Geoscience Canada

URBAN GEOLOGY 5. Edmonton Landfill Site Investigation: A Case Study Applying Hydraulic Information to Interpret a Glacially Disturbed Site

Laurence D. Andriashek, David G. Thomson and Reed Jackson

Volume 20, Number 4, December 1993

URI: https://id.erudit.org/iderudit/geocan20_4ser02

See table of contents

Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

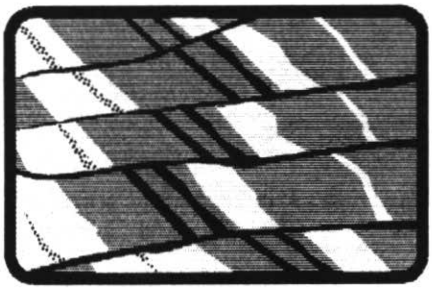
Explore this journal

Cite this article

Andriashek, L. D., Thomson, D. G. & Jackson, R. (1993). URBAN GEOLOGY 5. Edmonton Landfill Site Investigation: A Case Study Applying Hydraulic Information to Interpret a Glacially Disturbed Site. *Geoscience Canada*, *20*(4), 157–164.

Article abstract

Detailed characterization of the hydro-geologic setting was essential to model the potential for leachate migration from the proposed City of Edmonton Waste Management Centre at the Aurum site. Conventional geologic information from bore holes limited the ability to provide a detailed interpretation of stratigraphie units made geologically complex by glacial over-riding and thrusting. Supplementary information from hydraulic tests proved to be crucialin resolving difficulties in correlation of hydrostratigraphic units as additional geologic data became available. Piezo-meter readings and pumping tests established that two discrete aquifers a represent within an apparently single hydrostratigraphic unit. Glacialice thrusting and injection of a slab of displaced bedrock effectively severed the unit into two aquifers with dissimilar hydraulicproperties.



URBAN GEOLOGY 5. Edmonton Landfill Site Investigation: A Case Study Applying Hydraulic Information to Interpret a Glacially Disturbed Site

Laurence D. Andriashek and
David G. Thomson
Environmental Research and Engineering Department
Alberta Research Council
P.O. Box 8330, Station F
Edmonton, Alberta T6H 5X2

Reed Jackson
Stanley Associates Engineering Ltd.
Stanley Technology Centre
10160 - 112 Street
Edmonton, Alberta T5K 2L6

SUMMARY

Detailed characterization of the hydrogeologic setting was essential to model the potential for leachate migration from the proposed City of Edmonton Waste Management Centre at the Aurum site. Conventional geologic information from boreholes limited the ability to provide a detailed interpretation of stratigraphic units made geologically complex by glacial over-riding and thrusting. Supplementary information from hydraulic tests proved to be crucial in resolving difficulties in correlation of hydrostratigraphic units as additional geologic data became available. Piezometer readings and pumping tests established that two discrete aquifers are present within an apparently single hydrostratigraphic unit. Glacial-ice thrusting and injection of a slab of displaced bedrock effectively severed the unit into two aquifers with dissimilar hydraulic properties.

RÉSUMÉ

Une caractérisation détaillée du milieu hydrologique s'est avérée essentielle la modélisation des risques de migration du lexiviat provenant de la décharge de Aurum, proposée par le « centre de gestion des déchets » de la Ville d'Edmonton. Les informations provenant d'études géologiques conventionnelles à partir de puits de forage ne permettaient pas de comprendre de façon satisfaisante les unités stratigraphiques qui ont été perturbées par des chevauchements et des charriages d'origine glaciaire. Les informations provenant de tests hydrologiques ont permis de résoudre des problèmes de corrélation entre les unités hydrostratigraphiques, en apportant des renseignements géologiques additionnels. Les indications des piézomètres ainsi que les résultats de tests de pompage ont montré qu'il existait deux aquifères différents au sein de ce qui semblait n'être qu'une seule unité hydrostratigraphique. Les forces glaciaires ont charrié et enfoncé un plaque rocheuse à travers l'unité, ce qui a eu pour effet de la séparer en deux aquifères ayant des propriétés hydrologiques distinctes.

INTRODUCTION

In 1987, the existing landfill site in the City of Edmonton was nearing its capacity to accept municipal waste, and a process was initiated to select a new solid-waste-only waste management site. On the basis of a number of factors, mostly socio-economic concerns, the Aurum site was chosen as the most suitable. As part of the application to develop a sanitary landfill site, Stanley Associates Engineering Ltd. was contracted by the City of Edmonton to conduct a hydrogeological evaluation of the proposed Edmonton Waste Management Centre at the Aurum site. In the latter stages of the evaluation, the Alberta Research Council was contracted by the consultants to provide a review of the geologic and hydrogeologic interpretations of the investigations, and to carry out a numerical modelling study of potential leachate migration during the life of the site.

This paper addresses the technical aspects of the hydrogeologic investigation, focussing on the following:

1) the evolution of geologic interpretation as new information became available during the course of the investigation;
2) the limitations on geologic interpretations made from conventional borehole data; and
3) the value of hydraulic information in the interpretation of a site made geologically complex by glacial thrusting and displacement of units within the stratigraphic sequence.

Location and Background

The proposed Aurum waste management site occupies an area of about 2.5 km² in the northeast part of the City of Edmonton. The site is located on an undulating to rolling landscape which gently slopes to the North Saskatchewan River, approximately 0.5 km to the north (Fig. 1). An erosional scarp of the

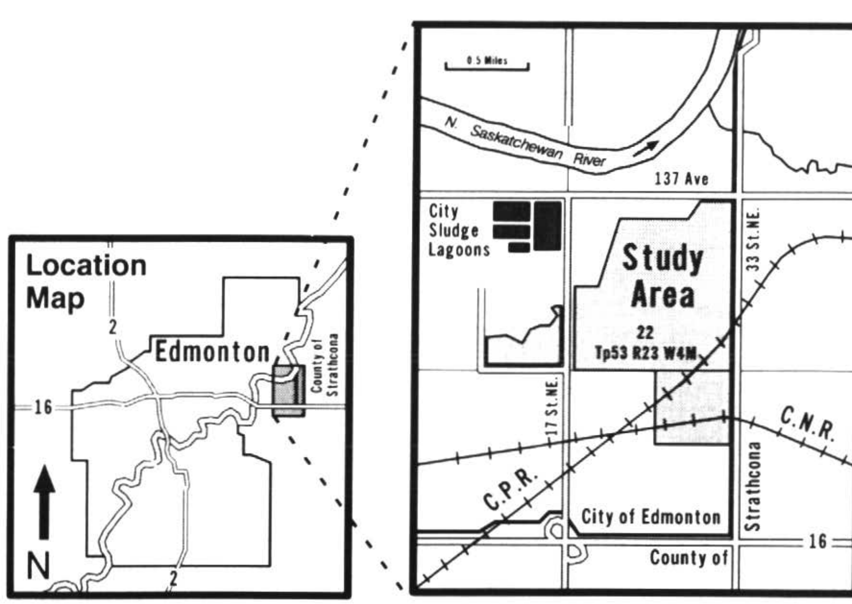


Figure 1 *Location of the proposed City of Edmonton Aurum waste management site.*

North Saskatchewan River forms a natural boundary along the west and northwest margin of the site. The County of Strathcona boundary limits access along the eastern and southern margins of the site. Rail-line rights of way and pipeline corridors further limit access in the southern part of the area.

