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THE PORT GRANBY RADIOACTIVE WASTE MANAGEMENT SITE

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● Environment Canada

CENTRE DE GESTION DES DÉCHETS RADIOACTIFS DE PORT GRANBY

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RÉSUMÉ

Le volume des eaux souterraines provenant du centre de Port Grandby qui sont déversées chaque année dans le lac Ontario est d'environ $2,5 \times 10^5$ m^3. Ces eaux amènent dans le lac environ $2,5 \times 10^7$ Bq de Ra 226 et 25 kg d'uranium. Ces deux éléments sont dilués dans des proportions acceptables à plus d'un mètre de la rive.

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EXECUTIVE SUMMARY

The Port Hope Uranium Refinery has discharged waste tailings to their Waste Management site from 1955-1977. Our Department has monitored this site and the water of Lake Ontario adjacent to the site since 1977. The concentrations of ^{238}U and ^{226}Ra in the lake are within MOE guidelines for drinking water.

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ABSTRACT

About 2.5×10^5 m^3 of ground water flows annually from the Port Granby site into Lake Ontario. This water carries with it about 2.5×10^7 Bq of Ra 226 and 25 kg of uranium into the lake. Both of these elements are diluted to within acceptable levels beyond a one metre distance from the shore.

THE URANIUM-RADIUM PROBLEM

A typical Canadian uranium deposit contains several thousand tonnes, usually as a mixed oxide in conjunction with other heavy metals such as lead and thorium (Trembly, 1981; Whillans, 1983). In nature the ^{238}U is in equilibrium with the first five daughter products in its decay chain. (The sixth daughter, ^{222}Rn, is a gas which often escapes and results in disequilibrium for it and its eight daughters, which are therefore not always a consideration in uranium ores). The fifth daughter of uranium, ^{226}Ra, is a health hazard because of its irreversible deposition in bone coupled with its long alpha decay half-life of 1600 years (Eisenbud, 1973).

Preliminary separation of uranium is usually accomplished at the mill by an acid oxidation which converts the oxide to a uranyl sulfate complex. At the same time most of the associated radium is precipitated and left at the mine or mill site. The uranium can be further purified by ion exchange and is then precipitated with ammonia to give yellowcake.

Figure 1 is a composite diagram which can be used to trace the radium and uranium concentrations from the mine to their final resting place in the environment. Assuming a starting ore composition of U_3O_8 (85% U) which is in secular equilibrium with its decay products gives a radium 226 content of about 0.3 mg per kg of ore. The radium has the same decay rate as the uranium, about 10^7 Bq per kg (1 Bq = 1 disintegration per second). The milling process usually removes more than 99% of the radium to give a composition represented by symbol 1 in Figure 1.

Canada has only one uranium refinery, at Port Hope, Ontario, where uranium is separated from the yellowcake to leave a residue containing the last of the radium and unrecovered traces of uranium, and with a composition given by symbol 2 in Figure 1. By coincidence, the residue has a radium to uranium ratio near that of the original ore. This residue was disposed of at a waste management site at Port Granby, primarily from 1955-1977. Two creeks drain the site and run into artificial catchbasins (see Durham and Joshi, 1980 and Platford et al, 1984 for maps of the site and for radium and uranium concentrations there). The catchbasins are about 50 m from the

lakeshore and have water compositions represented by symbol 3 in Figure 1. A row of piezometers, which will be referred to in the next section, was set up in 1981-3 along the beach and about 10 m from the shoreline. These piezometers had water concentrations given by symbols 4, 5 and 6 in Figure 1. The hatched area in the lower left

