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Topical Report No. 6

SURFICIAL GEOLOGY OF WASTE DISPOSAL AREAS, AECL PROJECT, CHALK RIVER, ONT.

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INTRODUCTION

General Statement: Since November 1955 the Geological Survey of Canada has been cooperating with Atomic Energy of Canada Limited (AECL) in research on the disposal of radioactive waste materials from nuclear reactors. In 1957, J.A. Fraser (1) reported on disposal at depth in porous

(1) Fraser, J.A. (1957) - "Disposal of Radioactive Waste Solutions in Porous Strata"; G.S.C. Admin, Files, 5-21.

strata. Subsequent work by the present writer (2) dealt with the nature and

(2) Gadd, N.R. (1958) - "Geologic Aspects of Radioactive Waste Disposal, Chalk River, Ontario"; G.S.C. Admin. Files, 21-G-11; February 1958.

distribution of surficial sediments at the Chalk River plant of AECL and their significance in the current and projected disposals. This report contains a map of surficial deposits of the vicinity of the AECL plant that supplements the preliminary report (2).

Some of the characteristics of rocks and surficial sediments of the AECL plant area are outlined below and are discussed in the preliminary report (Gadd, 1958) so that it may suffice here to give a brief resume of some aspects of waste disposal in the ground at the Chalk River site.

Bedrock of the area, although itself impermeable, does not appear to provide an adequate reservoir basin because of the degree and magnitude of fracturing and faulting. Therefore, the best available reservoir for radioactive liquid wastes is to be had where bedrock is veneered by impermeable material. Considering the physiographic features of the area, Perch Lake

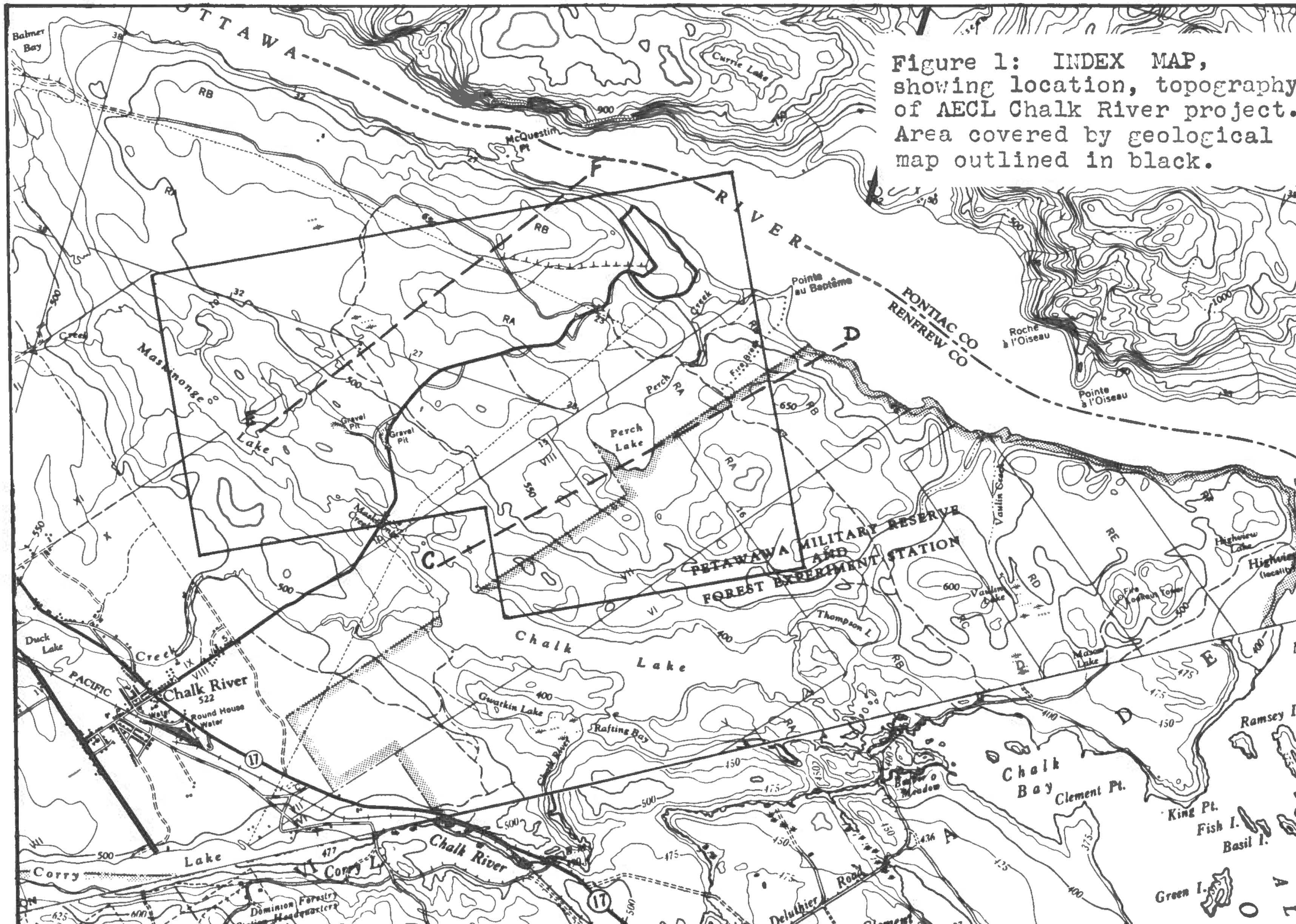

Figure 1: INDEX MAP, showing location, topography of AECL Chalk River project. Area covered by geological map outlined in black.