Geologic and hydrogeologic information for the site was collected from boreholes drilled during three phases of the field investigation. In the preliminary phase in 1987, four rotary boreholes were drilled through the Quaternary sequence and deep (>10 m) into the underlying bedrock to establish the stratigraphic units. Piezometers were installed in some of the deeper units in these testholes. At the completion of this phase of the investigation, the site was given a poor rating as a non-engineered industrial landfill because of the presence of a thick, water-bearing sand that was encountered in each of the holes. The City of Edmonton opted to proceed with a totally engineered and lined landfill site, and a detailed hydrogeologic investigation was completed in the fall of 1988. During this second phase of the investigation, an additional 12 rotary boreholes and 27 continuous-flight, dry-auger boreholes were completed on a 200 m grid across the property. The auger boreholes were drilled through the Quaternary drift sequence and completed into the upper part of *in situ* bedrock, or what was interpreted to be *in situ* bedrock, based on cutting samples. Piezometers were installed in all major stratigraphic units within most of these boreholes. Stanley Associates Engineering Ltd. prepared a report to the City in 1989, summarizing the hydrogeologic findings and making recommendations to support a conceptual landfill design. The consultant was subsequently requested to further expand the subsurface investigation to support a more detailed design, and to resolve difficulties in the geologic and hydrostratigraphic correlation. A third phase of the field investigation was initiated in 1990, at which time 24 additional auger boreholes were drilled on a 100 m spacing, primarily in the east half of the area, and two rotary holes were drilled to conduct pumping tests (Fig. 2). Borehole information from previous geologic investigations in the region provided supplementary data along the perimeter of the site.