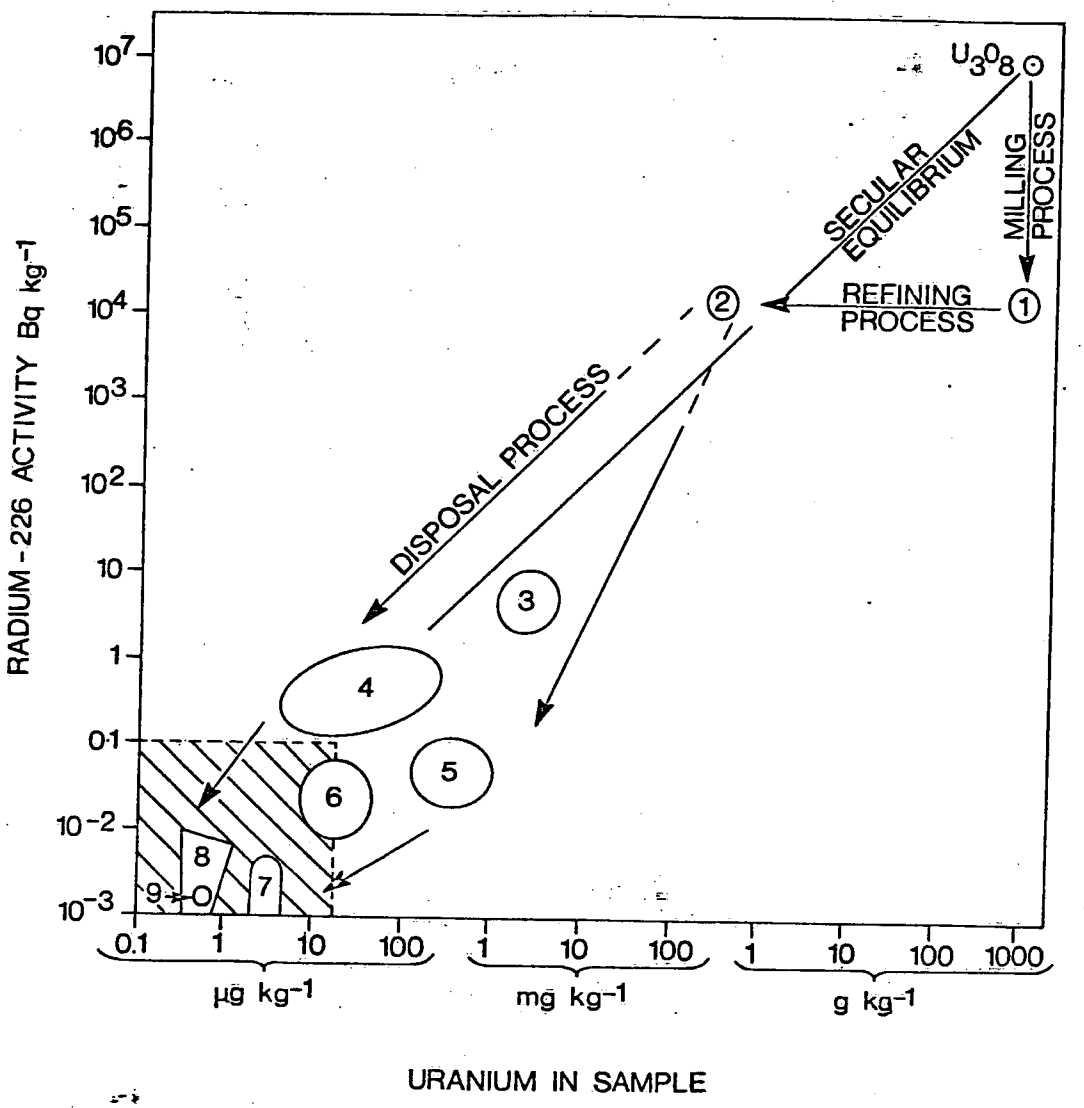

Figure 1 Radium/uranium ratio in typical solid and liquid compartments associated with the Port Granby site.

1. Typical milled yellowcake (solid).
2. Typical waste raffinate (solid).
3. Catchbasins at Port Granby WMS.

4,5,6. Piezometer water from three locations along beach at Port Granby.

