aquifer system. An aquifer system (Figure 123) includes one or more aquifers and related confining beds which function together as a single geohydrologic system under development conditions. The sustained yield of an aquifer system is the maximum rate of replenishment from precipitation and induced infiltration that can be effected without imposing unacceptable side effects upon the aquifer system. Undesirable side effects might include changes in the surface layer associated with lowering the water table, dewatering intertill aquifers and saline water encroachment.

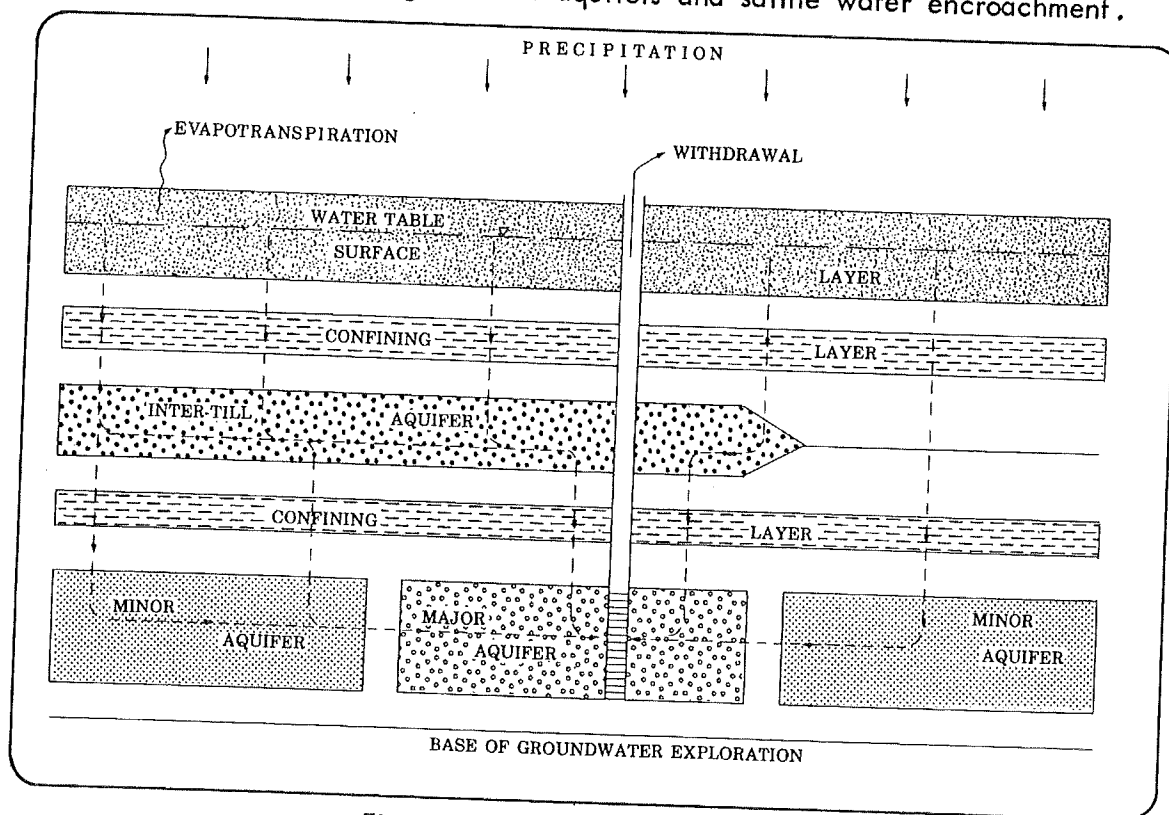


Figure 123: Aquifer System – Example

In Saskatchewan all but one of the high-yield aquifer systems considered in this study are friable bedrock sand units or cohesionless sand and gravel deposits within the drift. Regional geologic studies indicate that the bedrock sand aquifers are made up of fine- to medium-grained, well-sorted sand. Similarly most of the aquifers in the drift are composed mainly of fine- to medium-grained subangular to subrounded, well-sorted sand. Field permeability measurements and textural determinations of these materials at many locations throughout the province indicate that these sand units have an average hydraulic conductivity of about 3.5×10^2 cm/sec ($K = 600$ igpd/ft²) which is comparable with the range of values cited by Terzaghi and Peck (1967, p.55). Information from several hundred electric logged testholes drilled during the regional geologic mapping program indicates that the high-yield aquifers are comprised mainly of sand, hence it is considered that the hydraulic conductivity value of 600 igpd/ft² can be considered as a reasonable estimate for the high-yield aquifers. Coarser-textured beds are undoubtedly present in all of the Empress Group and intertill aquifers, and indeed such beds are much sought after in most groundwater exploration programs. Although there is a very real advantage to be gained in finding coarse-textured zones in which to construct high-capacity wells, the benefit relates to the ease of well construction, to lower operation and maintenance costs and to the decreased number of wells required to exploit the aquifer system rather than to any increase in the total yield of the system.

High-permeability zones allow more efficient coupling of the production wells to the aquifer system. For example, in the Estevan Valley Aquifer (Walton, 1970, p.255) the average hydraulic conductivity in the completion zone was found to be 7,500 igpd/ft². Only 5 to 10 wells in such material would be required to extract the estimated net yield of the Estevan Aquifer System. That such beds are exceptional and discontinuous was evidenced by the barrier boundary effects detected within the first few minutes following the start of the pumping test at that location. Indeed, it can be generalized that the better the execution of the well-site exploration program, the more likely it is that the pumping test will show barrier boundary effects confirming that the well has been situated in a portion of the aquifer having above-average permeability. Too many people fail to discriminate between aquifer exploration and well-site exploration. Aquifer exploration entails identification of the stratigraphic setting of permeable beds and the assessment of their continuity, thickness and texture. Well-site exploration entails the search within an aquifer for the exceptionally permeable segments in which wells can be most effectively coupled to the aquifer system. A high-yield aquifer must be continuous and, as has already been indicated, field evidence indicates that the continuum will be sand having a permeability of about 600 igpd/ft².

It is essential to consider in what sort of aquifer a permanent production well should be constructed. A typical well designed for continuous production at 1 cfs would require a 12-5/8 inch OD casing to accommodate a typical pump with 1 cfs capacity. The well screen would have a 12-inch diameter for installation through the bottom of the casing. Criteria outlined by Walton (1970, pp. 292-299) provide further guidance for the development of a suitable well design. A screen slot size of 0.015 inches would provide a stable natural filter pack in medium-grained sand. The screen length based on the optimum entrance velocity criterion would then be about 100 feet. The presence of coarser-textured material in the completion zone or construction of a filter-packed well would substantially reduce the length of screen required. Nevertheless, it would be reasonable for this study to consider that the completion zone for a typical high-yield aquifer in Saskatchewan should include at least 50 to 100 feet of medium-grained sand or coarser material. On this basis we can consider for calculation purposes that the transmissivity of a high-yield aquifer should be at least $600 \times 100 = 60,000$ igpd/ft. The drawdown in a production well in such an aquifer would probably lie somewhere in the range of 20 to 50 feet depending upon the quality of well-construction practice. To allow for well losses and interference between adjacent wells it is necessary to consider that the minimum available drawdown in a high-yield aquifer should be at least 50 feet.

In an extensive aquifer under steady-state production conditions, all of the water produced is derived from vertical leakage through the confining layers and no water is derived from storage within the aquifer. Under these conditions it is possible to utilize a mathematical model (Walton, 1970, p. 217-219) to estimate the area of influence around a well producing at a constant rate of 1 cfs. Depending upon the thickness and vertical permeability of the confined layer, the area of the cone of influence may be expected to range from 5 to 500 square miles. Clearly, any high-yield aquifer must be continuously present over a large area and thus must present a readily identifiable target for aquifer exploration.

In summary, a high-yield aquifer in Saskatchewan should comprise 50 to 100 feet of fine- to medium-grained sand with an average transmissivity of 60,000 igpd/ft, an available drawdown of at least 50 feet, and a minimum more or less continuous areal extent of 5 to 500 square miles. It should include some segments having a transmissivity 2 to 10 times greater than average in which wells can be most effectively constructed.

Yield Estimation: The yield of high-yield aquifer systems (Figure 123) will depend principally upon the amount of water in storage within the aquifer and upon the amount of water which can be induced to enter the system by vertical infiltration through the confining beds and laterally through minor aquifers to the high-yield aquifers. Bredehoeft and Young (1970) point out that groundwater systems differ from surface water systems in that some disturbance of the system equilibrium is a prerequisite for any development, that is, some water may have to be taken from storage within the system to create the necessary hydraulic gradients, and that the time delay in groundwater systems may be very long so that it cannot be assumed that steady state conditions ever exist during groundwater development.

In a virgin aquifer system (op. cit., p. 5)

$$(1) \quad R_o - D_o = 0$$

where R_o = mean rate of recharge under virgin conditions
 D_o = mean rate of discharge under virgin conditions

At some time, t , after the start of a groundwater development

$$(2) \quad (R_o + \Delta R_o) - (D_o + \Delta D_o) - Q_K + dv/dt = 0$$

where ΔR_o = the change in the mean rate of recharge
 ΔD_o = the change in the mean rate of discharge
 Q_K = the rate of withdrawal as a result of development
 dv/dt = the rate of change of storage of the groundwater system

Assuming water table conditions, then

$$(3) \quad s_a = \Delta V_k / S_y A_b$$

s_a = average basin-wide drawdown
 ΔV_k = volume of water removed from storage after some time, t
 S_y = specific yield of the aquifer
 A_b = area of the basin

In Saskatchewan, however, the high-yield aquifers are confined and would remain so under the level of development envisaged in this study. For a confined aquifer system the correlative conceptual model may be derived by rearranging the equation (Walton, 1970, p. 362).

$$Q_c/A_c = 2.78 \times 10^7 (K'/M') \Delta H$$

where

K' = vertical hydraulic conductivity of confining layer,
igpd/ft²

m' = thickness of confining layer, feet

ΔH = average change in hydraulic head in the aquifer, feet

A_c = area over which recharge can occur, miles²

Q_c = yield of the aquifer, imperial gallons per day

so that

$$\Delta H = Q_c / (2.78 \times 10^7 (K'/M') A_c)$$

It is convenient in the above development to refer to Q_c/A_c as the leakage coefficient. For an aquifer system to reach a new equilibrium where $dv/dt = 0$ there must be some change in the rate of recharge and/or rate of discharge. It is these changes which are of interest to us.

In assessing the water resources of the Saskatchewan-Nelson Basin, any reduction in groundwater discharge ΔD cannot be credited as a net increase in the basin water resources because it merely reduces the amount of surface outflow. In this study, therefore, the additional water resource available as a result of groundwater development is that derived by increasing the average rate of groundwater recharge by groundwater development. This is the term ΔR_0 and it is here called the net groundwater yield.

Provided only that ΔR_0 can be attained and equilibrium conditions approached again before unacceptable changes occur in the environment, then the rate of groundwater withdrawal Q_K necessary to impose the changes in recharge ΔR_0 may be regarded as the sustained yield of the groundwater system. This will be greater than the net groundwater yield by the decrease in groundwater discharge D_0 which inevitably must occur as a result of groundwater development.

The areal extent of high-yield aquifers and the thickness of their superincumbent confining layers have been defined by the regional geological mapping program. The vertical hydraulic conductivity value used has been selected to provide a conservative estimate of the net groundwater yield. The value for ΔH is more difficult to approximate. For extensive aquifers it can be estimated by a trial and error approximation by assuming a value of ΔH , and calculating the net groundwater yield. The number of wells (each

producing 1 cfs) required to extract the calculated aquifer yield was determined and the well spacing calculated. The average ΔH was then estimated by summing the interference effects of all wells within the area of influence. The number of wells is limited by available drawdown and by the upper limit of ΔR_0 arbitrarily selected as less than 10 percent of precipitation. In narrow valley aquifers the effects of less permeable side walls can only be estimated crudely by this method. The value for ΔH is discussed separately for each aquifer system. In general, ΔH will be substantially smaller than the available drawdown because the drawdown in the vicinity of a pumping well is a function of the logarithm of the distance from the well. In an extensive aquifer the ΔH will range from $1/3$ to $1/6$ of the available drawdown.

In this study, high-yield aquifers which would derive most of their production from induced infiltration from trunk streams, for example, the portion of the Tyner Valley Aquifer from the Alberta boundary to Tyner (Figure 121) are not included in calculating the total net groundwater yield. Water produced from such aquifers would be derived mainly from surface water resources which have already been accounted for in calculating surface water resources. Such aquifers perform a transfer function, they filter the water, and also function as a heat exchanger. Meyboom (1963a) described the performance of the portion of this aquifer in the vicinity of Medicine Hat, Alberta.

Natural Recharge: In calculating the increase in groundwater recharge ΔR_0 , it is not necessary to measure the natural recharge R_0 under virgin conditions; however, it is essential that $R_0 > 0$, that is, that equation (1) is satisfied and we can treat the groundwater system as a dynamic system.

Hydrographs from the regional observation wells (Figure 121) (Menely, 1970; Menely and Whitaker, 1970) clearly indicate that the groundwater regime is in dynamic equilibrium with the climate. Recharge occurs intermittently from spring snowmelt and summer rainfall. Groundwater outflow is greater than input throughout the winter months. A continuing program of interpretation of the information received to date suggests that the water level trend in different aquifers reflects the average precipitation calculated as a moving mean summed for periods ranging from 3 to 15 years.

Production from the Regina Aquifer System is now about 11,000 acre-feet per year according to the Saskatchewan Water Resources Commission.

According to Lissey (1962) this rate was sustained for many years without any marked diminution of the supply available and later information from the Commission indicates that this situation remains unchanged. Similarly at Yorkton, production is currently about 1,100 acre-feet per year (personal communication, City Engineers Office). The City of Yorkton has been producing water from this well field since the 1930's and measured water levels in the well field are now higher than levels reported in earlier years when production was considerably less. Again there is no evidence of depletion of the aquifer. Water levels in the well field do, however, reflect changes in the amount of precipitation.

The water levels in observation wells making up the Saskatchewan regional network are generally higher than they were when construction started on the network in 1964. Similarly, water levels measured now in farm wells are consistently higher now than those reported by the Geological Survey of Canada well inventory carried out in 1935. The amplitude of the water level variation with climate is a function of the particular aquifer system and is also dependent upon the location and depth of the well in the aquifer system. The available water-level information indicates that equation (1) is satisfied in Saskatchewan and that the groundwater systems are in dynamic equilibrium with the climate.

Water Quality: The chemical composition and concentration of groundwater are the limiting factors determining its value as a resource in Saskatchewan. Water quality is expressed in this report by bar diagrams of the type shown in Figure 124. These provide a visible display of the compositional characteristics of the water and at the same time provide numerical data for critical parameters such as total ionic concentration, conductivity, hardness, chloride and sulphate concentration. Almost all of the analyses used were run by the Chemistry Division, Saskatchewan Research Council. Some are contained in published reports by Rutherford (1966, 1970); however, many are unpublished water analyses included in the open-file records of the Geology Division. Water analyses obtained by J. A. Vonhof in the Esterhazy area for the Inland Waters Branch were also made available for this study.