The following section discusses the

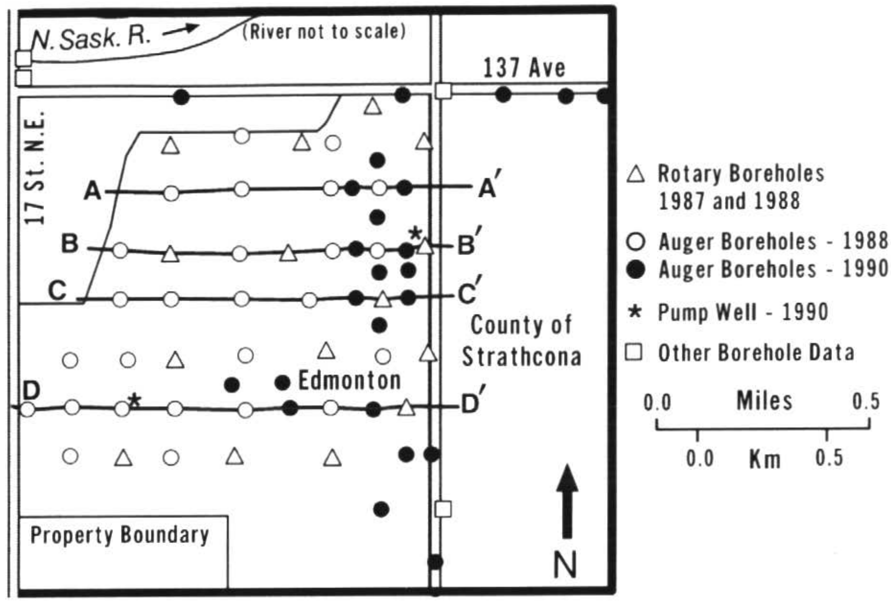


Figure 2 *Location of boreholes and geologic cross-sections.*

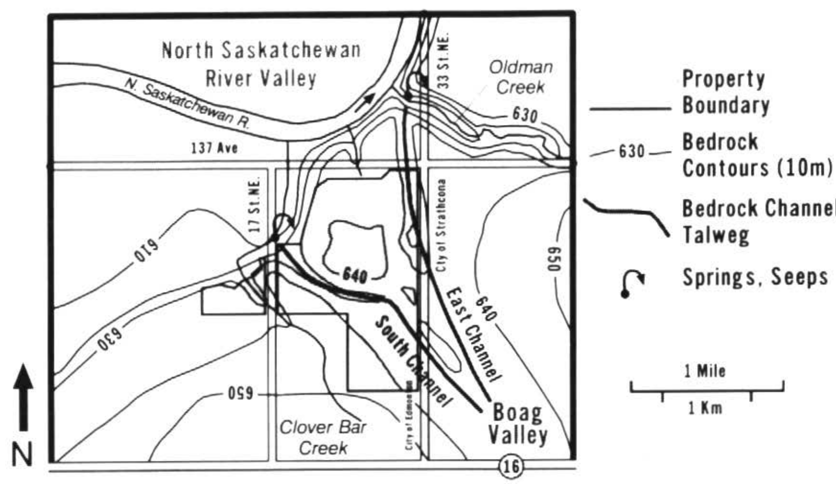


Figure 3 *Regional bedrock topography showing talwegs of bedrock channels.*

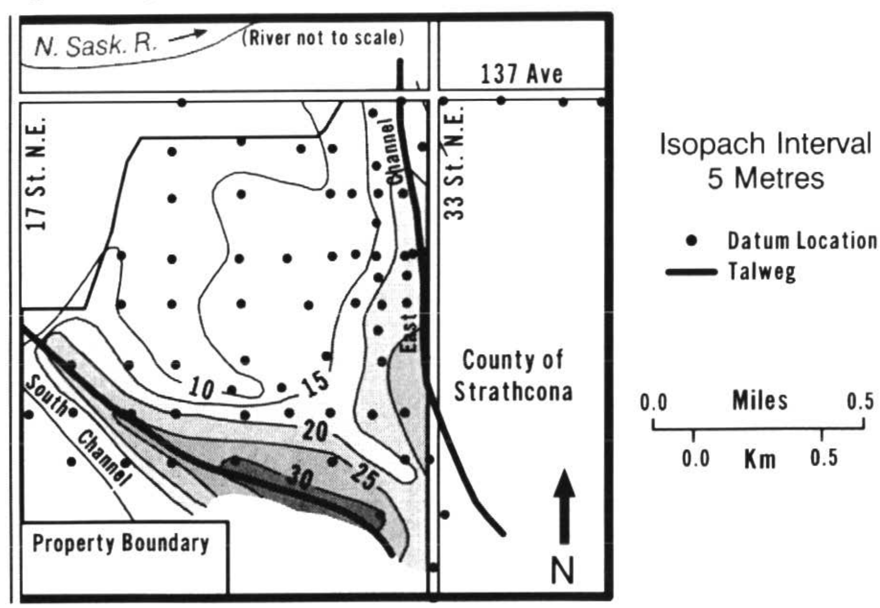


Figure 4 *Thickness of drift overlying bedrock.*

results of that investigation, focussing on the evolution of the interpretations and assumptions about the hydrogeologic setting of the site as information became available during the three phases of the investigation.

Bedrock Topography, Buried Channels, and Drift Thickness

The Edmonton area is located on Upper Cretaceous claystone, sandstone, siltstone, ironstone and coal of the Horseshoe Canyon Formation (Irish, 1970). Most rock units within the formation are generally soft, poorly indurated, and capable of being penetrated by a dry auger. During the Late Tertiary and Early Quaternary, the bedrock surface was exposed and modified by fluvial erosion. A number of bedrock channels developed on the landscape of the region. The Beverly Channel, which is the main channel, is located north of the Aurum site (Carlson, 1967; Kathol and MacPherson, 1975; Andriashek, 1984). A tributary of the Beverly Channel, the Boag Valley (Carlson, 1967; Andriashek, 1984), trends north through the Aurum site, and dominates the bedrock topography. The valley consists of two branches. The East Channel trends north along the east property boundary, and the South Channel trends northwest along the southern boundary (Fig. 3). The talwegs of these buried channels are believed to merge southeast of the site.

Multiple glacial events during the Quaternary filled in the bedrock channels with as much as 30 m of stratified and nonstratified sediment, masking any present-day surface expression of the valley (Fig. 4). Post-glacial fluvial erosion by the North Saskatchewan River cut down through the drift and bedrock sequence to as much as 15 m below the base of the South Channel in the northwest corner of the site. The north end of the East Channel was similarly truncated by recent erosion along Oldman Creek. Groundwater discharge in the form of springs and seeps occurs at the outcrops of these hanging bedrock channels (Fig. 3).

Table 1 **Stratigraphy at the Aurum site, City of Edmonton.**

AGE	UNIT	LITHOLOGY
	SURFICIAL	
Quaternary	— Glacial Lake Edmonton	Silt and Clay
	— Upper Till	Clay Loam Till
	— Glacially Displaced Bedrock and Highly Plastic Clay Till	Claystone, Clay Till
Tertiary	Empress Formation	
	— Preglacial Terrace Sand	Sand, Gravel
	— Preglacial Channel Sand	Sand, Gravel
	BEDROCK	
Upper Cretaceous	Horseshoe Canyon Formation	Claystone, Siltstone, Sandstone, Coal

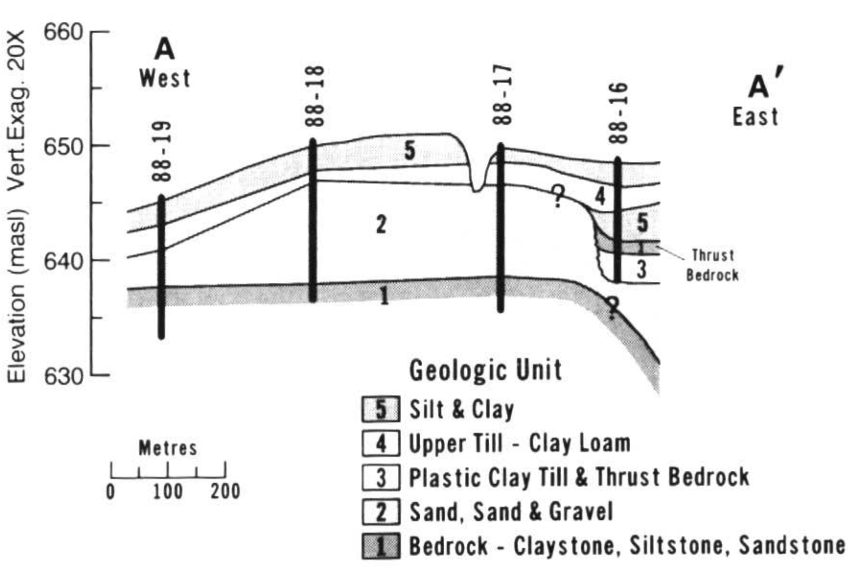


Figure 5 *Geology along cross-section A-A′ (based on 1987 and 1988 borehole information).*

SITE GEOLOGY AND HYDROSTRATIGRAPHY

The geologic interpretation of the site evolved as new information became available during the three-year investigation period. The discussion of the geology and hydrostratigraphy of the site is divided into two sections, an initial interpretation based on geologic information collected to the end of 1988 (Phases 1 and 2), and the final interpretation, which was based on additional geologic information and supplemented with the hydraulic information that was collected and compiled near the end of the third phase in 1990.

All units were described from borehole cuttings, in most cases, dry-auger flight samples. No man-made or natural exposures of the entire stratigraphic sequence are present at the site, although nearby outcrops along the banks of the North Saskatchewan River and Oldman Creek afforded examination of some of the units.

Interpretations Following Phases 1 and 2 of the Investigation

Table 1 lists the stratigraphic units encountered within the boreholes at the Aurum site.

The lowermost surficial unit consists of a basal sand, and gravelly sand of preglacial fluvial origin. The unit occurs in both the east and south channels of the Boag Valley, as well as on the bedrock terrace adjacent to the channels. The sand and gravel are composed dominantly of light-coloured quartzite and dark-coloured chert rock fragments derived from the local bedrock and the Cordilleran region to the west. The unit is correlative with the salt-and-pepper coloured sand of the Empress Formation (Whitaker and Christiansen, 1972;

Andriashek and Fenton, 1989), which is also referred to as the Saskatchewan Sand in the Edmonton region (Stalker, 1968). Pink-coloured granitic rock fragments, indicative of glacially transported sediment from the Canadian Shield northeast of the region, are conspicuously absent.