7. Water one metre from shore.
8. Water 5-10 m from shore
9. Average Lake Ontario water.

Hatched area in lower left corner indicates water which meets MOE drinking water guidelines.

hand corner of Figure 1 gives the 1983 Ontario Ministry of the Environment objectives for drinking water (0.1 Bq L^{-1} for ^{226}Ra and 20 µg L^{-1} for uranium. Symbols 7 and 8 are, respectively, the lake levels 1 m and 5-10 m from shore for 15 samples taken along the shore from both the surface and bottom lake water, and were designed to give realistic averages of the water composition. All these values were less than the MOE objectives and were near the average for Lake Ontario, given by symbol 9 (IJC, 1983). Based on these values, and on a similar study by Durham and Joshi (1980) in 1977, we conclude that contamination of lake water by the site is not a problem.

THE PORT GRANBY GROUND WATER SYSTEM

The main disposal area is a rectangular block extending for a distance of about 300 m along Lake Ontario and bounded on the east and west by small gorges which drain into the east and west catchbasins. The area is shown in cross section in Figure 2. The

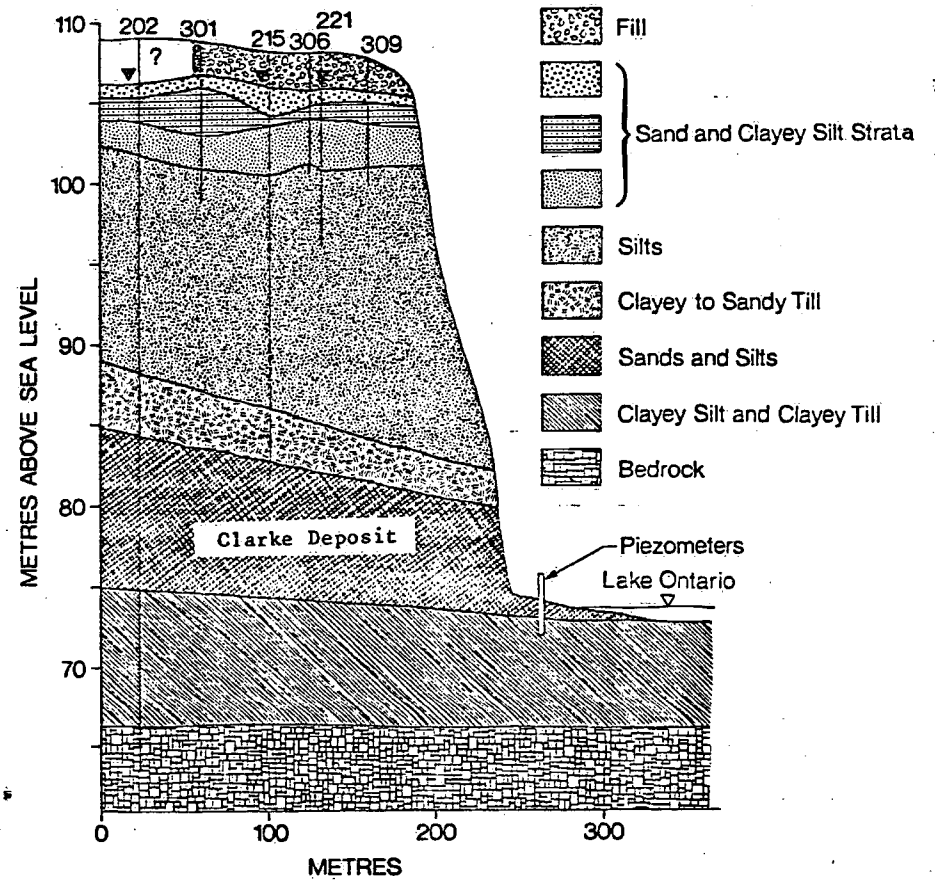

Figure 2 Cross section of the Port Granby site.

geological strata have been evaluated by means of the extensive series of boreholes which have been drilled at the site, some of which are illustrated by vertical lines. The hydraulic conductivities of the various layers are given in Table 1. The hydraulic conductivity is the volume rate of discharge under given hydraulic conditions, as defined later in this section. The most permeable layer is the Clarke

TABLE 1. Hydraulic Conductivities of Port Granby Waste Management Site

Layer (Figure 2)	K ($cm\ d^{-1}$)
Fill	1
Upper Strata	100-300
Silt	30
Upper Till	$0.1\text{-}10^{-3}$
Sand and Silt (Clarke Deposit)	3000
Clay Till	10^{-2}
Bedrock	10^{-4}

See Freeze and Cherry (1979) for nomenclature.

deposit extending from beach level to about 10 m higher, and this layer represents an important channel for the flow of ground water.