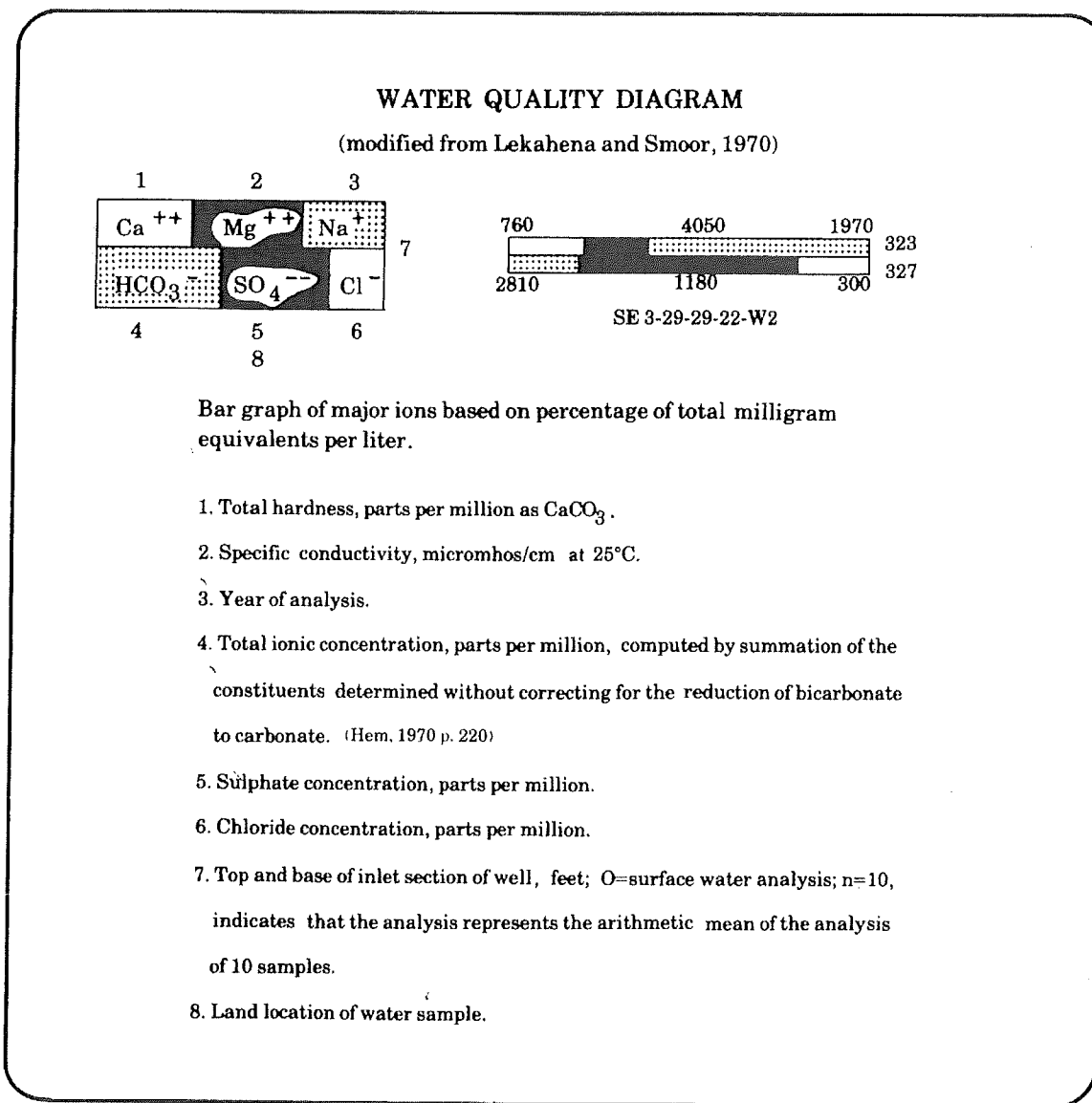


Figure 124: Water Quality Diagram

In this study the upper total ionic concentration limit of potable water was defined as being 4,000 ppm. Aquifers containing more highly mineralized water were not considered. The average water quality and its variation are presented separately for each aquifer system. None of the aquifer systems for which analytical information is available contains water that is suitable for irrigation purposes. The total ionic concentration of groundwater in many

aquifer systems is too high to be desirable for public water supplies; however, most contain water which is usable for stock-watering purposes. Extensive treatment would be required for many industrial purposes. Groundwater in Saskatchewan is attractive as a source of cooling water because of its low temperature. The average groundwater temperature may be estimated by considering that the geothermal gradient in Saskatchewan is about $1^{\circ}\text{F}/50$ feet and that the surface equilibrium temperature is only a few degrees higher than the average annual air temperature which for most of Saskatchewan is only 35 to 40°F . The groundwater temperature of high-yield aquifers at or above the bedrock surface is thus generally in the range of 42 to 50°F .

Ground Settlement Associated with Groundwater Development:

The amount of ground settlement which might result from groundwater development can be approximated from soil mechanics consolidation theory (Terzaghi and Peck, 1967). Consolidation of the aquifer and adjacent confining beds will result from the increase in effective stress acting on the geologic framework as a result of lowering the hydraulic head by pumping. The amount of consolidation will depend upon the compressibility of the aquifer system and this, in turn, depends very strongly on the geological history and particularly on the loading history of the aquifer system. All of the high-yield aquifers in the province have been subjected to one or more loading cycles by continental ice sheets 10,000 to 20,000 feet thick. Although the loading history is extremely complex all of the aquifers and confining beds are overconsolidated by an amount greater than the increased effective stress which would be caused by groundwater development. Consequently, the settlement caused by application of an additional load due to pumping would be small. Although more refined analyses could be carried out, preliminary estimates suggest that the magnitude of settlement would be less than 0.5 feet over most of the aquifer and would be somewhat larger only within a few hundred feet of production wells. Therefore, the ground settlement as a result of groundwater development in Saskatchewan is expected to be negligible.

Sources of Information: The principal source of information for this report has been the geologic mapping, test drilling, water quality and observation well measurements carried out by the Geology Division, Saskatchewan Research Council, since 1963. Additional information has been obtained from studies carried out by the Chemistry Division. These investigations were funded jointly by the provincial and federal governments under the ARDA program. Invaluable information on stratigraphy and water quality in deeper aquifers has been obtained from information submitted by the petroleum and potash industries to the Saskatchewan Department of Mineral Resources.

Information about municipal and industrial water quality was obtained from the Saskatchewan Water Resources Commission. Because their information was obtained from a variety of sources of varying reliability and because many of the analyses were incomplete, it proved impossible to use this information. The great majority of the water analyses used in the study were made either by the Chemistry Division, Saskatchewan Research Council or by the Calgary laboratory of the Water Quality Division, Inland Waters Branch. A few analyses were run by commercial laboratories. No valid generalization about the quality of water actually used for various purposes in Saskatchewan can be made until reliable and properly documented water analyses have been obtained from all users.

High-Yield Aquifer Systems in Saskatchewan

The high-yield aquifer systems shown in Figure 121 are defined on the basis of the criteria already discussed. The area of each aquifer was measured by planimetry on the 1:2,000,000 aquifer map. Groundwater flow directions indicated are based on the limited hydraulic head information now available, and on general gravitational groundwater flow considerations.

The net groundwater yield cited for each aquifer system is shown in Table 26. The estimates are based on a carefully managed development in which a comparatively few high-capacity wells (or well fields) would produce the entire sustained yield for each aquifer system. Concentration of too many high-capacity wells in any limited portion of the aquifer will result in local overdevelopment, regardless of the fact that individual wells may be capable of yielding a great deal of water. The maximum net groundwater yield would be derived from a very large number of wells widely distributed throughout the aquifer with each well producing a relatively small amount of water. Groundwater is a distributed resource which can be most effectively used by large numbers of widely distributed low-consumption users. It is thus ideally suited to serve many of the needs of the rural population of Saskatchewan. Concentrated uses which have a requirement of more than several thousand acre-feet per year, or which require water having a total ionic concentration less than 1,000 ppm, must be served by alternative sources of supply.

Table 26
Drift Aquifers in Saskatchewan

Aquifer System	Area (Miles ²)	H (ft.)	Leakage Coefficient (gpd/mi ² /ft)	Net Groundwater Yield (acre-feet/year)
A. Major Bedrock Aquifers				
MONTREAL L. - DORE L. - PETER POND L. AQUIFER SYSTEM	19,000	N/C *	N/C	> 1 x 10 ⁶
NIPAWIN - HUDSON BAY - CUMBERLAND AQUIFER SYSTEM	15,000	N/C	N/C	> 1 x 10 ⁶
B. Major Drift Aquifers				
SHELLBROOK AQUIFER SYSTEM	2,800	N/C	N/C	50,000
NOKOMIS AQUIFER SYSTEM				
Hatfield Valley Aquifer - Domremy segment	3,500	100	140	50,000
Lebret segment	700	50	140	5,000
Pathlow Aquifer	200	100	190	5,000
Wynyard Aquifer	1,200	50	370	26,000
Strasbourg Aquifer	460	10	280	1,000
				<u>87,000</u>
YORKTON AQUIFER SYSTEM				
Yorkton-Bredenbury Aquifer	1,000	10	1,120	12,000
Welby Aquifer	220	10	1,120	3,000
Langenburg Aquifer	440	50	250	6,000
Melville Aquifer	600	20	220	3,000
				<u>24,000</u>
REGINA AQUIFER SYSTEM				
Regina Aquifer	1,400	10	N/C (see text)	25,000
ESTEVAN AQUIFER SYSTEM				
Estevan Valley Aquifer	190	100	190	11,000
Weyburn Aquifer	70	50	280	1,000
				<u>12,000</u>
TYNER AQUIFER SYSTEM				
Tyner Valley Aquifer	850	50	280	13,000
Dalmeny Aquifer	350	20	800	6,000
Tessier Aquifer	600	10	1,120	7,000
Rosetown Aquifer	550	10	280	2,000
Judith River Formation	1,580	5	110	10,000
				<u>38,000</u>
BATTLEFORD AQUIFER SYSTEM				
Battleford Valley Aquifer - Baldwinton segment	300	40	180	3,000
- Lilac segment	500	40	280	6,000
				<u>9,000</u>

Total yield of bedrock aquifers

Total yield of drift aquifers

Total net groundwater yield

> 2,000,000

245,000

> 2,245,000

* Not Calculated.

High-Yield Bedrock Aquifers

Bedrock Aquifers include the Lower Cretaceous Blairmore/Swan River Group; the Nisku, Souris River, Dawson Bay and Winnipegosis Formations collectively termed the Devonian carbonate aquifers; the Silurian Interlake Group; and the Winnipeg-Deadwood Formations of Ordovician and Cambrian Age (Figures 121, 122). These aquifers are present at depth beneath the plains of southern Saskatchewan, where they typically contain highly mineralized water (Porter and Fuller, 1959; Hitchon, 1964). Groundwater enters the Saskatchewan-Nelson Basin across the southern boundary of the basin and discharges to surface where these formations outcrop beneath the drift in northern Saskatchewan and western Manitoba. It should be noted that these aquifers are continuous across the northern boundary of the Saskatchewan-Nelson Basin to the Churchill Basin; the groundwater divide between these two basins is poorly defined.

Although the general principles of regional groundwater circulation and their significance for water quality are well established, there are many seeming anomalies in the observed water quality for deep aquifers in Saskatchewan. These anomalies cannot be explained by any simple application of the regional flow principles. Fresh water enters the deep bedrock aquifers in western Alberta and the northern United States and moves laterally in a northeasterly direction, with movement concentrated along those paths which offer the minimum resistance to flow. Fresh water flushing has proceeded furthest along the most continuously permeable paths, so there is extensive stratigraphic interdigitation of fresh and saline water which can be attributed to lateral flushing.

All of the information now available about deep aquifers in southern Saskatchewan was obtained as a result of petroleum exploration where the object of the search has been oil and not water. Because petroleum accumulations are typically associated with high-salinity formation water (100,000 - 200,000 ppm) (Porter and Fuller, 1959; Hitchon, 1964) concentrated by the same processes that favor accumulation of petroleum, exploration is directed selectively toward local high-salinity regions in the subsurface flow environment. In contrast, much lower salinity (less than 35,000 ppm) formation water may be associated with regions of more active groundwater circulation. Water quality information is thus biased to some unknown extent by the biased sampling of subsurface environments.

Introduction of fresh water from local recharge areas such as the Cypress Hills and Touchwood Hills (Hitchon, 1969a, p. 192-193) accounts in part for the systematic decrease in total concentration observed in all aquifers toward the northeast in the direction of groundwater flow. Fracturing associated with salt-solution structures (DeMille, 1964, Christiansen, 1967c) would increase the vertical permeability which would favor local introduction of fresh water into aquifers lying above the Prairie Formation * (Figure 122).

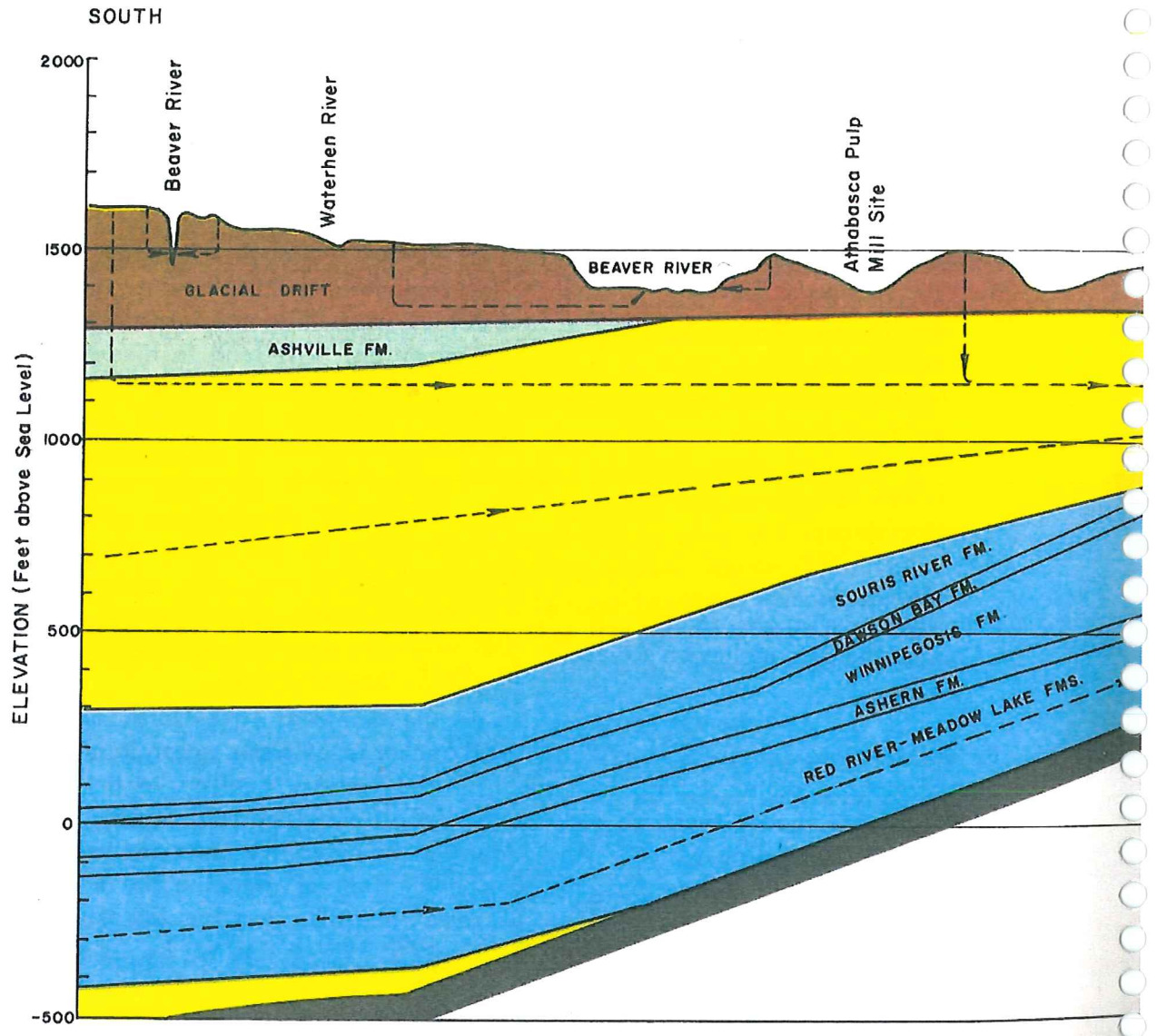
It appears certain that there is a dynamic balance in the bedrock aquifers between saline water moving laterally through the major aquifers in a northeasterly direction toward the outcrop area and fresh water added locally by vertical recharge. The practice of waste disposal into deeply buried bedrock aquifers, such as the Deadwood Formation, will tend to disrupt the hydrodynamic equilibrium and will tend to increase the lateral flow of saline water toward the outcrop area. Because the system is a hydraulic continuum, the effect of increasing the hydraulic head deep in the basin will be transmitted rapidly to the discharge area. Similarly, development of the fresh groundwater resources of the Swan River Group in the Carrot River Lowland (Figures 121, 122) would reduce the hydraulic head in that unit, not only creating a tendency for increased upward movement of more mineralized water from the underlying carbonate aquifer but also allowing more lateral discharge of saline water to the Saskatchewan River in the Cumberland area.