Glacial sediment overlies the preglacial sand and gravelly sand over the entire study area. A mixed complex consisting of glacially thrust bedrock and a highly plastic clay till was recognized in boreholes located in the eastern part of the site. The displaced bedrock is dominantly claystone, and is indistinguishable from that of the Horseshoe Canyon Formation. The plastic clay till is composed primarily of glacially reworked claystone with numerous weak clasts of claystone and rare indurated clasts of granitic and quartzitic composition. The till is dense, has a low permeability, and is easily differentiated from the overlying regional clay loam till that lies in contact with preglacial sand in the western part of the site. Where preglacial sand is absent, the plastic clay till serves as a stratigraphic marker to differentiate glacially displaced bedrock sequences from *in situ* bedrock.

Glacial Lake Edmonton sediment (Gravenor and Bayrock, 1956; Bayrock and Hughes, 1962) forms the uppermost stratigraphic unit at the site. The sediment consists of rhythmically bedded silt and clay, with minor amounts of sand and ice-rafted till layers.

In the central and northwest part of the site, the stratigraphic sequence is interpreted to be relatively uniform, and correlations of units are straightforward. Preglacial sand and gravelly sand extends over most of the site, with deposits in terrace settings interpreted to be continuous and correlative with sand in both channels of the Boag Valley (Figs. 5, 6, 7). The sand is thickest (>20 m) along the talweg of the South Channel, but thins to less than 1 m along the edge of the escarpment that bounds the northwest corner of the site (Figs. 8, 9).

The stratigraphic sequence is more complex in the eastern and southeastern part of the site where glacially displaced bedrock and associated plastic clay till overlie preglacial sand in both channel and terrace settings (Fig. 10). The sequence of displaced bedrock and plastic clay till is as much as 10 m thick (Fig. 8), but shows great variation in thickness from borehole to borehole,

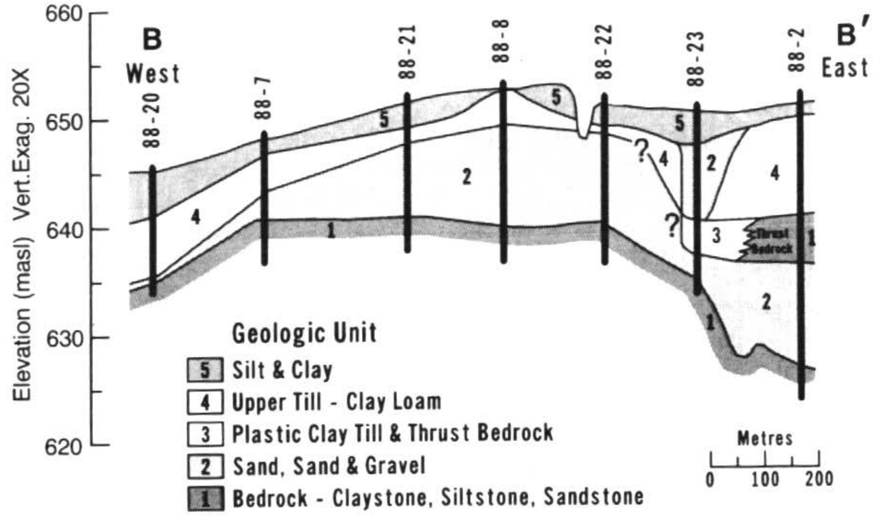


Figure 6 *Geology along cross-section B-B′ (based on 1987 and 1988 borehole information).*

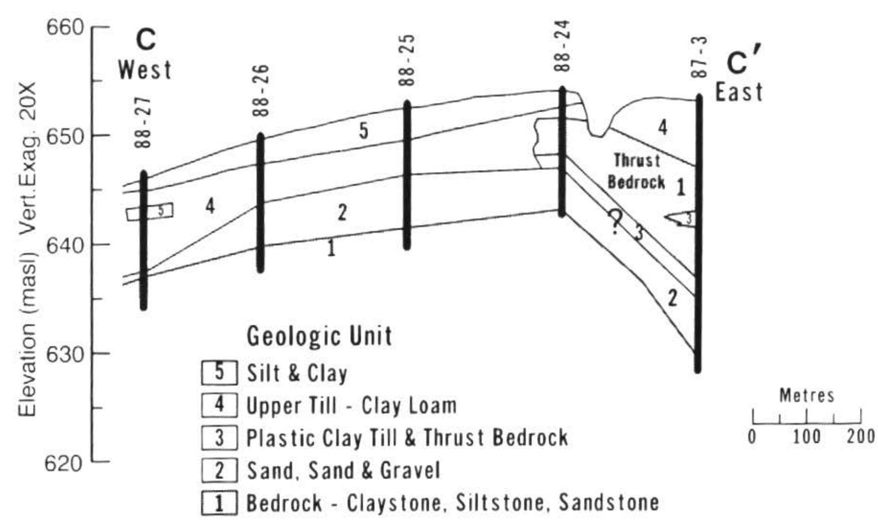


Figure 7 *Geology along cross-section C-C′ (based on 1987 and 1988 borehole information).*

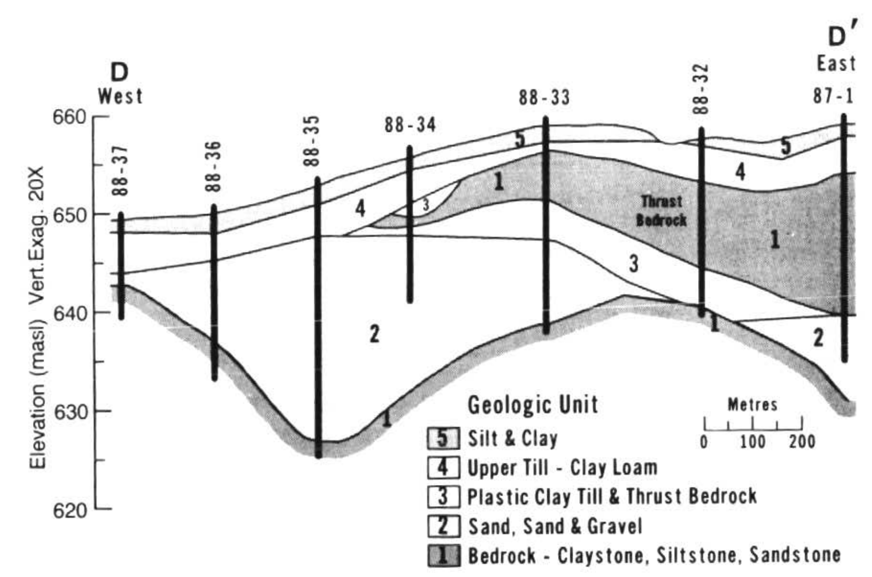


Figure 8 *Geology along cross-section D-D′ (based on 1987 and 1988 borehole information).*

making correlations based solely on stratigraphic position and elevation tenuous. This variability and abruptness in contact made it particularly difficult to establish the lower contact of the thrust bedrock with the underlying units. Of greatest hydrogeologic concern was the geometry of the contact with the sand (Figs. 5, 6, 7). Questions were raised as to whether sand was continuous beneath the thrust bedrock, or if displaced bedrock was thrust into the sand, pinching off the terrace deposits from those in the East Channel.