The field studies will be tabulated in a future report, and indicate the occurrence of pronounced downward hydraulic gradients over much of the study area. This is evidenced by a decreasing head with depth in all the wells on the site. The variation of water level with well depth can be seen from the geological cross sections.

Hydraulic head contours were prepared from the existing piezometer data (Figures 3 and 4). The map shows the shape of the ground-water head and the apparent direction of horizontal flow. The horizontal gradient taken from the slope of the water table varies from 0.025 to 0.08.

The pattern and velocity of ground water flow in the saturated zone is governed by the hydraulic conductivity of the overburden deposits.

Recharge to the upper lacustrine silt deposits is estimated to vary from 10 to 25 cm per year. The vertical gradient observed at the site is 0.5, while horizontal gradients are 0.05 or less. This suggests a preferential downward flow of ground water.

Ground water flow in the upper till unit, and particularly beneath the site, is controlled by predominantly downward hydraulic gradients in the till. The head distribution in the nested and single piezometers shows downward hydraulic gradients ranging from about 0.1 to near unity. The variation in head differential within the upper till unit is probably due to the heterogeneous nature of the deposit. The actual pattern and velocity of ground water flow in the heterogeneous till deposit beneath the site will be dominated by the hydraulic head difference across the flow path and the hydraulic conductivity of the deposits within the upper till unit. Since the three-dimensional head distribution is predominantly downward, the overall ground water flow path in the till beneath the recharge area, in which the waste disposal site is located, will be primarily downward.