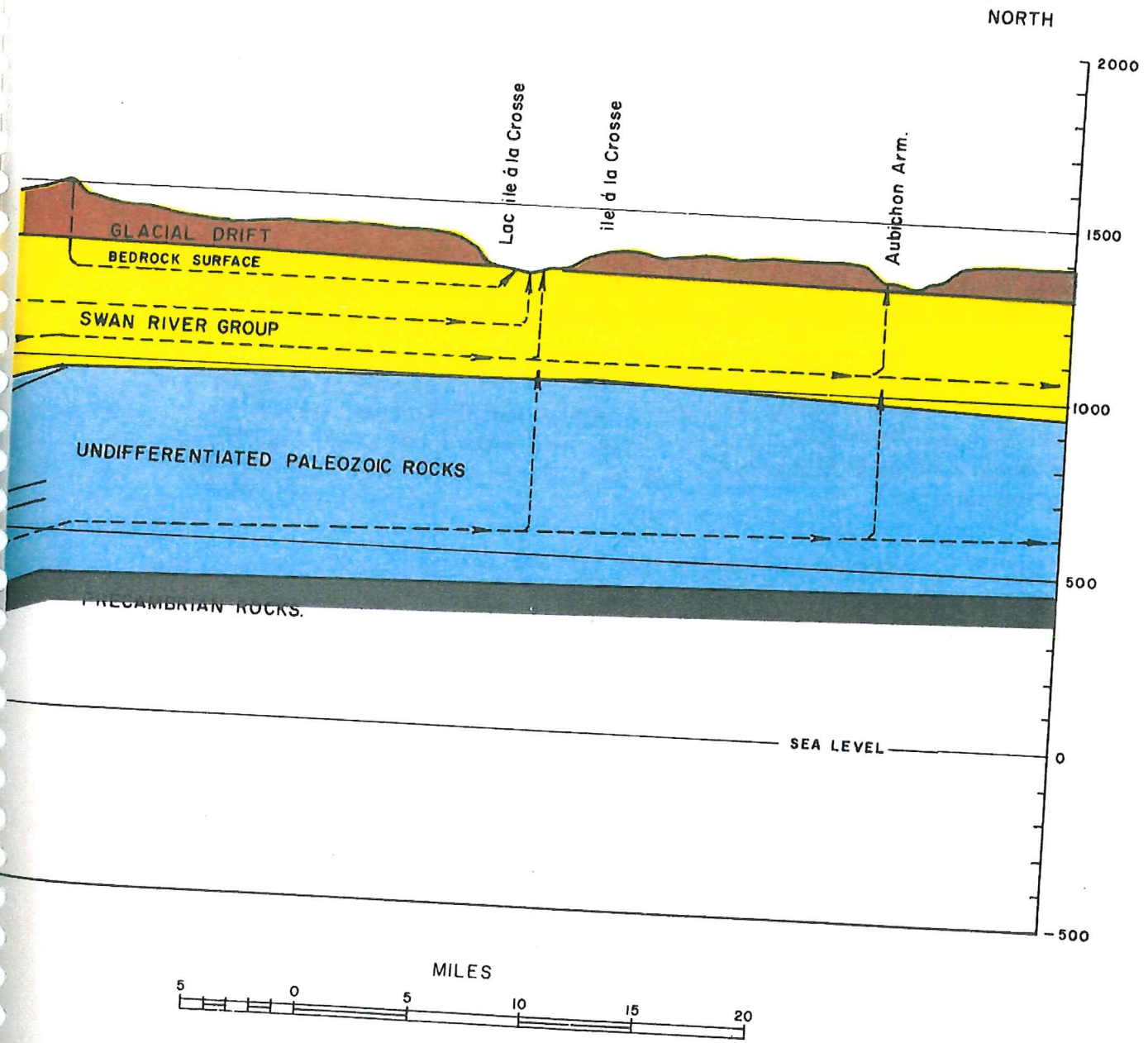
The same situation exists in the Montreal Lake-Dore Lake-Peter Pond Lake area (Figure 121). There, local recharge of fresh water is now tending to suppress saline water discharge from the bedrock aquifers to the Churchill River system. Local recharge reduces the longitudinal hydraulic gradient and also dilutes the saline water. Any reduction in hydraulic head in the fresh water region of the system has the compound effect of reducing the amount of dilution of the saline water and at the same time allowing the lateral movement of saline water to increase.

Development of the major bedrock aquifers for their fresh groundwater resources as well as their utilization for waste disposal require a much better understanding of the hydrogeology than we now have.

Montreal Lake-Dore Lake-Peter Pond Lake Aquifer System: This aquifer system covers an area of at least 19,000 square miles and previous strata are known to be several hundred feet in thickness. The uppermost major

* Also known as the Prairie Evaporite Formation.





HORIZONTAL 1:250,000
VERTICAL 1 CM. TO 100 FT.
VERTICAL EXAGGERATION 82x
Compiled by S.H. Whitaker, March 1971

Figure 125: Stratigraphy Along Beaver River – Saskatchewan

aquifer in the system (Figure 121) is the Swan River Group. The southern boundary is defined by the estimated position of water having a total ionic concentration greater than 4,000 ppm in the Swan River Group. Toward the north, progressively older formations may also be expected to contain usable groundwater (Figure 125). The Swan River Group is overlain by drift ranging in texture from sandy clay to sand through which recharge may occur readily. It appears from the limited information compiled to date (Figure 125) that there is a more or less complete interconnection of lakes and streams particularly those of the Churchill River system with this aquifer.

The natural groundwater recharge is unknown. Present withdrawal is essentially zero. The net groundwater yield of this system may be crudely estimated to be greater than 1 million acre-feet per year (Table 26). Production at this rate would represent an increase in recharge to the system amounting to about 10 percent of the annual precipitation.

The quality of water obtainable from this aquifer system is not known. Interpretation of electric logs in the Dore Lake area suggests that the total ionic concentration may be less than 2,000 ppm in the Swan River Group (Figure 125) throughout much of the area. Further investigation is required.

Nipawin-Cumberland House - Hudson Bay Aquifer System: This system covers an area of at least 15,000 square miles. The uppermost major bedrock aquifer in both the Nipawin and Hudson Bay areas (Moran and Whitaker, 1969) is the Swan River Group (Figures 122, 126) and aquifers may extend downward through this group into the underlying Paleozoic rocks. In the Cumberland House area lower Paleozoic carbonate rocks subcrop beneath the drift (Kupsch, 1952) and are good aquifers (Figure 122). These aquifers are overlain by drift and underlain by other permeable deposits containing more saline water. For the purposes of this report, the vertical transitions to groundwaters with total ionic concentrations in excess of 4,000 ppm define the lower boundaries of these major aquifer systems. The southwestern boundary of the Swan River Group aquifers in these areas is similarly defined by the occurrence of water having a total ionic concentration of more than 4,000 ppm (Figure 126). The water in the Hudson Bay aquifer is the sodium bicarbonate/sulphate type whereas in the Nipawin area, water in the Swan River Group is of the sodium chloride type. The wide spread of observed total ionic concentration values reflects the systematic decrease in concentration toward the north and east (Figures 126, 127).

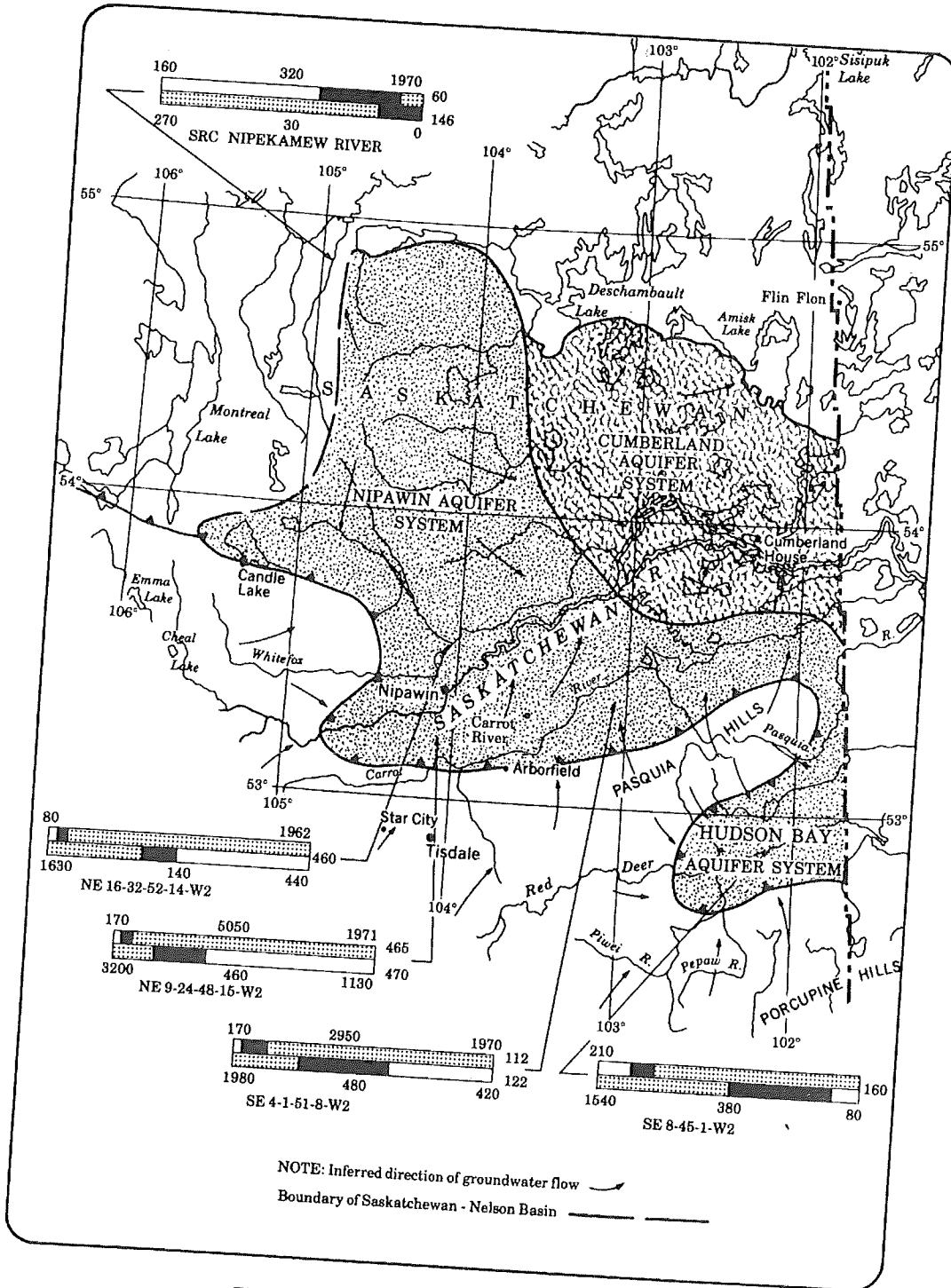


Figure 126: Nipawin, Cumberland, Hudson Bay Aquifer System

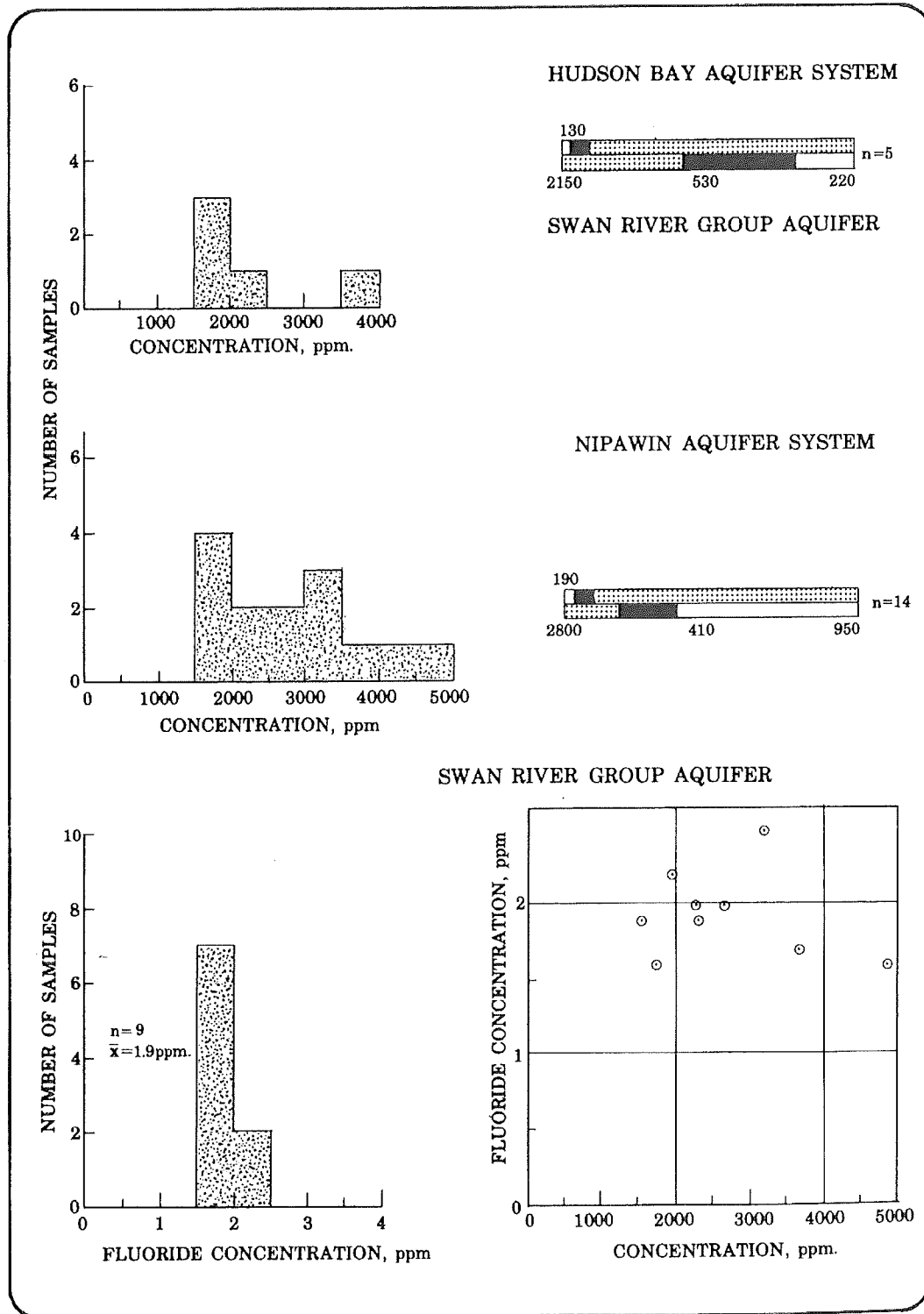


Figure 127: Nipawin, Hudson Bay Ionic Concentration

In the Nipawin area the water in the Swan River Group contains an average concentration of 1.0 ppm fluoride (Figure 127). Present withdrawal is for rural domestic use only.

Nothing is known of the quality or quantity of water in the Cumberland area. These carbonate rocks may have permeability characteristics similar to those measured by Render (1970) in the Winnipeg area.

The natural recharge to the major aquifers in these areas is unknown. It is possible that the net groundwater yield from this area may be at least 1×10^6 acre-feet per year (Table 26), a production which would represent an increase in recharge equal to about 10 percent of the annual precipitation.

The carbonate aquifers in the Cumberland area may be expected to be more or less completely interconnected with the Saskatchewan River and would function as storage elements indistinguishable in function from the lakes covering the Cumberland Lowland. Any water resource development in that area must recognize that this aquifer system is an integral part of the total hydrologic environment.

High-Yield Drift Aquifers

Shellbrook Aquifer System: The Shellbrook Aquifer System includes the Hatfield Valley Aquifer north of the North Saskatchewan River and covers an area of about 2,800 square miles (Figures 128, 129). It is overlain by drift and underlain by the Swan River Group and deeper aquifers. The water quality is known at only a few locations. The estimated net groundwater yield of this aquifer system is 50,000 to 100,000 acre-feet per year (Table 26). The interaction between this system and lakes and streams in the area is unknown. Present withdrawal is small, however it does supply rural domestic and municipal needs.

Nokomis Aquifer System: This aquifer system includes the Pathlow, Wynyard and Strasbourg Aquifers (Figure 130) all of which are interconnected with the Hatfield Valley Aquifer which also forms part of the system. To the north the system drains to the South Saskatchewan River in the vicinity of St. Louis; to the south it drains to Last Mountain Lake and to the Qu'Appelle Valley. Figures 130 and 131 show the variation in water quality in this system. The total ionic concentration varies considerably, however, the water composition is dominantly the sodium-sulphate type.