Preglacial sand was found to be absent only in the southeast corner of the site, where it is believed to have been eroded by over-riding glacial ice. In this area, a slab of displaced bedrock and associated basal plastic clay till was deposited on the bedrock ridge that separates the East and South channels of the Boag Valley (Figs. 8 and 9).

It was assumed during the investigation stages of Phases 1 and 2 that, for the purposes of establishing the framework for the hydrogeologic model, terrace sand was correlative with sand in both channels of the Boag Valley. Further, with the exception of the southeast corner, it was believed that terrace and channel sand units were hydraulically connected and could be modelled as a single, discrete aquifer.

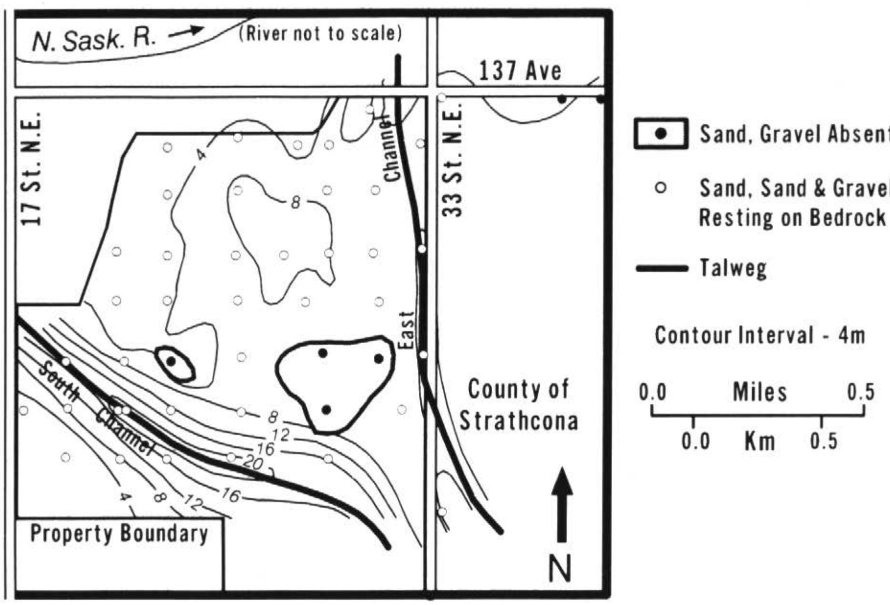


Figure 9 *Distribution and thickness of sand and gravel resting on bedrock (based on 1987 and 1988 borehole information).*

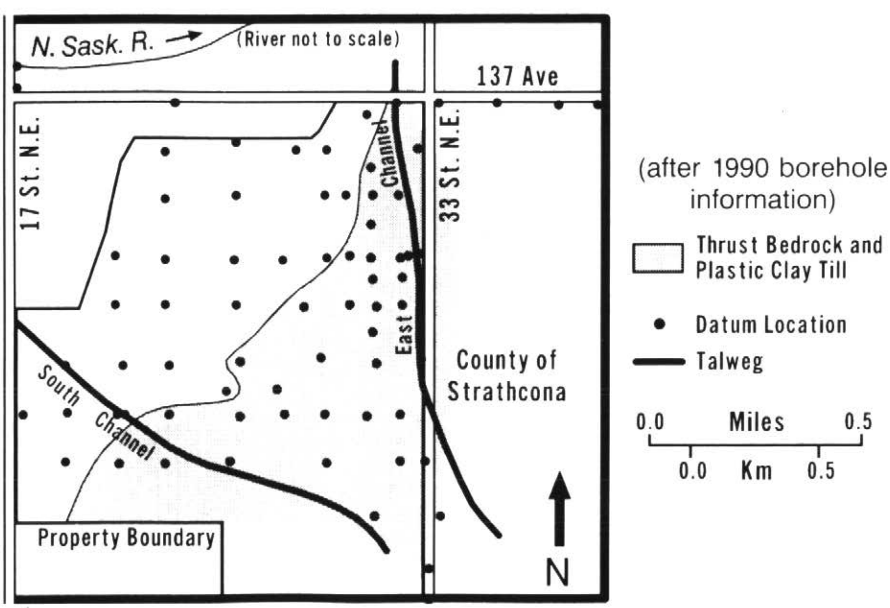


Figure 10 *Distribution of glacially thrust bedrock and plastic clay till (includes 1990 borehole information).*

Interpretations Following Phase 3 of the Investigation

Uncertainty remained at the end of Phases 1 and 2 of the investigation regarding the interpretation of the thrust bedrock and plastic clay till unit along the east side of the study area. Two concerns remained unresolved. First, the displaced bedrock could not be differentiated from *in situ* bedrock in the southeast part of the site. In this area, the underlying sand and plastic clay till were absent. Second, the contact between the western edge of the thrust bedrock and the underlying sand unit could not be confirmed. This had serious implications concerning the lateral continuities of the terrace sand and channel sand.

In 1990, the third phase of the investigation was completed. Additional dry-auger boreholes were drilled on a 100 m spacing to resolve the stratigraphic complexity associated with ice thrusting, and to verify the hydraulic continuity between terrace sand, and sand in the East Channel.

The results from the 1990 field investigation are depicted in a series of east-west oriented cross-sections shown in Figures 11 through 14. They incorporate the additional geologic information, as well as the hydraulic information collected from piezometers completed in the terrace and channel sand deposits during Phases 1 to 3. The term "measured piezometric level" shown in the figures, refers to the water level measured in standpipe piezometers. The term "observed water level" refers to the level of standing water measured in open boreholes at the completion of drilling.

The additional boreholes established that the western edge of the thrust bedrock has a very abrupt lateral contact with the sand in the northeast part of the site. The geologic information was inconclusive, however, in establishing whether terrace sand was laterally continuous with channel sand, or whether displaced bedrock was thrust into *in situ* bedrock, effectively truncating the sand aquifer. For example, in cross-sections A-A', and B-B' (Figs. 11, 12) the new geologic information shows that the terrace sand and East Channel sand are correlative and laterally continuous. Information from 1990 boreholes located on cross-sections C-C′ and D-D′ (Figs. 13, 14), on the other hand, supports a much different interpretation. The data indicate that ice-thrust bedrock separates terrace sand from channel sand, and rests directly on *in situ* bedrock along the western margin of the East Channel. Without drilling additional boreholes on a spacing even tighter than 100 m, the configuration of the thrust bedrock-sand contact appeared to be unresolvable.