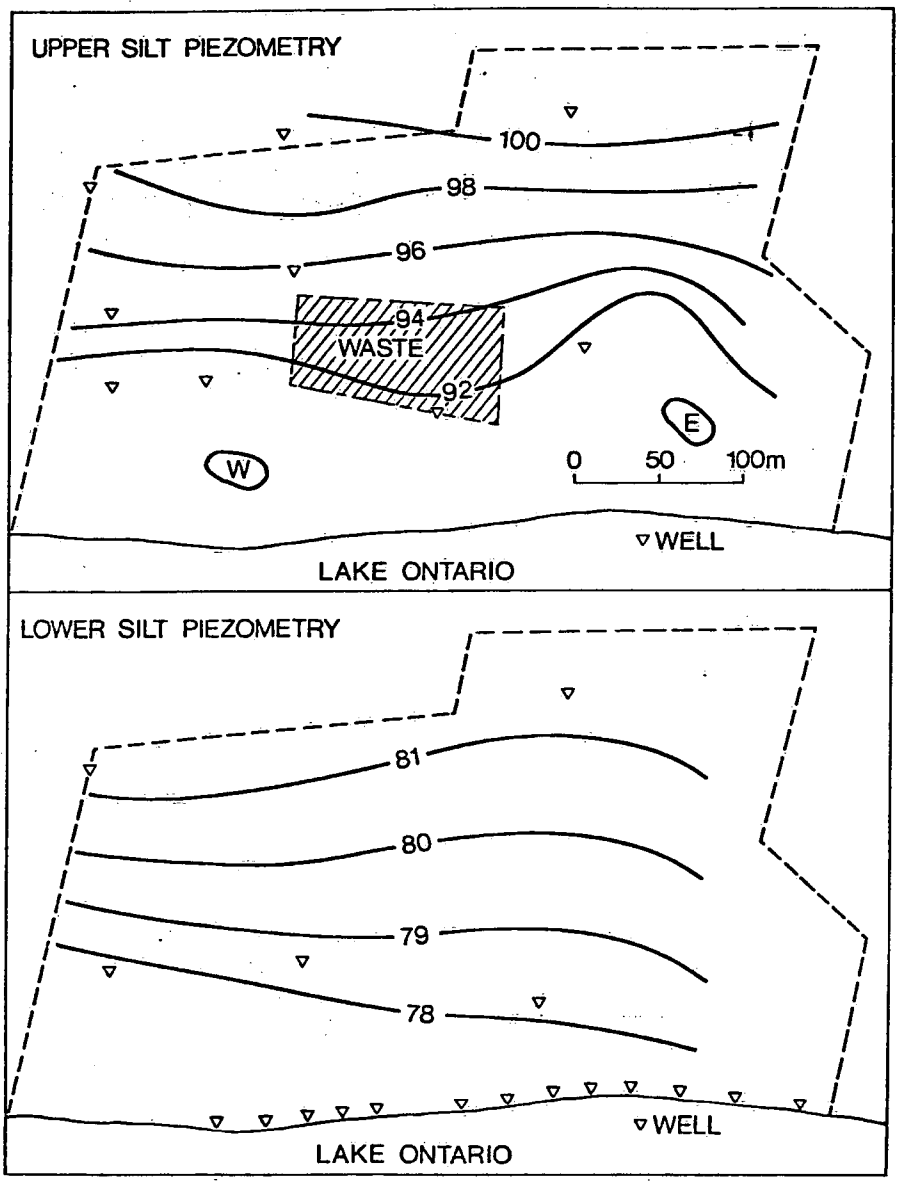

Figure 3 Hydraulic head contours at the level of the upper silts.

Figure 4 Hydraulic head contours at the level of the lower silts (Clarke deposit).

Springs that occur in the gullies to the east and west of the site and along the lakeshore can be observed at elevations of 100 to 105 m. The flow path of infiltration at the site is first-downward and then southward with eventual discharge into Lake Ontario.

The velocity of ground-water flow in the various deposits can be computed by the relationship:

$$V = \frac{K \Delta H}{n_e}$$

where V = velocity of ground-water flow
K = hydraulic conductivity
ΔH = hydraulic gradient across flow path
n_e = effective porosity

The hydraulic gradient is a dimensionless quantity which gives the change of height of water head with distance. The effective porosity is the pore space available for fluid transmission. The hydraulic conductivity of the upper till unit varies from about 10^{-1} m d^{-1} to 10^{-3} m d^{-1}. Assuming an average hydraulic gradient of 0.6, the velocity range in the upper till would be in the order of 2 to 200 centimetres per year.

While the actual flow pattern of ground water in the sand underlying the till in the site cannot be ascertained from the available test data, the general direction is southward, toward Lake Ontario. Assuming hydraulic continuity between the deep lacustrine deposits, the horizontal gradient in this deposit would be about 0.01 or less. Assuming a hydraulic conductivity of 20 cm d^{-1} and an effective porosity in sand of 0.2, the flow velocity would be about 300 cm $year^{-1}$.

In summary, the lacustrine deposits are exposed at the surface and thus it is expected that the rates of infiltration will be greater there. Since the vertical hydraulic gradient is also high, any contaminant will move downwards as well as laterally.

The ground-water discharge from the waste disposal site between the east and west creeks is computed by applying Darcy's law.

$$Q = KLH\Delta H$$

where Q = the ground-water discharge to Lake Ontario.
K = hydraulic conductivity
L = length of the shoreline
H = thickness of the water bearing formations
ΔH = hydraulic gradient

The hydraulic gradient obtained from the existing piezometers ranges from 0.01 to 0.02 with an average value of 0.015. The length of the shoreline is 300 m. Thus, the ground-water flow to Lake Ontario from the site is 2.5×10^5 m^3 y^{-1}. This annual volume of water is about 3-4% of the total solid volume of the site, assuming a depth of about 35 m. If the ^{226}Ra activity in the shore piezometers averages about 100 Bq m^{-3}, about 2.5×10^7 Bq y^{-1} is carried into the lake. But the total amount of ^{226}Ra which has been disposed of at the site is 2.3×10^{13} Bq, so that only about 10^{-6} of this is lost from the site per year. A comparable calculation for uranium indicates that about 25 kg of this element reaches the lake.

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