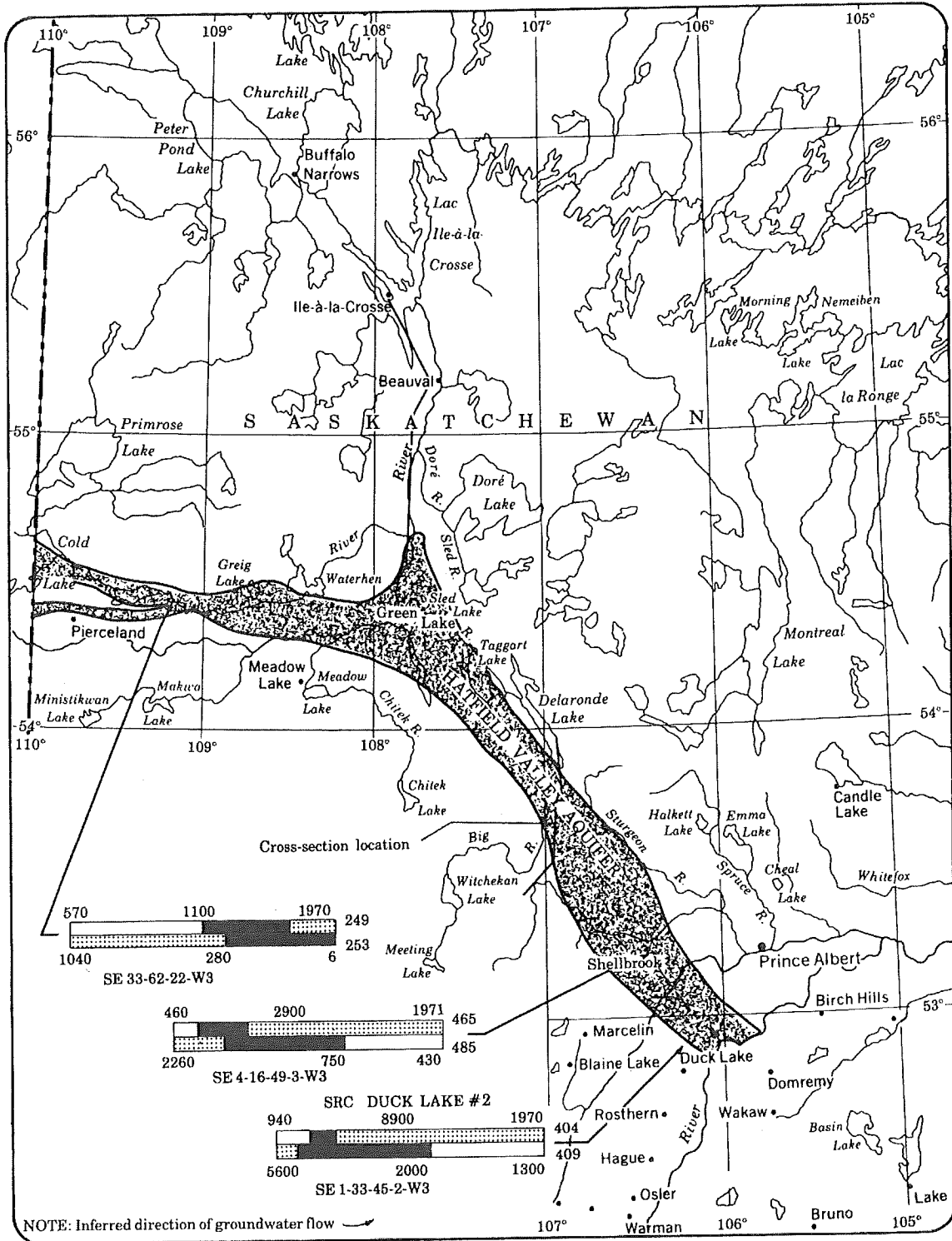


Figure 128: Shellbrook Aquifer System – Plan

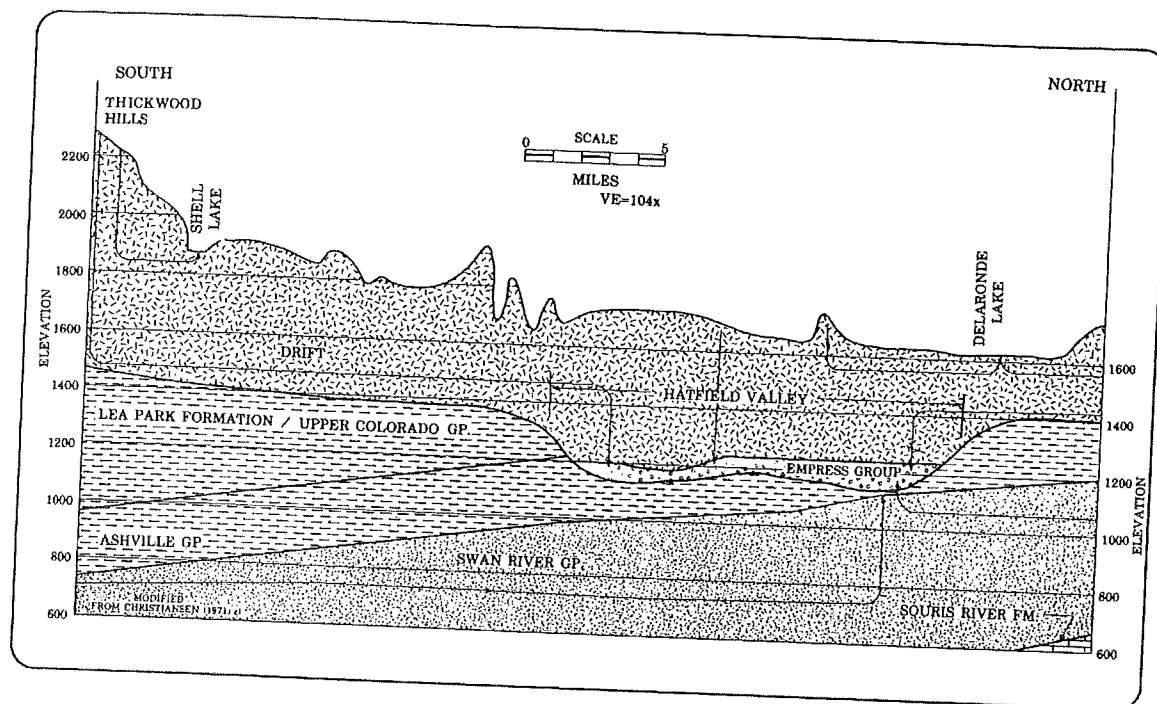


Figure 129: Shellbrook Aquifer System – Stratigraphy

The northern part of the Hatfield Valley Aquifer from Nokomis to St. Louis contains poor quality water (Figure 130). Longitudinal drainage is inhibited by the length of the longitudinal drainage paths and by disruption of the continuity of the Hatfield Valley Aquifer by glacial erosion and by collapse structures (Figure 122) (Christiansen, 1970b). The net groundwater yield is estimated to be about 54,000 acre-feet per year (Table 26).

The Pathlow Aquifer is characterized by exceptionally good quality water (Figure 130) which in the Pathlow district exists under flowing artesian conditions. Farm wells are reported to flow up to 1 cfs with shut-in pressures in excess of 40 to 50 psi. Discharge from this system is through major springs north of Pathlow into the Carrot River. The estimated net groundwater yield is about 5,000 acre-feet per year (Table 26).

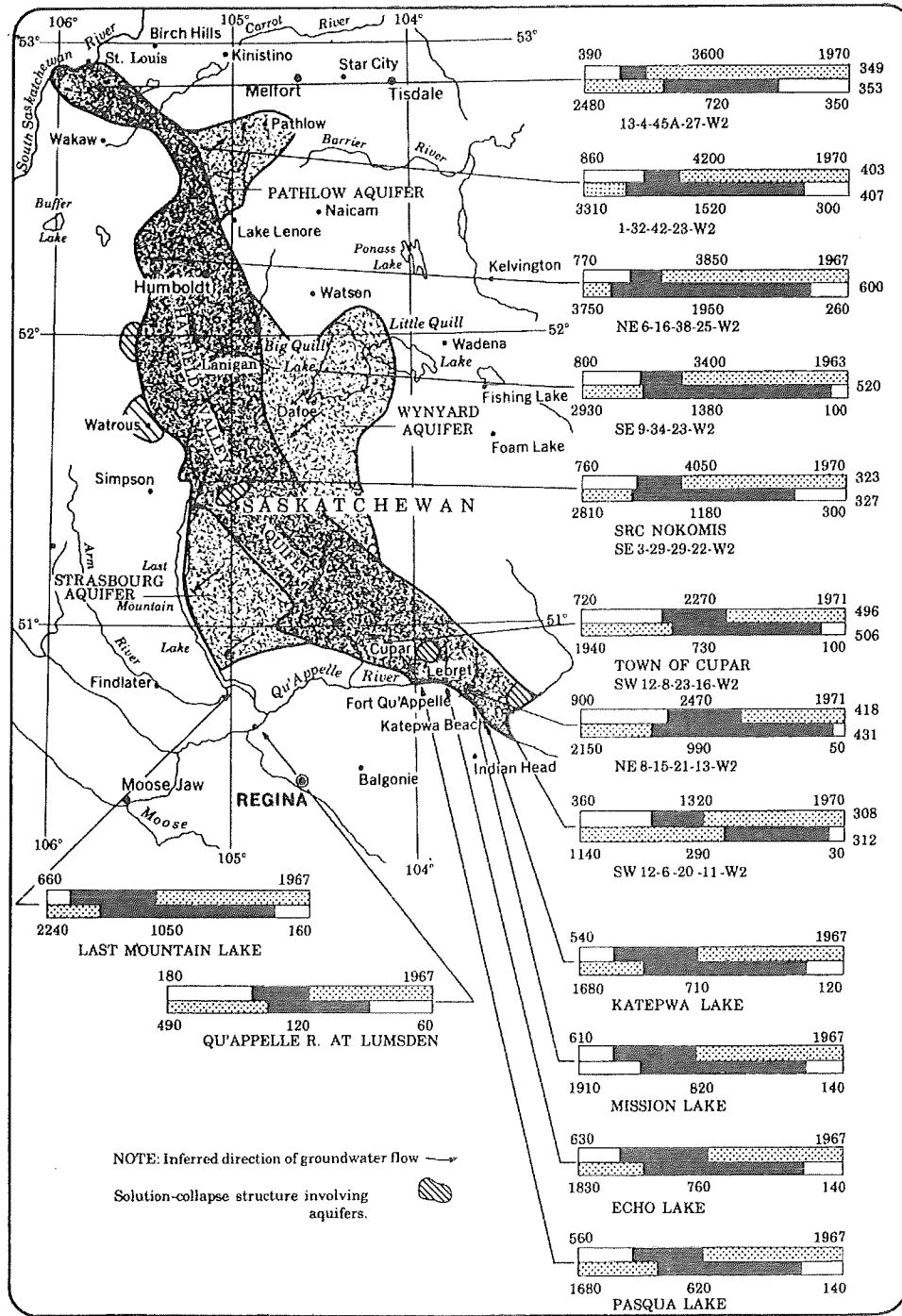


Figure 130: Nokomis Aquifer System – Plan

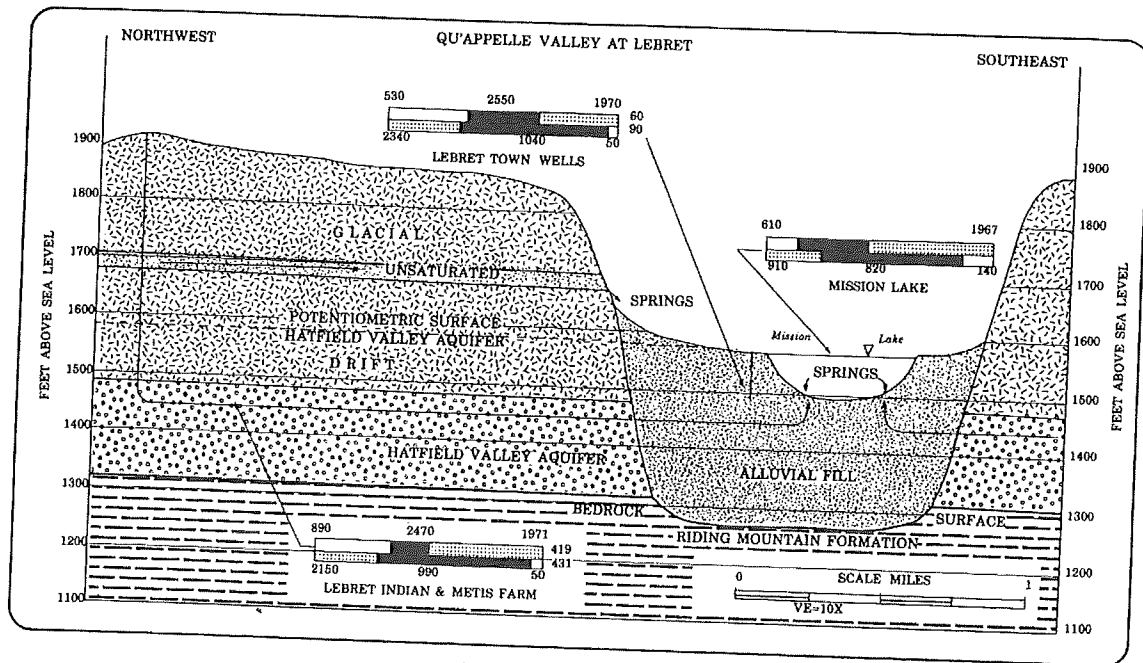


Figure 131: Nokomis Aquifer System – Stratigraphy

The Wynyard Aquifer (Figure 130) is completely interconnected with the Hatfield Valley Aquifer and with the Quill Lakes. Recharge from local precipitation discharges through this aquifer both to Quill Lakes and to the Hatfield Valley Aquifer. If the water levels in the Quill Lakes become sufficiently high, however, most of the groundwater discharge would be diverted to the Hatfield Valley Aquifer - in effect, the Quill Lakes would function as part of the recharge area. Under such conditions the salinity of the Quill Lakes would become as low as those reported by Rawson and Moore (1944) (16,600 ppm). The present concentration ranges from 40,000 to 70,000 ppm (Langham, 1970).

Little information has been obtained about the Strasbourg Aquifer (Figure 130). It includes sand deposits at the base of the drift and may also include the Judith River Formation (Christiansen, 1970b, section B-B'). It provides the interconnection between the Hatfield Valley Aquifer and Last Mountain Lake. The nature of this interconnection is not fully

understood. Nevertheless, there is little doubt that when the lake is relatively low, there should be a tendency for increased groundwater discharge from the Hatfield Valley Aquifer into Last Mountain Lake. Similarly, when the lake level is higher, more water should be bypassed along the Hatfield Valley to discharge directly into the Qu'Appelle Valley.

The Hatfield Valley Aquifer is directly interconnected with the Qu'Appelle Valley (Figures 130, 132) in the vicinity of Fort Qu'Appelle and Lebret. Groundwater discharges from the Hatfield Valley Aquifer into the Qu'Appelle Lakes, in part through submarine springs such as those reported by local residents to be present in Mission Lake.

From the Village of Cupar south to the Qu'Appelle Valley (Figure 130), precipitation infiltrating to the Hatfield Valley Aquifer moves laterally to the Qu'Appelle Valley. Groundwater here is of better quality (Figure 132, Lebret segment) than elsewhere in the Hatfield Valley Aquifer. The drain effect of the Qu'Appelle Valley increases the vertical hydraulic gradient adjacent to the valley and thereby increases the amount of natural recharge to a maximum. The natural groundwater discharge from the Hatfield Valley Aquifer to the Qu'Appelle River is estimated to be about 10,000 acre-feet per year (Table 26) based both on the anticipated vertical input to the system and on the amount of water that might reasonably be expected to be transmitted laterally through the aquifer.

The weighted average water quality for the Qu'Appelle Lakes (Figure 130) based on analyses by Rutherford (1970) indicates that the composition and concentration of the lake water are very similar to those for the adjacent Hatfield Valley Aquifer. The concentration trends for the lake water suggest that the focus of groundwater discharge from the Hatfield Valley Aquifer is into Mission Lake.

The effect of the Hatfield Valley Aquifer on the Qu'Appelle River system is that of a very large storage element which will always act so as to tend to maintain the level of Mission Lake at a constant elevation. Discharge from this aquifer provides a substantial continuing source of mineralized deoxygenated water to the bottom of the lakes throughout the year at a temperature of 45 to 50°F.

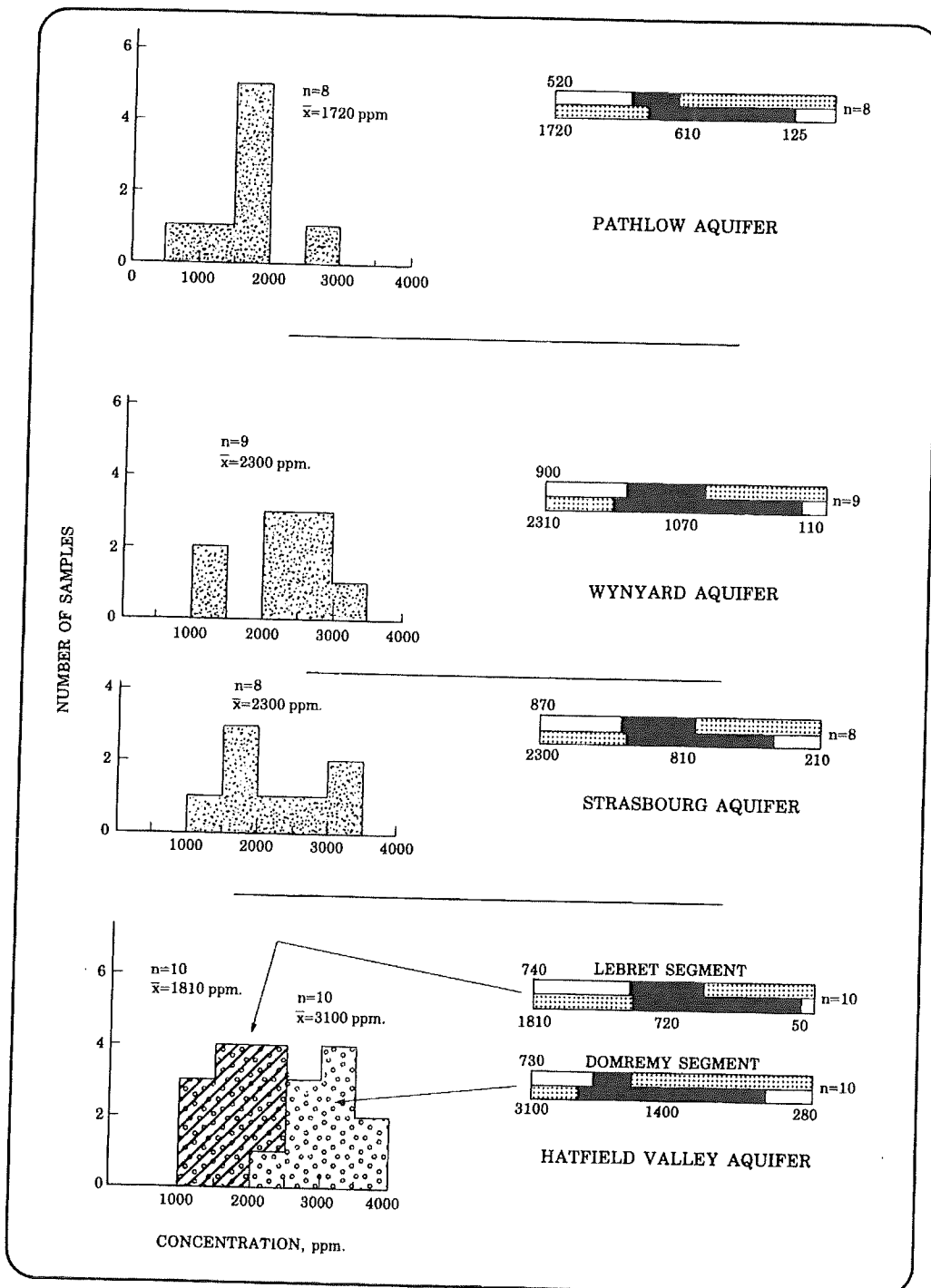


Figure 132: Pathlow, Wynyard, Strasbourg, Hatfield Valley Ionic Concentration

Yorkton Aquifer System: The Yorkton Aquifer System (Figure 133) includes the Yorkton-Bredenbury, the Hatfield Valley, the Welby and the Melville Aquifers. Cross sections (Figures 134, 135) show the stratigraphic and groundwater flow relationships between the intertill aquifers (such as the Yorkton-Bredenbury Aquifer) and the Hatfield Valley Aquifer. The Welby Aquifer (Beckie and Balzer, 1970) is an intertill aquifer which is apparently a continuation of the Yorkton-Bredenbury Aquifer. The Melville Aquifer comprises glacial and preglacial sand deposits found beneath the lowermost till; it also includes part of the Hatfield Valley Aquifer southwest of Melville (Figure 133).