Hydraulic information proved crucial in resolving the difficulty of correlating the sand units, and in establishing the thrust bedrock-sand contact. Water-table levels from piezometers completed in the basal sand, or in the upper bedrock surface in contact with the sand, indicate that unsaturated conditions exist in both the terrace sand and sand in the South Channel (Figs. 11 to 14). Sand in the East Channel is not only saturated, but the piezometric surface is also significantly higher, with a steep hydraulic gradient separating the terrace and South Channel sand aquifer from the East Channel aquifer (Figs. 11 to 14). The steep gradient coincides with the western edge of the displaced bedrock, which supports the interpretation that glacial thrusting has either severed the connection between the East Channel sand and terrace sand along the thrust margin, or has scoured out most of the sand, thereby decreasing the transmissivity along the channel flank. A planimetric view of the piezometric surface (Fig. 15) shows that terrace sand and sand in the South Channel behave similarly, with both draining to the North Saskatchewan River escarpment to the northwest. The East Channel sand aquifer drains northward and has a steep hydraulic gradient along its western flank. The north-south orientation of this gradient is believed to approximate the subsurface configuration of the contact along which glacially displaced bedrock has been thrust through the aquifer, to rest directly on *in situ* bedrock, or where the sand has been significantly thinned by glacial scour.

Pumping test observations support the interpretation of complete hydraulic discontinuity between the two aquifer systems. Figure 16 shows the extent and effects of drawdown in the sand at the end of a week-long pumping test at

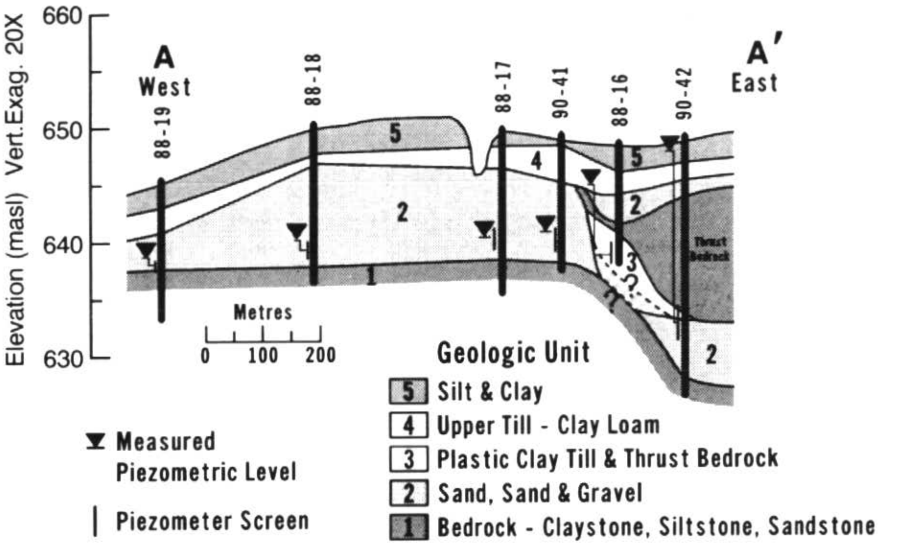


Figure 11 *Revised geologic interpretation along cross-section A-A ′, including 1990 borehole information and piezometer data.*

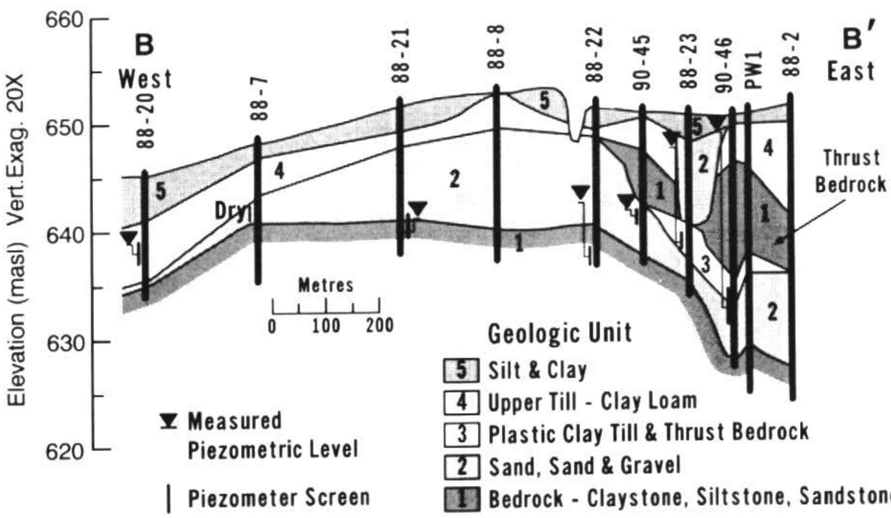


Figure 12 *Revised geologic interpretation along cross-section B-B ′, including 1990 borehole information and piezometer data.*

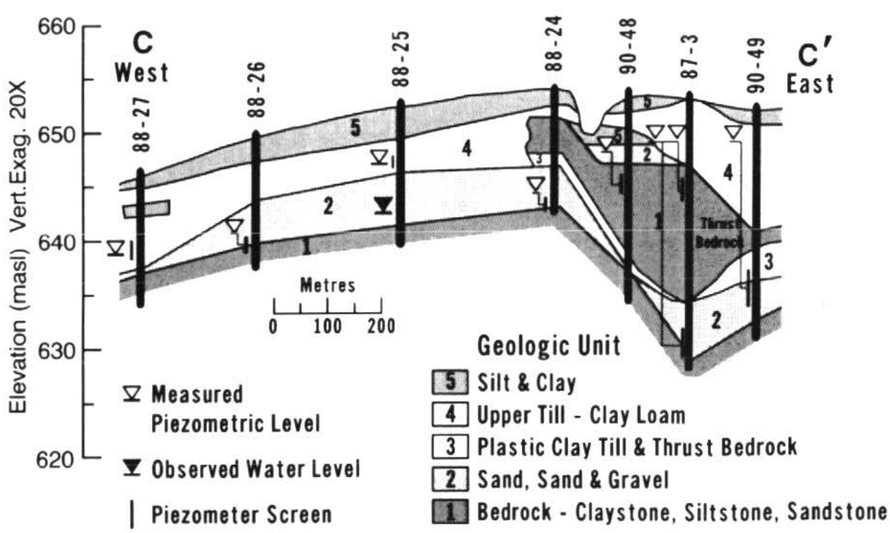


Figure 13 *Revised geologic interpretation along cross-section C-C ′, including 1990 borehole information and piezometer data.*