Groundwater discharge from this system is governed by the Hatfield Valley Aquifer which functions as a deeply buried sand drain collecting water from the Yorkton-Bredenbury Aquifer and draining into Crooked Lake to the southwest and into the Assiniboine River near Shellmouth to the northeast. The Welby Aquifer drains directly into the Qu'Appelle River (Beckie and Balzer, 1970).

The areal and stratigraphic variations of water quality are shown in Figures 133, 134 and 135 and the average concentration and composition are shown in Figure 136. The analyses of water from the Welby Aquifer indicate that the water is quite similar to that in the Yorkton-Bredenbury Aquifer.

The Yorkton Aquifer is directly connected to Crescent Creek and Leech Lake so that both surface water and groundwater in this area must be allocated as part of a common resource. Both are entirely dependent upon local precipitation. The Yorkton Aquifer presently supplies the City of Yorkton with about 300 million gallons of water per year (1,100 acre-feet per year). It has provided the entire water supply for the city for many years with no evidence of any aquifer depletion. The city well field is under continuous production performance monitoring by the City Engineering staff. The net groundwater yield of the Yorkton-Bredenbury Aquifer is estimated to be at least 12,500 acre-feet per year (Table 26).

The Hatfield Valley Aquifer is utilized by Langenburg as a source of municipal water supply and by International Mineral and Chemical Corporation as a source of processing water for their No. 1 mine near Esterhazy (Vonhof, well inventory information). The estimated withdrawal is 500 to 1,000 acre-feet per year. The Welby Aquifer is used by Sylvite of Canada as a source of industrial water supply (Beckie and Balzer, 1970).

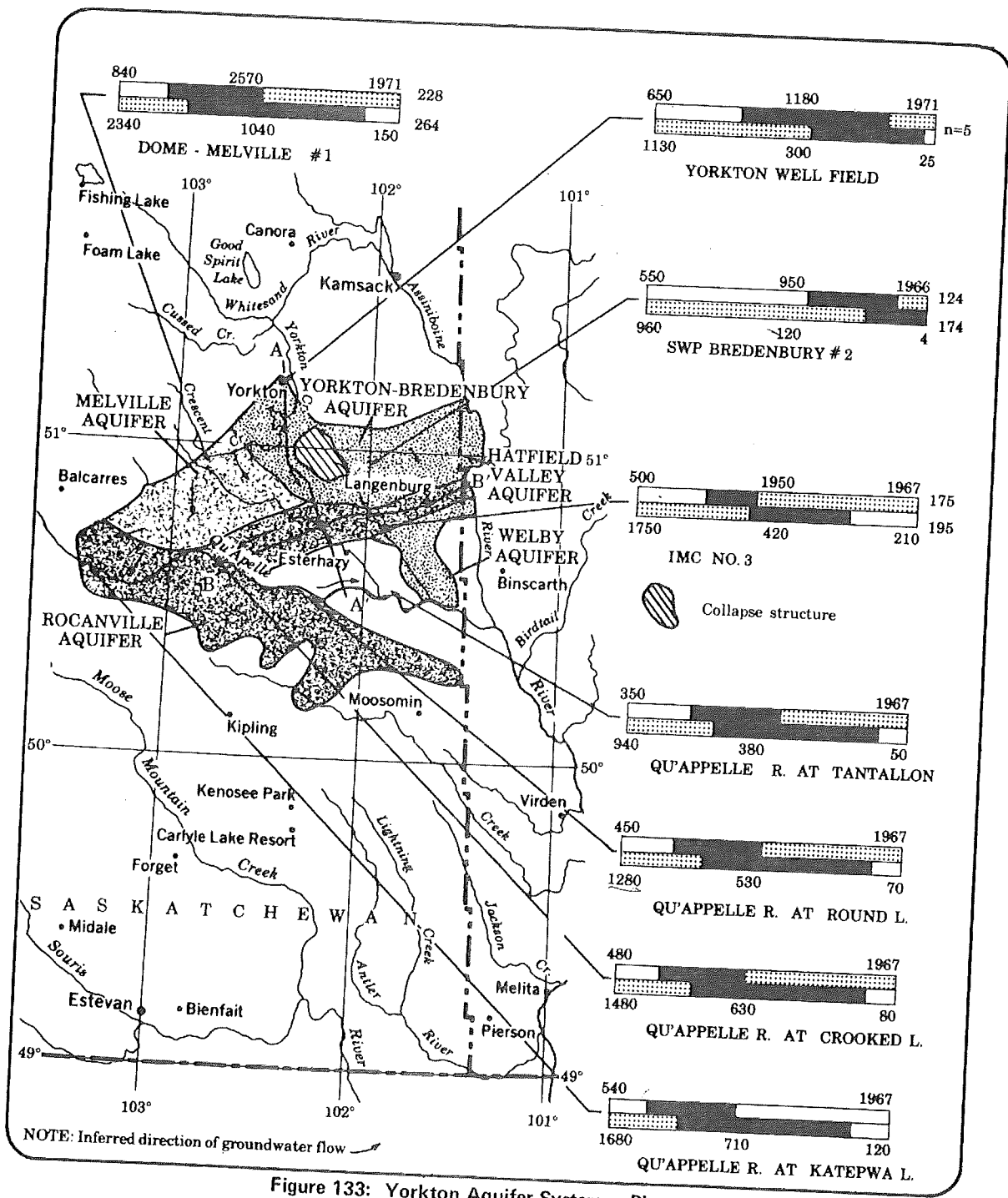


Figure 133: Yorkton Aquifer System – Plan

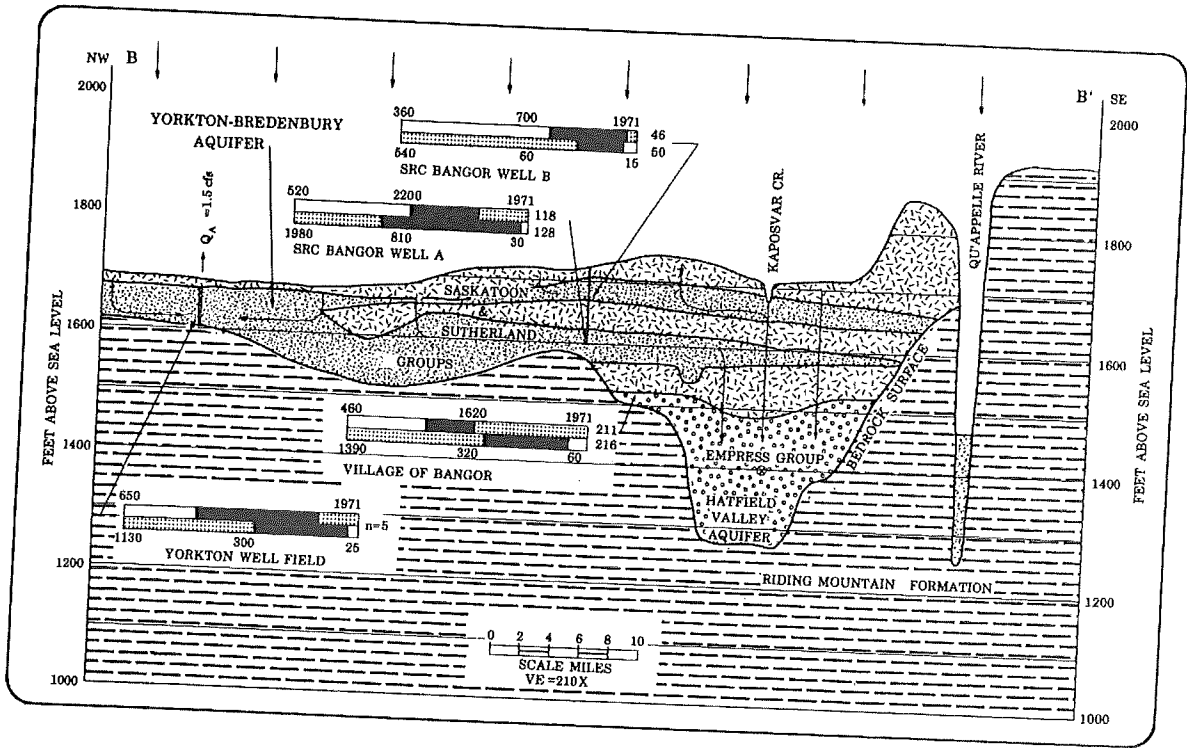


Figure 134: Yorkton Aquifer System – Stratigraphy

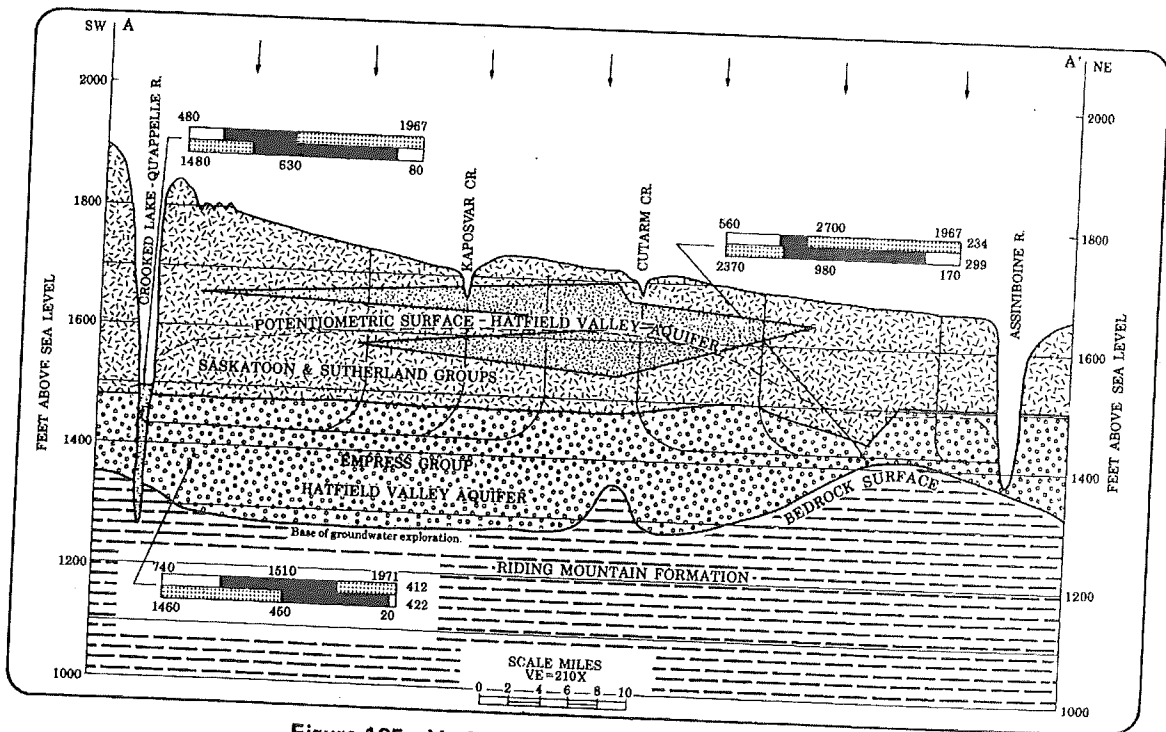


Figure 135: Yorkton Aquifer System – Stratigraphy 2

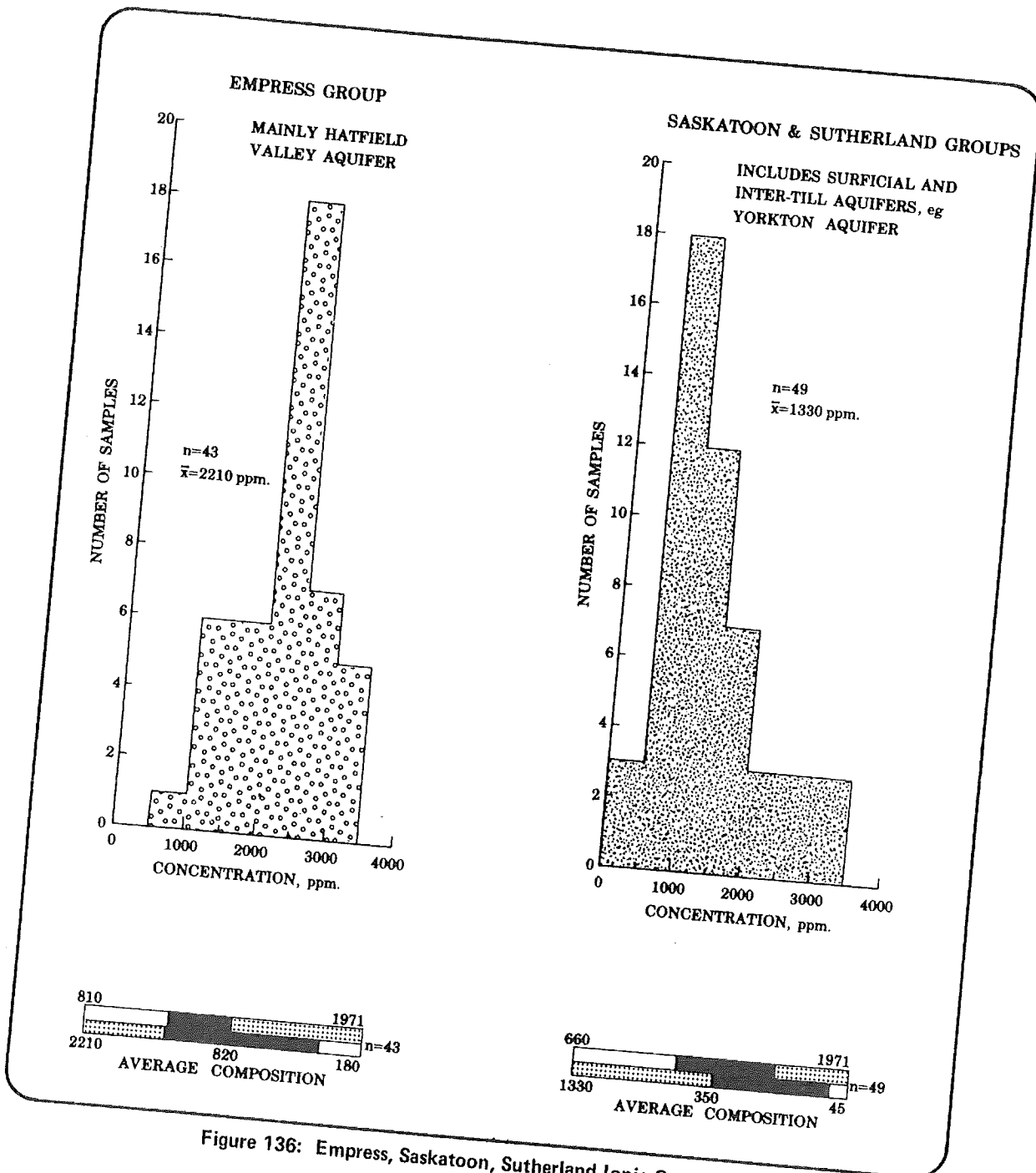


Figure 136: Empress, Saskatoon, Sutherland Ionic Concentration

This aquifer system drains to the Qu'Appelle River and the observed water quality in Crooked Lake is quite similar to that found in the Hatfield Valley (Figures 133 and 135). Note that the ionic concentration of water decreases in a downstream direction along the Qu'Appelle River presumably as a result of dilution by fresh tributary drainage. The water quality at Tantallon is, however, still quite similar to that of water discharging from the Welby Aquifer in that vicinity.