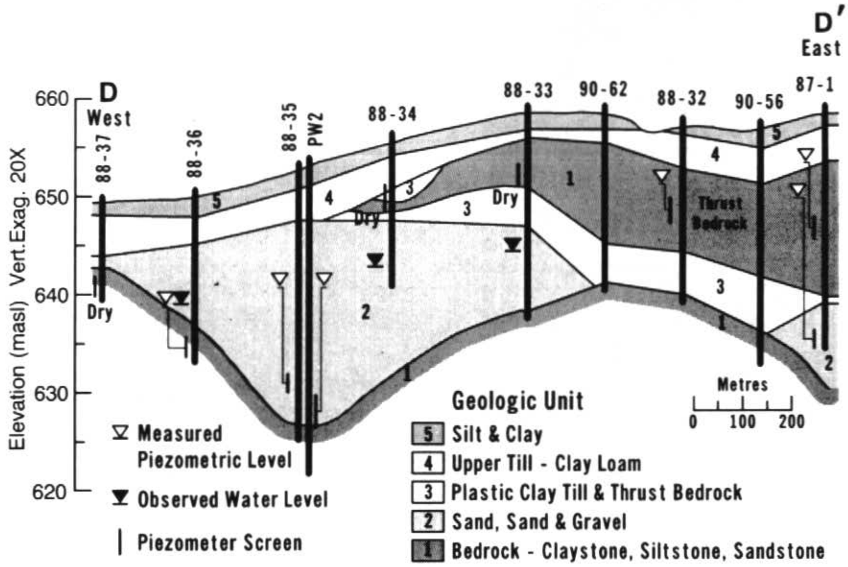


Figure 14 *Revised geologic interpretation along cross-section D-D ', including 1990 borehole information and piezometer data.*

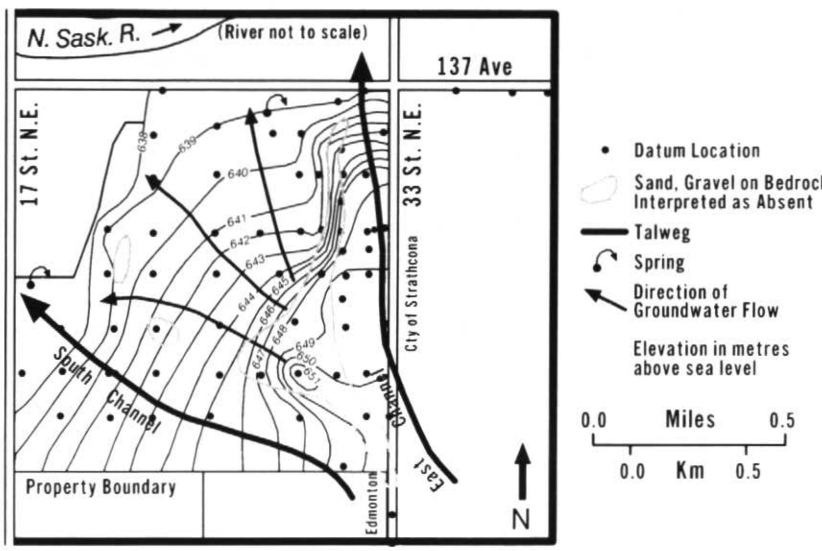


Figure 15 *Piezometric surface contours showing inferred direction of groundwater flow. Note steep hydraulic gradient along western edge of the East Channel where basal sand is interpreted to be absent.*

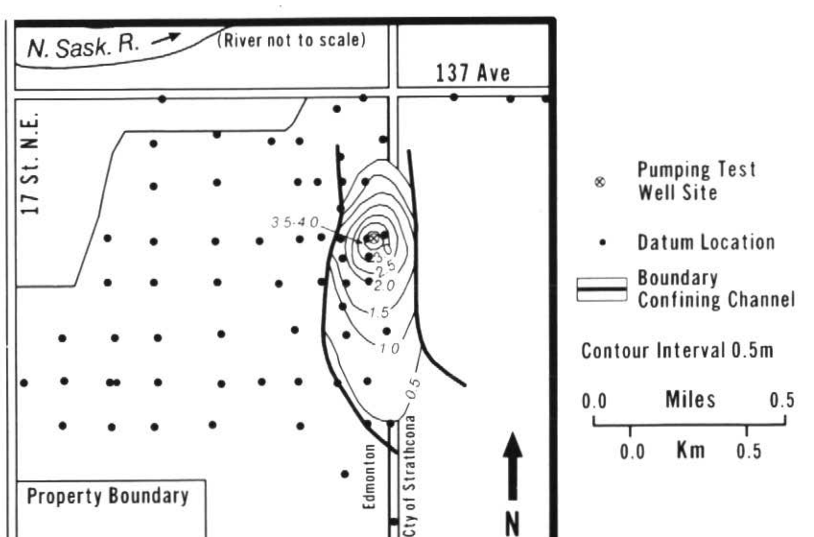


Figure 16 *Configuration of drawdown at pumping well located in East Channel sand.*

test hole PW1, located in the East Channel. The well was pumped at a rate of 2.5 $L \cdot s^{-1}$ to maximize drawdown as a means of delineating aquifer boundaries. The absence of drawdowns in wells located in both South Channel and terrace settings indicates that the East Channel is laterally confined by the thrust bedrock and that the aquifer is hydraulically disconnected from the terrace and South Channel aquifer. The eastern confining boundary was not established by test drilling, but is an extrapolation of the thrust bedrock slab on the bedrock surface.

CONCLUSIONS

On the basis of the geologic information from the 1990 boreholes, and the additional hydraulic information from both piezometers and pumping test, we conclude that:

1) The basal sand within the Aurum site is not continuous throughout. Sand in the terrace is separated from sand in the East Channel by a slab of ice-thrust bedrock that has severed the unit along the western margin of the channel.
2) A bedrock ridge separates the two channels in the southeast corner, with ice-thrust bedrock resting directly on *in situ* bedrock along the ridge. From geologic and hydraulic evidence, it is inferred that sand in the East Channel is not connected to sand in the South Channel.
3) Although not confirmed by test drilling, the pumping test also confirms that the eastern boundary of the East Channel is similarly defined by thrust bedrock resting on the bedrock surface.

Based on these conclusions, the 1988 interpretation of the subsurface contact between the ice-thrust bedrock and the underlying sand (Figs. 5, 6) was revised to include the interpretations supported by the hydraulic data. In some areas where the 1990 geologic information continued to support stratigraphic correlation and lateral continuity between terrace and East Channel sand — for example, cross-section B-B' (Fig. 12) — a somewhat more complex and convoluted geologic contact was required to account for the hydraulic observations. An example of this is illustrated in the final stratigraphic interpretation of that cross-section (Fig. 17) in which an injected tongue of displaced bedrock and plastic clay till (that has truncated the basal sand) has been introduced to the cross-section to account for the saturated and unsaturated conditions, and differential water-table elevations that exist within the aquifer.

The assumption made in 1988, that the basal sand is a single hydrostratigraphic unit resting directly on bedrock over most of the site, was subsequently revised following the conclusions based on the hydraulic information and data from the 1990 drill program. The final interpretation, depicted in Figure 18, shows sand being absent along both flanks of the East Channel, where it is believed that ice-thrust bedrock and high-plastic clay till rest directly on *in situ* bedrock. This information was used as the basis for a numerical contaminant transport model. The model had to be designed to treat the basal sand as two discrete aquifers. The terrace and South Channel behaved collectively as an unconfined aquifer. The East Channel was modelled as a confined aquifer with elevated head levels.

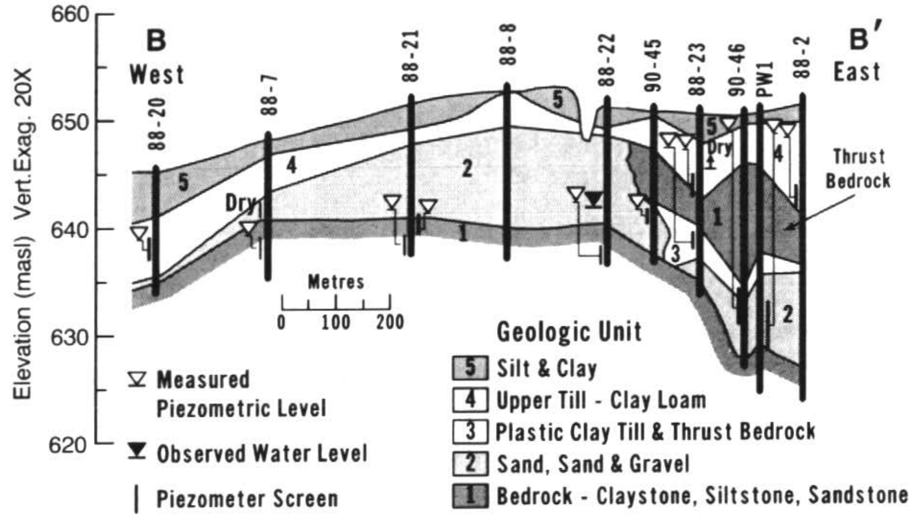


Figure 17 *Final hydrostratigraphic interpretation along cross-section B-B ' based on geologic and hydraulic information. An abrupt contact between sand and thrust bedrock accounts for the saturated and unsaturated conditions in boreholes 88-23 and 90-45, respectively.*

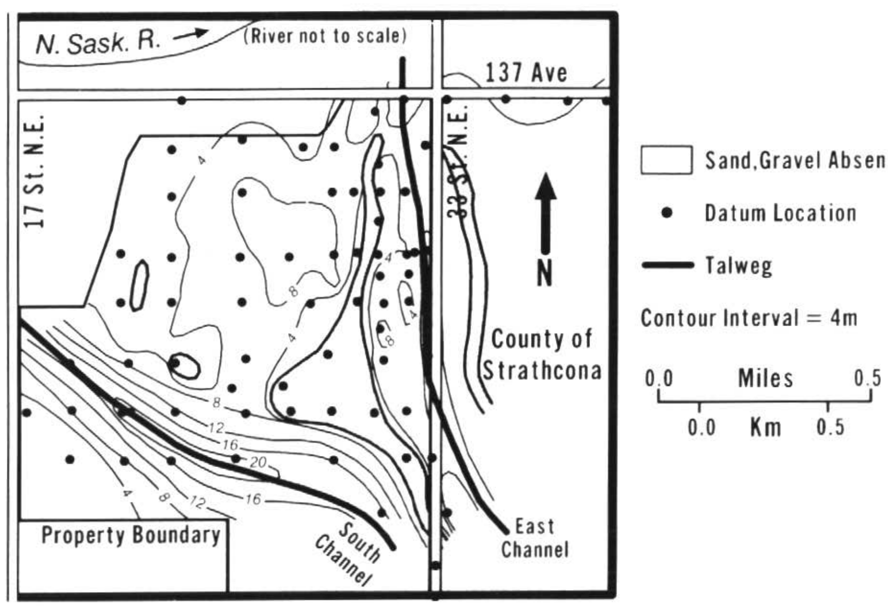


Figure 18 *Revised distribution and thickness of sand and gravel (interpretation based on 1990 borehole data, and hydraulic information).*

REFERENCES

Andriashek, L.D., 1984, Quaternary stratigraphy of the Edmonton map area, NTS 83H: Alberta Research Council, Open File Report 198804, 27 p.

Andriashek, L.D. and Fenton, M.M., 1989, Quaternary stratigraphy and surficial geology of the Sand River area, 73L: Alberta Research Council, Bulletin 57, 154 p.

Bayrock, L.A. and Hughes, G.M., 1962, Surficial geology of the Edmonton district, Alberta: Alberta Research Council, Preliminary Report 62-6, 40 p.

Carlson, V.A., 1967, Bedrock topography and surficial aquifers of the Edmonton district, Alberta: Alberta Research Council, Report 66-3, 21 p.

Gravenor, C.P. and Bayrock, L.A., 1956, Stream-trench systems in east-central Alberta: Alberta Research Council, Preliminary Report 56-4, 11 p.

Irish, E.J.W., 1970, The Edmonton group of south-central Alberta: Canadian Petroleum Geology, Bulletin, v. 18, n. 18, p. 125-156.

Kathol, C.P. and MacPherson, R.A., 1975, Urban geology of Edmonton: Alberta Research Council, Bulletin 32, 61 p.

Stalker, A.M., 1968, Identification of Saskatchewan gravels and sands: Canadian Journal of Earth Sciences, v. 5, p. 155-163.

Whitaker, S.H. and Christiansen, E.A., 1972, The Empress group in Saskatchewan: Canadian Journal of Earth Sciences, v. 9, p. 353-360.

Accepted, as revised, 15 March 1994.