Regina Aquifer System: The Regina Aquifer System covers an area of about 1,400 square miles (Figure 137) including all the area considered by Lissey (1962) in his study of the groundwater resources of the Regina area. All of the aquifers studied by Lissey are now considered to lie within the complex intertill sand unit associated with the Condie moraine (Christiansen, 1971b) (Figure 138) and are considered for the purposes of this study to function as a single aquifer system recharged by local precipitation and discharging to Wascana Creek and to the Qu'Appelle River. The current withdrawal from the Regina Aquifer System, including both municipal and industrial withdrawals, is estimated to be about 11,000 acre-feet per year (Saskatchewan Water Resources Commission, personal communication). The estimated net groundwater yield in addition to the present withdrawal is about 25,000 acre-feet per year (Table 26).

The net groundwater yield was estimated by considering the vertical hydraulic conductivity of the confining layer to be variable as has been demonstrated from geological studies (Christiansen, 1961). It was considered to be 100 times greater than average over 1 percent of the aquifer area, 10 times greater than average over 10 percent of the area and equal to the average (0.002 gpd/ft^2) over the remaining 89 percent of the area (recent information indicates that this average value is itself probably very conservative). This in effect triples the estimated net groundwater yield. No great accuracy is presumed for this estimate but it nevertheless effectively demonstrates the hydrologic significance of glacial landforms such as kames in creating high-permeability gaps in the confining layer such as those found in the vicinity of Pilot Butte.

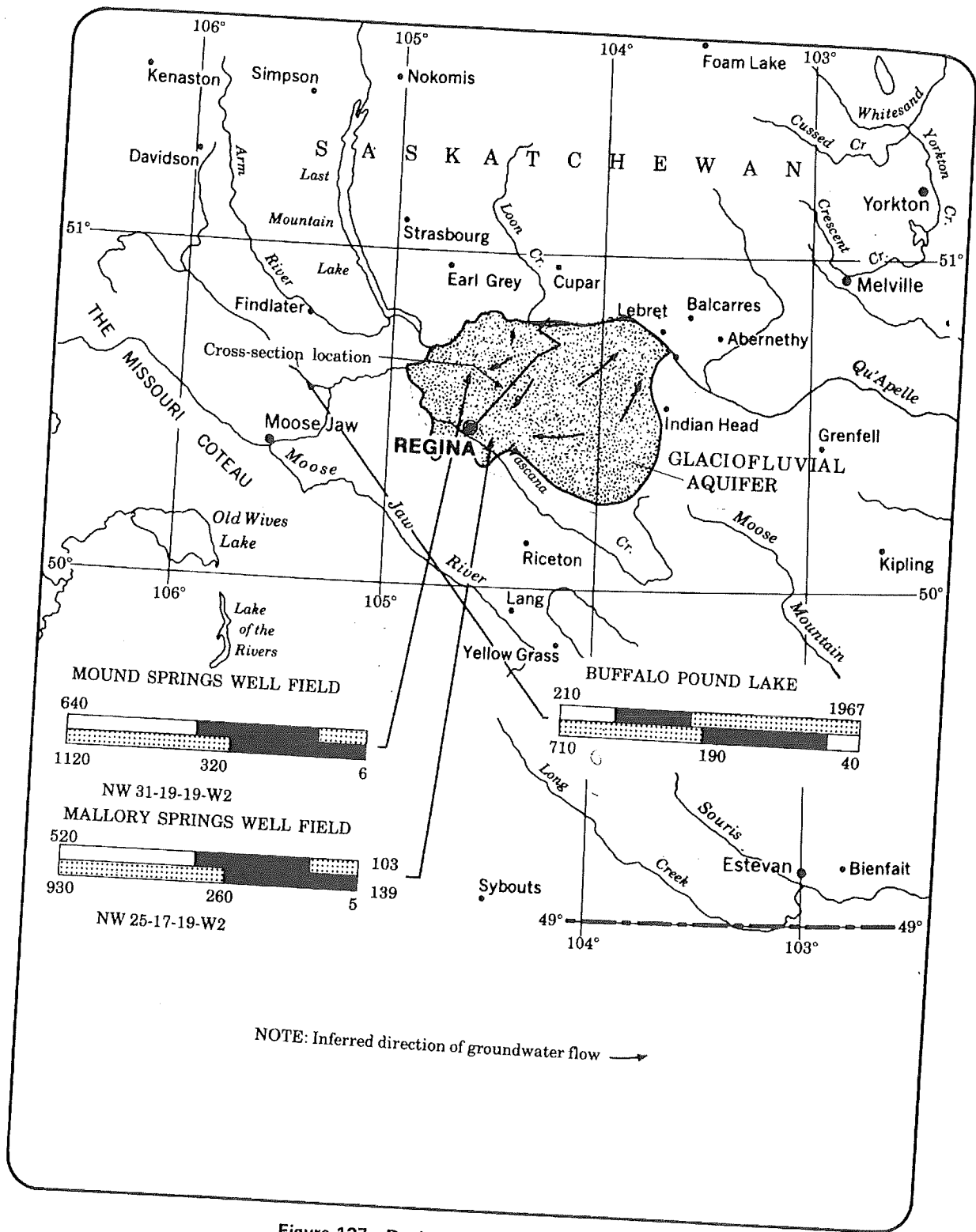


Figure 137: Regina Aquifer System – Plan

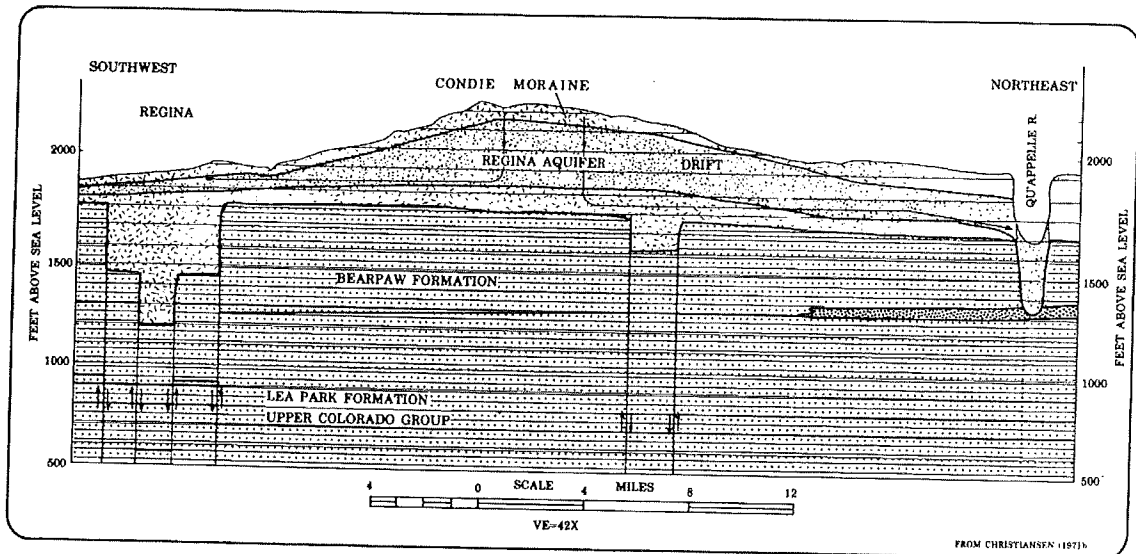


Figure 138: Regina Aquifer System – Stratigraphy

Estevan Aquifer System: The Estevan Aquifer System (Figure 139) includes the Estevan Valley, the Weyburn Valley and the Ravenscrag Formation Aquifers. Figure 140 shows the stratigraphic setting of the Estevan Valley Aquifer which functions as a drain collecting water from the adjacent area and diverting it to the Souris River northwest of Estevan and in the vicinity of Oxbow. The geohydrology of this area was studied by Walton (1970) during the period 1963 to 1965 under the sponsorship of the Saskatchewan Department of Industry and Commerce and the supervision of the Saskatchewan Research Council. Walton designed and constructed an electric analog model to analyse the hydrologic behavior of this system and concluded that 5 to 10 mgd (up to 13,000 acre-feet per year) could be produced from the Estevan Valley Aquifer in the vicinity of the site shown in Figure 140. A more recent study (Meneley and Whitaker, 1970) documented the hydrologic response of this aquifer system to natural and artificial changes. Its water quality is shown in Figure 141.

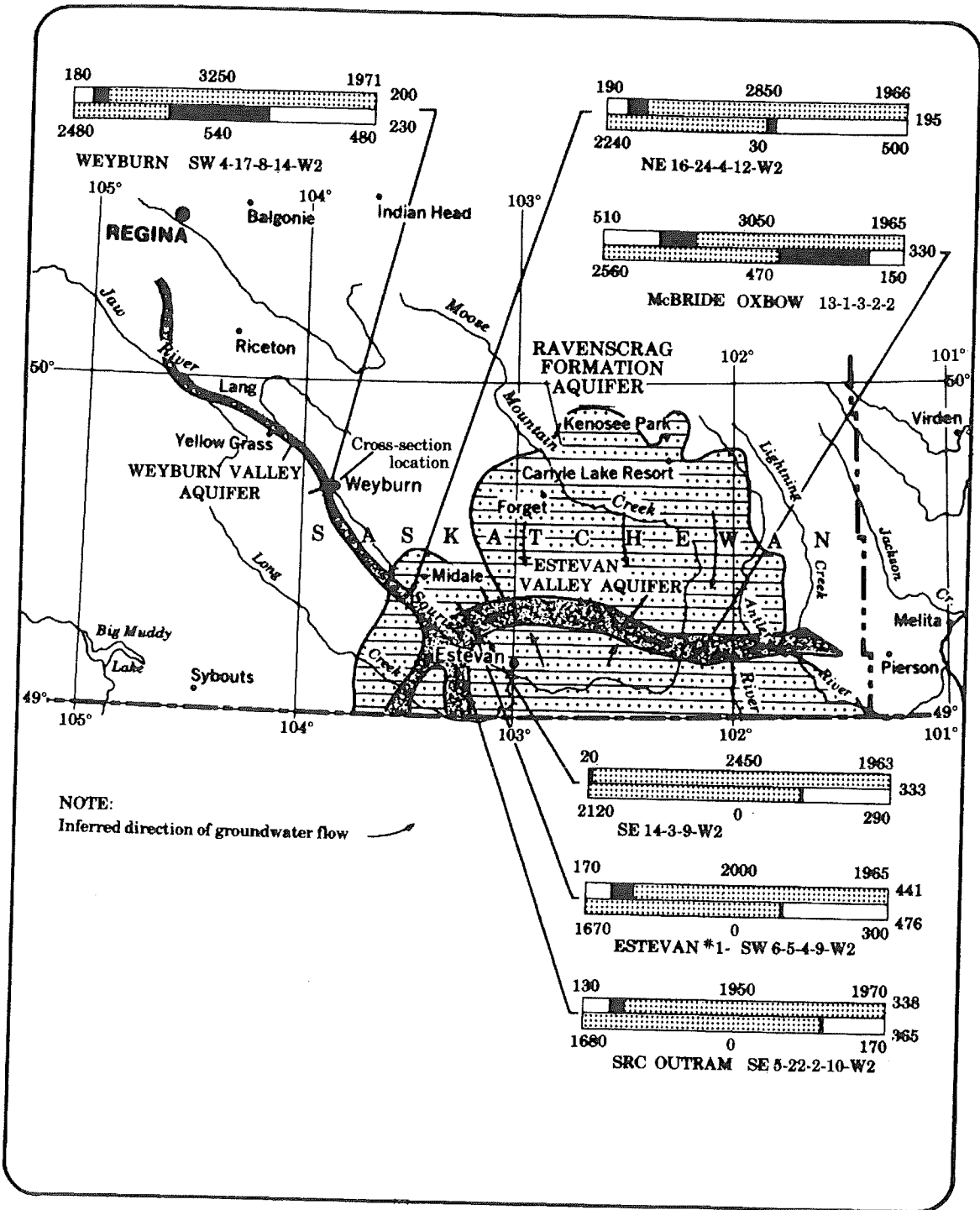


Figure 139: Estevan Aquifer System – Plan

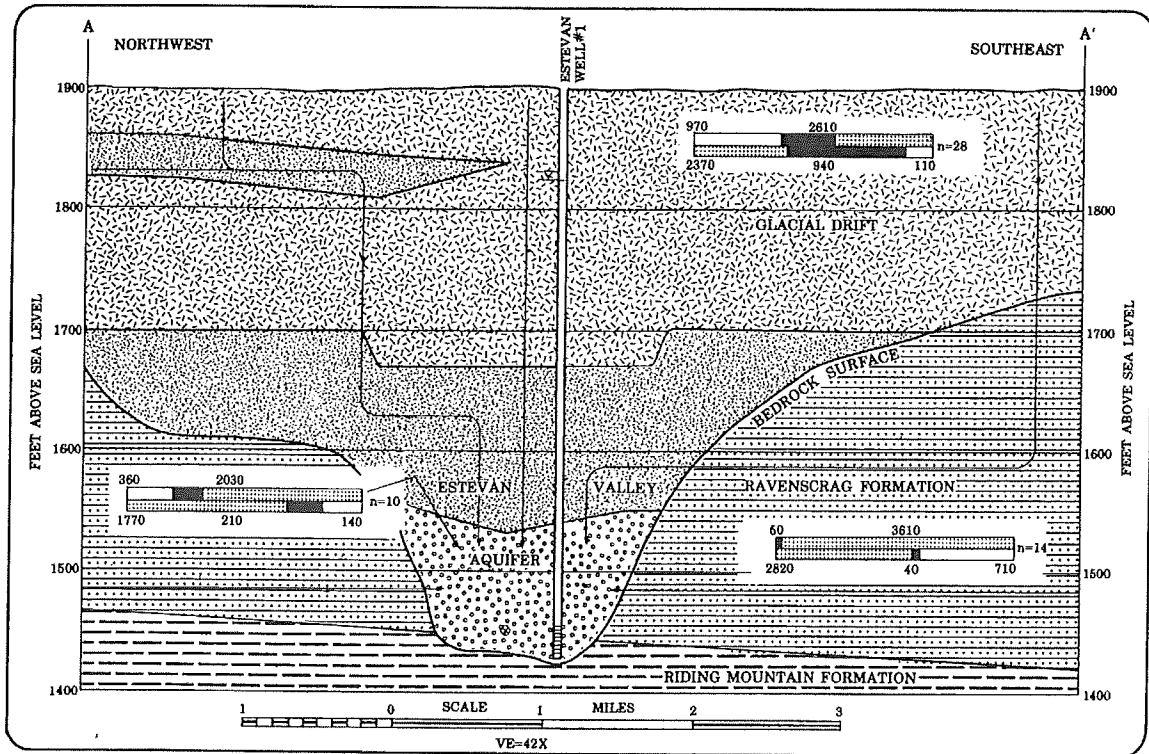


Figure 140: Estevan Aquifer System – Stratigraphy 1

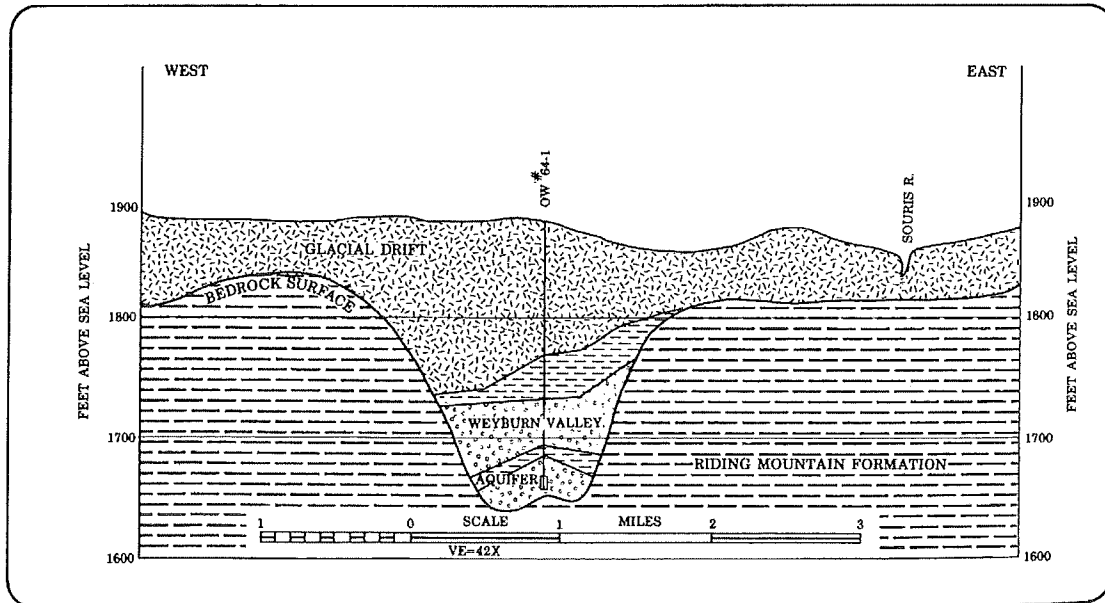


Figure 141: Estevan Aquifer System – Stratigraphy 2

The Weyburn Valley Aquifer was discovered and investigated in the Weyburn district by J.D. Mollard and Associates in 1964 and 1965 during a project sponsored by the Saskatchewan Department of Industries and Commerce. This aquifer is a typical glacial meltwater valley aquifer (Figures 139, 142, 143) sharply incised into shale, filled with longitudinally continuous sand and gravel deposits and overlain with till. This is a classic channel aquifer. A production well was constructed for the City of Weyburn and the production performance of this aquifer has been monitored by the Saskatchewan Research Council and the City of Weyburn (Figure 144) since 1964. The initial water level observations record the recovery from the initial evaluation tests carried out in 1964 and the subsequent drawdown since production started in 1966. These data indicate that the aquifer is not yet approaching equilibrium and thus demonstrate the time delay associated with full development of aquifer systems. Seasonal recharge to the aquifer is evident, but is masked in part by pumping variations. The net groundwater yield for the Weyburn aquifer is about 1,000 acre-feet per year (Table 26).

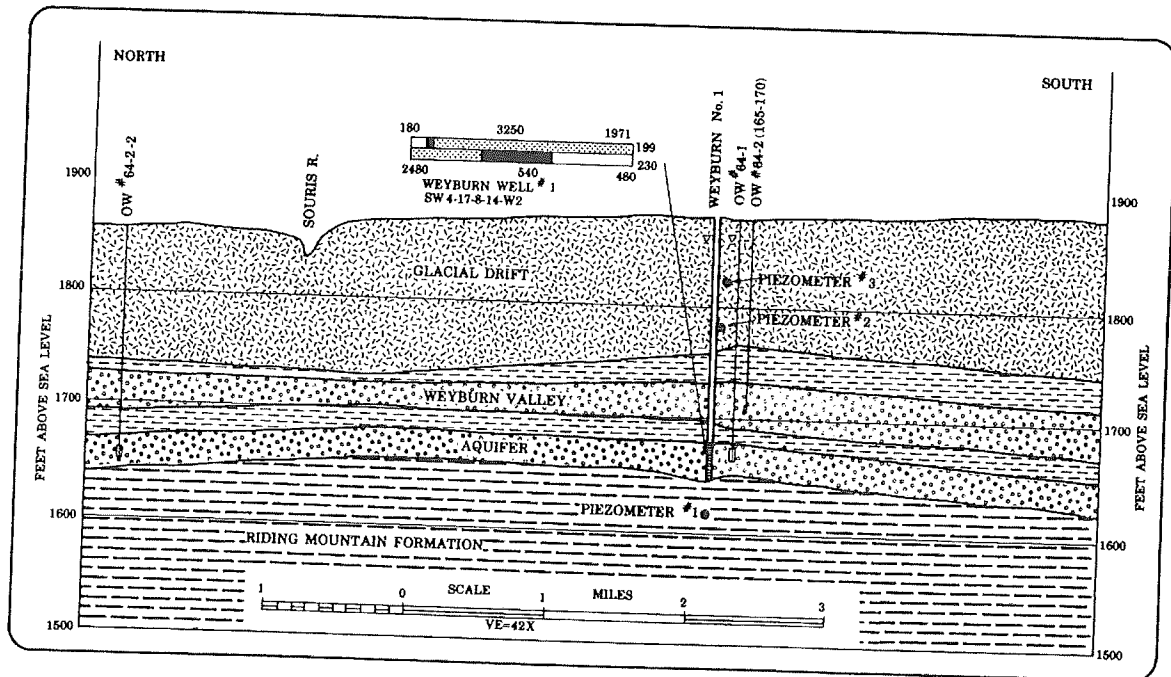


Figure 142: Estevan Aquifer System – Stratigraphy 3

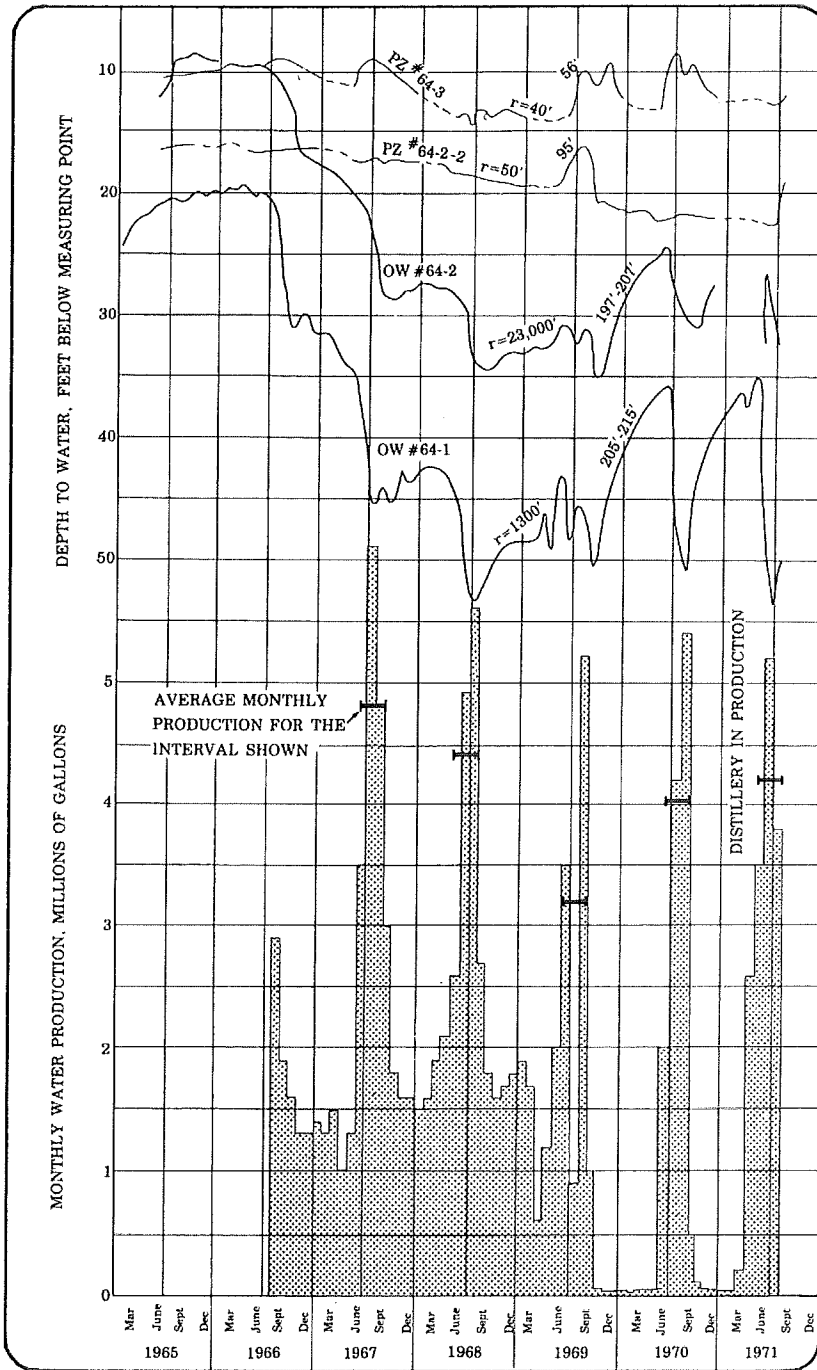


Figure 143: Estevan Aquifer Well – Production Performance

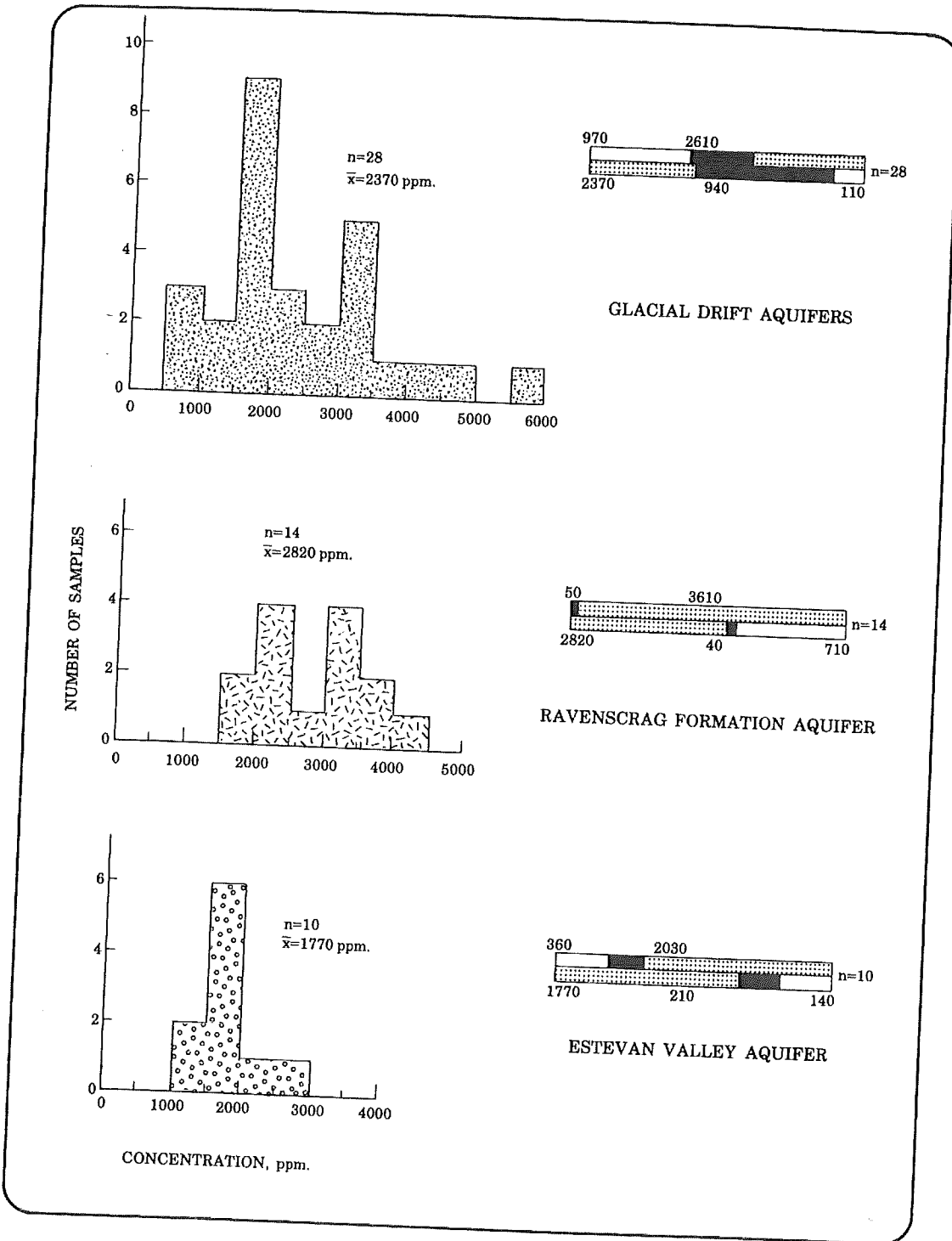


Figure 144: Estevan, Ravenscrag, Galcial Drift Ionic Concentration

It is estimated that the natural discharge from the Estevan Valley Aquifer is about 5 to 10,000 acre-feet per year into the Souris River from Dead Lake (southwest of Midale) to Estevan and in the vicinity of Oxbow. According to the Water Survey of Canada this is approximately the same as the minimum annual discharge from the Souris River at the International Boundary. In the present study it is estimated that the net groundwater yield for the Estevan Valley Aquifer is about 11,000 acre-feet per year (Table 26) - approximately the same as that estimated by Walton (1970). Present groundwater withdrawal from this aquifer system is for rural domestic purposes only. If net groundwater yield were increased to 11,000 acre-feet per year, natural discharge would be reduced significantly. It might then be necessary to develop groundwater production at a rate of 17,000 to 22,000 acre-feet per year and return the natural discharge directly to the river to maintain the international treaty obligations.

Tyner Aquifer System: The Tyner Aquifer System (Figures 145,146) has been described in detail for the Saskatoon area (Meneley, 1970) and the Rosetown area (Christiansen and Meneley, 1971). The western part of this aquifer from Tyner west to the Alberta boundary was not considered in calculating yield estimates because this part of the aquifer would derive most of its water by induced infiltration from the Saskatchewan River under development conditions.

The Tyner Valley Aquifer is a particularly well-defined geological entity and the water quality (Figure 147) is equally predictable. The only significant variation in quality is found in the vicinity of Osler near the discharge end of the system. There, as in all of the major aquifer systems, the total dissolved solids concentration decreases in the direction of groundwater flow. This is considered to reflect increased vertical infiltration to the system as a result of the low hydraulic head in the aquifer in the vicinity of the discharge drain to the North Saskatchewan River.

The net groundwater yield for the Tyner Aquifer System is about 38,000 acre-feet per year (Table 26). Further investigation would be required if the interaction between this aquifer system and the Saskatchewan Rivers is to be delineated. This is particularly important in the area north of Saskatoon where it is possible that there is an interconnection between the South and North Saskatchewan Rivers and where there may be interbasin movement of water at the present time.

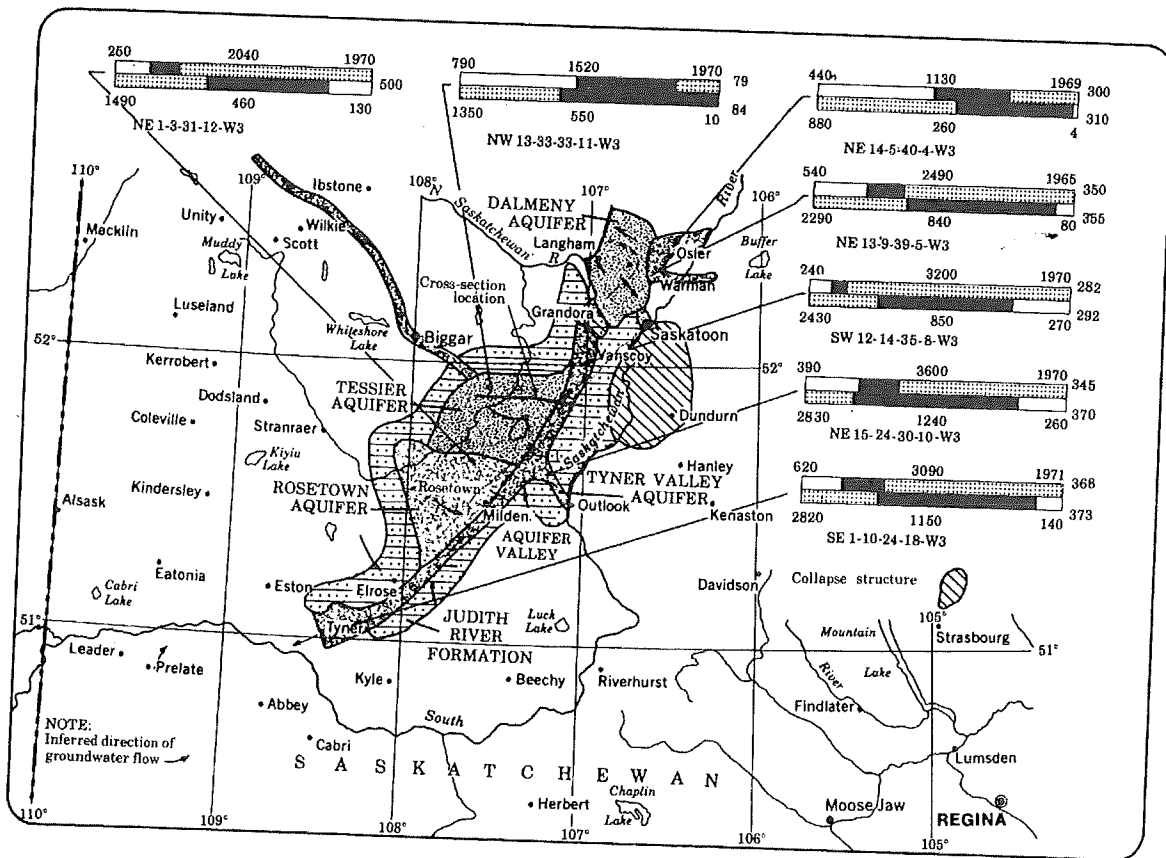


Figure 145: Tyner Aquifer System – Plan

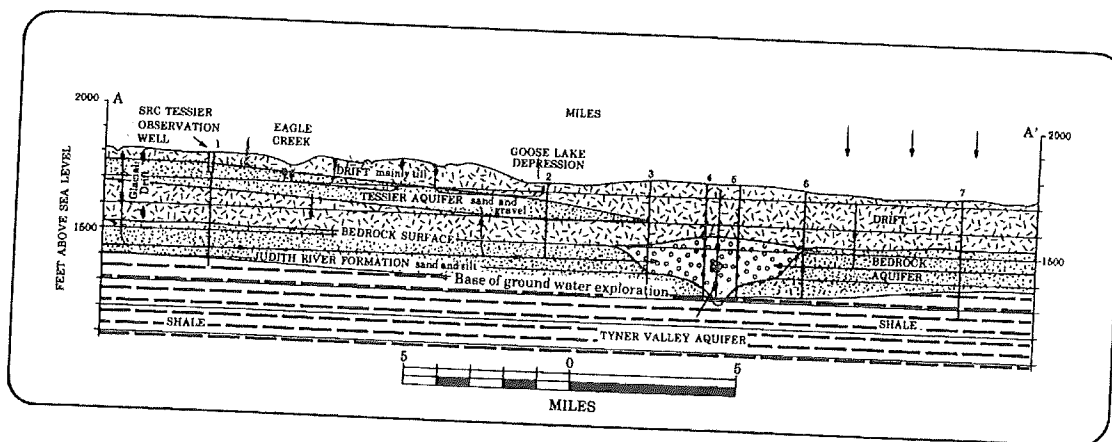


Figure 146: Tyner Aquifer System – Stratigraphy

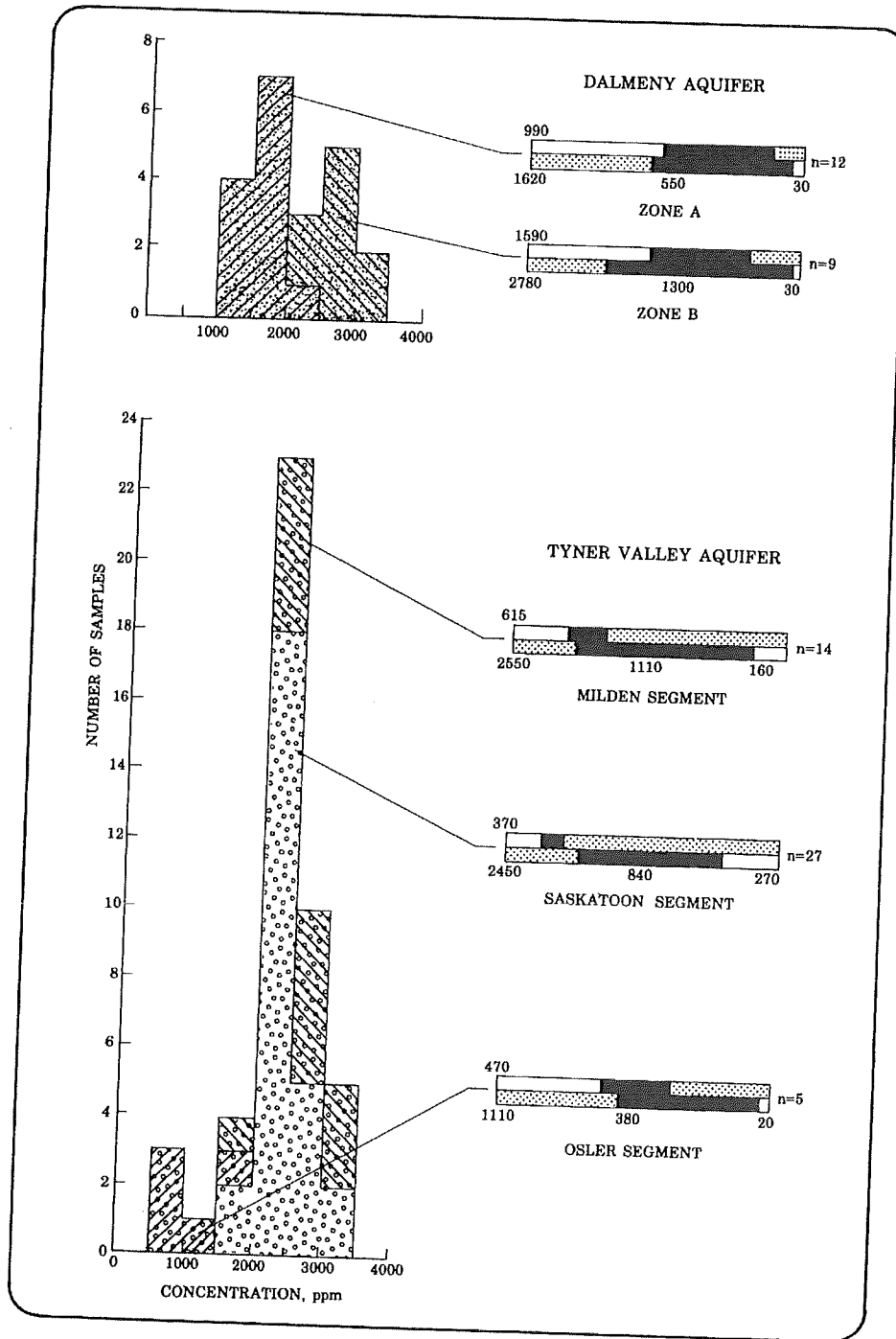


Figure 147: Dalmeny, Tyner Valley Ionic Concentration

This aquifer system provides an excellent example of the significance of permeability distribution in the geologic environment in governing the groundwater flow pattern in a real, stratified, heterogeneous flow medium. Although the system is still a gravitational flow system, the flow pattern cannot be deduced from consideration of the topography alone as has been done elsewhere.

Battleford Aquifer System: The Battleford Aquifer System (Figures 148, 149) includes the Battleford Valley Aquifer and a number of smaller glacial meltwater valleys cutting obliquely across the trend of the Battleford Valley. In addition, the Judith River Formation may contribute significant quantities of water to narrow valleys such as the southeast-trending valley through Biggar. The presence of pervious strata in the walls of a channel aquifer of this type substantially increases the effective width of the channel aquifer.

The Battleford Valley Aquifer drains to the North Saskatchewan River north of North Battleford. It controls the groundwater drainage for a large area extending westward to the Alberta boundary along the trend of the Battleford Valley. The southeast-trending valley from Lloydminster through Lashburn (Figure 148) and the northeast-trending valley from Lloydminster toward Paradise Hill also function as drains.

The net groundwater yield of this aquifer system is estimated to be about 9,000 acre-feet per year (Table 26).

Other Aquifer Systems: Insufficient time and the lack of essential information prevented compiling the yield of some of the major aquifer systems which are known to be present. Of these, the Rocanville Valley Aquifer in southeastern Saskatchewan is undoubtedly discharging water to the Qu'Appelle River. Its outline has already been shown on Figure 133 and is based on the Melville regional geologic map (Christiansen, 1971a). Information concerning water quality in this aquifer is also sparse.

The Swift Current Aquifer System is an important aquifer system in southwestern Saskatchewan, both from the point of view of water supply and also as a source of sodium sulphate input to Chaplin Lake. The Swift Current Valley Aquifer is also a major aquifer in the Dilke district. There it functions to an unknown degree as a drain diverting water from the Arm River via a sub-surface route to Last Mountain Lake. They may account for some part of the decrease in flow along the Arm River observed by Meyboom (1964) and attributed to phreatic consumption.

1000-7.3
260

outside Eand
Boundary of Batt. Val
2700
870 = 3.3

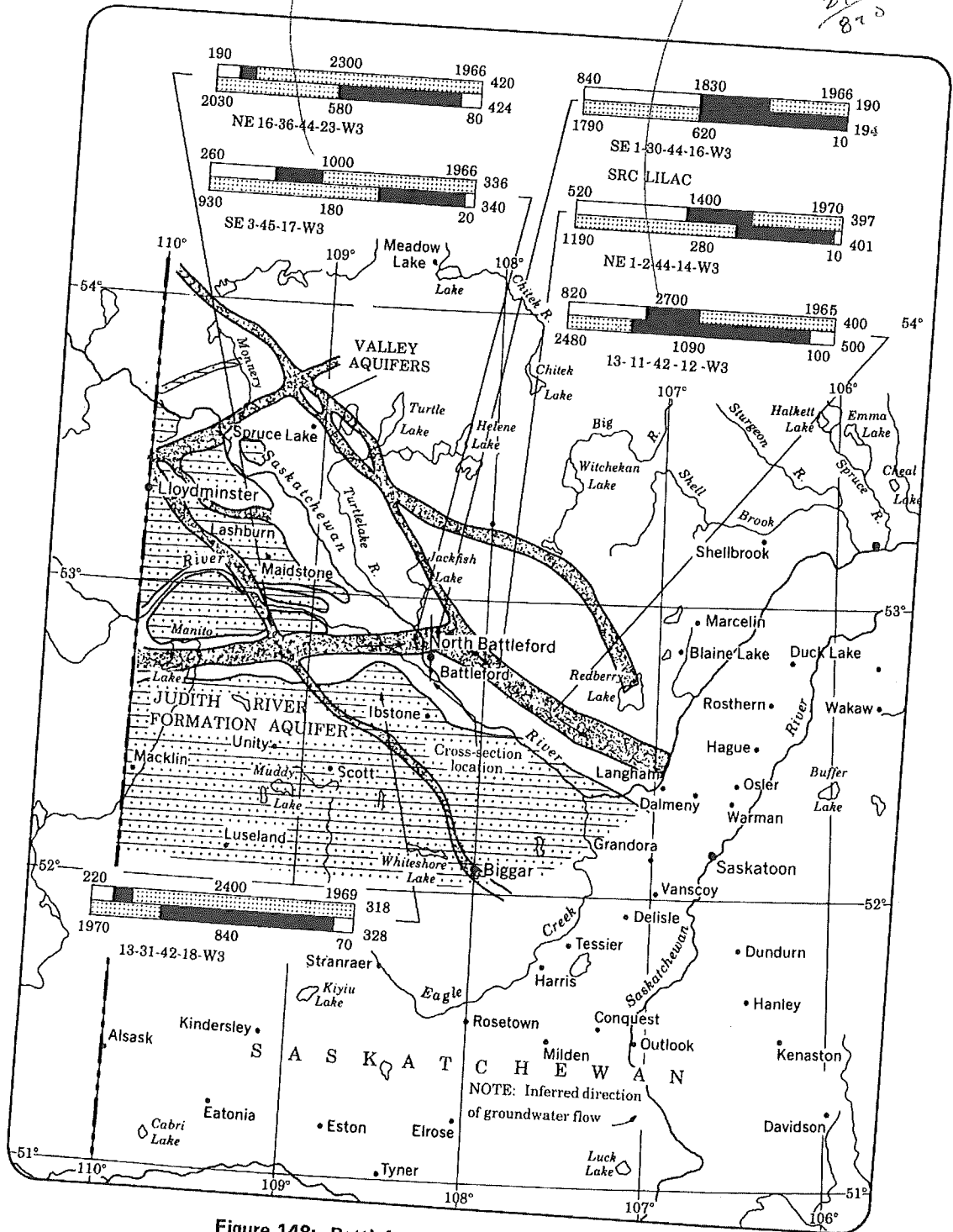


Figure 148: Battleford Aquifer System – Plan

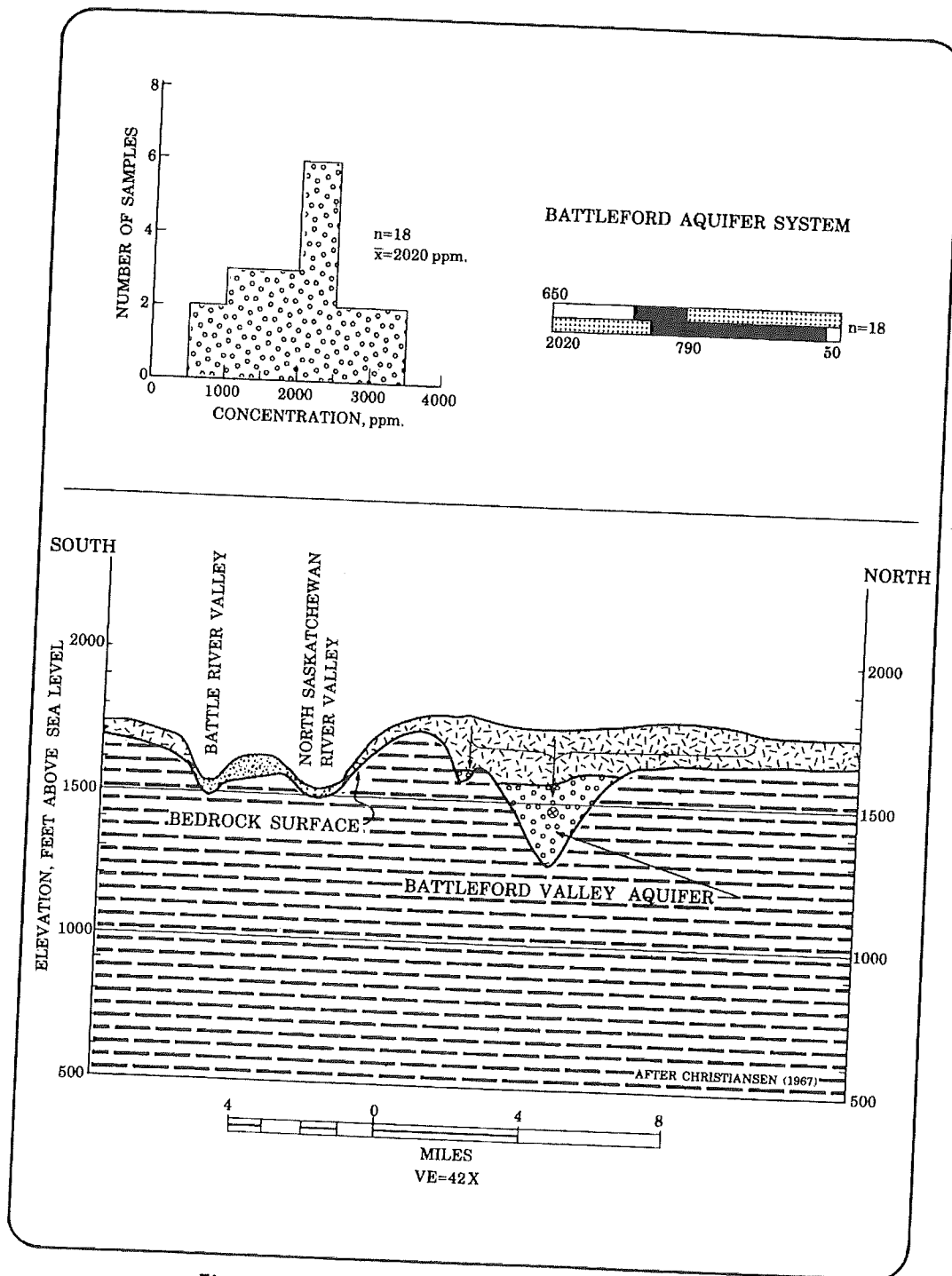


Figure 149: Battleford Aquifer System – Stratigraphy

Many narrow glacial meltwater channels are known to be present in northwestern Saskatchewan in the Lloydminster-Meadow Lake areas. These are larger than the Weyburn Valley Aquifer previously discussed and certainly will be major aquifers. Compilation of the regional geology of that area is still in progress.

Summary and Conclusions

The drift aquifers of southern Saskatchewan have an estimated net groundwater yield of about 245,000 acre-feet per year. The major bedrock aquifers in the northern part of the Saskatchewan-Nelson Basin and the Churchill Basin have a net groundwater yield greater than 2×10^6 acre-feet per year. The total sustained yield of these aquifer systems would be much greater - by an amount equal to the streamflow depletion which would occur under maximum development conditions.

The quality of groundwater available from major drift aquifers ranges from 1,000 to 4,000 ppm total ionic concentration, with the bulk of it in the 1,000 to 2,500 ppm range. It is unsuitable for irrigation on the basis of its quality.

The quality of water in the major bedrock aquifers in northern Saskatchewan seems to be substantially better but additional information is required to substantiate these preliminary findings.

The Qu'Appelle River is the major groundwater drain in Saskatchewan because of its low elevation and because of its position relative to several major aquifers. The interaction between surface water and groundwater is most significant in the Qu'Appelle and Souris River Basins. In the case of the Qu'Appelle Basin the groundwater component may, in fact, govern basin behaviour.

Groundwater in Saskatchewan is a renewable resource, replenished continuously by precipitation. Natural water levels vary according to the climate.

Recommendations

A major geologic and hydrologic study should be directed toward evaluating the groundwater resources of the major bedrock aquifers. Particular emphasis should be placed on defining lateral and stratigraphic variations in water quality throughout the basin. A major monitoring system is required to determine the consequences of deep waste disposal on the fresh water resources of the major bedrock aquifers in Saskatchewan and Manitoba. This is urgently required to protect the extremely high quality water resources of northern Saskatchewan.

Work should be continued to delineate major aquifer systems more precisely, with particular emphasis on the permeability and continuity of the confining beds which limit the net groundwater yield of these aquifer systems. Work should be concentrated on the major aquifer systems contiguous to the Qu'Appelle River and Souris River because water quality in both these aquifer systems is generally similar to or better than that in the adjoining surface-water systems. There is also a possibility that the aquifer systems could yield larger total quantities of water.