Drainage Basin is the only natural basin available. It is lined, at least in part, by glacial till that may or may not be an effective barrier to movement of radioactive liquid wastes. Though permeable, the glacial till is the least permeable of wide-spread surficial materials. For these reasons its areal extent and its permeability are of prime interest. Recommendations on an exploratory program are made in the preliminary report, (Gadd, 1958).

Ground-water movement in the Perch Lake Drainage Basin is complex and not well known, but the movement is generally southward. A and B disposal areas drain naturally to Perch Lake and via Perch Creek to Ottawa River. The drainage system is monitored rigorously and it is known that to date activity is retained in the vicinity of the disposal areas so that the water in Perch Lake is potable. In the opinion of the writer, sites within the Perch Lake Drainage Basin provide the greatest possible delay between disposal of wastes and outflow of ground and surface water in streams tributary to the Ottawa River. Thus, although Perch Lake Basin is far from being an ideal disposal site, it has proven adequate for current demands. No other part of the area described in this report should be considered for development as a disposal site.

Buildings and storage tanks at the plant site are founded on materials that are among the most permeable of the area. The writer therefore would support any plan to remove storage tanks from the plant area to a site as far removed as possible from the Ottawa, i.e. to the Perch Lake Basin.

The writer would stress that the Perch Lake Basin was not selected as a disposal site on the basis of his geologic findings. Rather, location of the plant in the Chalk River area dictated a selection of disposal areas within certain limits. This report confirms selection of Perch Lake Basin as the best of possible choices. However, for future development of experimental or industrial plants based on radioactive fuel, the writer would recommend strongly that geologic setting and its potential for waste disposal be considered as one of the prime factors in the choice of site. Investigations based on practical experience should be made well in advance of plant construction.

<u>Location and Access</u>: The area shown in the accompanying map, and

described briefly herein, includes part of the restricted area of the AECL project at Chalk River, Ontario, and a small triangular area along the northern limit of Petawawa Military Reserve. It includes Perch Lake, most of Maskinonge Lake, some smaller lakes, and lies chiefly between Maskinonge Lake and Ottawa River (see Figure 1). Small lakes are named in this report according to common usage by AECL personnel.

Access from Highway 17 at Chalk River, Ontario, is by private road that extends eastward from the village to the AECL plant on the west bank of the Ottawa River; a distance of about six miles. The asphalt-surfaced access road enters the south edge of the map-area at the south end of Maskinonge Lake and swings northward, then eastward to the main gate of the plant. Fire trails extending northward and southward from the main road afford ready access by car to most parts of the area. Cleared power lines and survey lines made foot traversing between the roads relatively simple during the period of field work.

Acknowledgements: Compilation of field data was done on the following maps produced for AECL from original survey by Aero Surveys Ltd., Ottawa:

Perch Lake - (April 1955)
West Perch Lake - (November 1956)
North Perch Lake - (June 1958)

These maps, whose scale is 1" to 200', were combined and reproduced on the approximate scale of 1" equals 375' by Topo Aerial Survey Co. Ltd., Ottawa, under the title "Perch Lake Drainage Basin and Environs". This latter map served as base for the compilation of the geological map presented in this report.

The writer gratefully acknowledges the efforts of Dr. C.A. Mawson and Dr. E.J. Evans in obtaining map prints required for the work and thanks them and their associates for many additional services. Officials of AECL generously provided office space in the plant and granted privileges that facilitated office and field work within the restricted areas.

Access to areas lying within the Petawawa Military Reserve was made

possible through the courtesy of the Officer Commanding, Petawawa Military Camp. Training schedules that greatly facilitated planning for field work were furnished regularly by Capt. Galbraith of the Headquarters Staff.

Topography and Drainage: Most of the map-area lies on a former large island in the Ottawa River that measures approximately 9½ miles long between Balmer Bay and Highview (see Figure 1) and nearly three miles wide between Maskinonge Creek and Ottawa River at the AECL plant. An abandonned western channel of the Ottawa is now occupied by a chain of lakes extending southward and southeastward from Balmer Bay through two small unnamed lakes, Maskinonge Lake and Chalk (Sturgeon) Lake to Chalk Bay. But for the stream connections and small rapids in this chain at two points, Maskinonge Creek and Burnt Bridge (at the N end of Chalk Bay), the area east of the channel would be a peninsula. Since it is referred to as a physiographic unit several times in this report, the area described above, lying between the abandoned channel of the Ottawa River and the present Ottawa valley, will be referred to as the 'peninsula'.

The 'peninsula' is essentially a bedrock ridge elongate in a northwesterly direction whose maximum elevation is greater than 650 feet, some three hundred feet above the level of Ottawa River. Profiles across the 'peninsula' at CD and EF (see Figure 1 and Figure 2) show a central depression occupied by Perch Lake and No-name Lake. This depression is named the Perch Lake drainage basin (Gadd, 1958). The drainage divide delimiting Perch Lake drainage basin (shown on the map, as a heavy dashed line) follows rock ridges and other topographic highs from a point about one-quarter mile north of No-name Lake southeastward between No-name and 233 Lake and thence southward to a point south of Perch Lake, then eastward to the map boundary and then northwestward along prominent rock-cored drift-covered ridges parallel to Ottawa River.

Surface drainage within Perch Lake drainage basin, which includes that from "A" and "B" disposal areas, ultimately passes through Perch Lake and is discharged to Ottawa River by way of Perch Creek.

Surface waters in areas of the 'peninsula' outside the Perch Lake drainage basin are carried to the Ottawa River and the Maskinonge - Chalk Lake

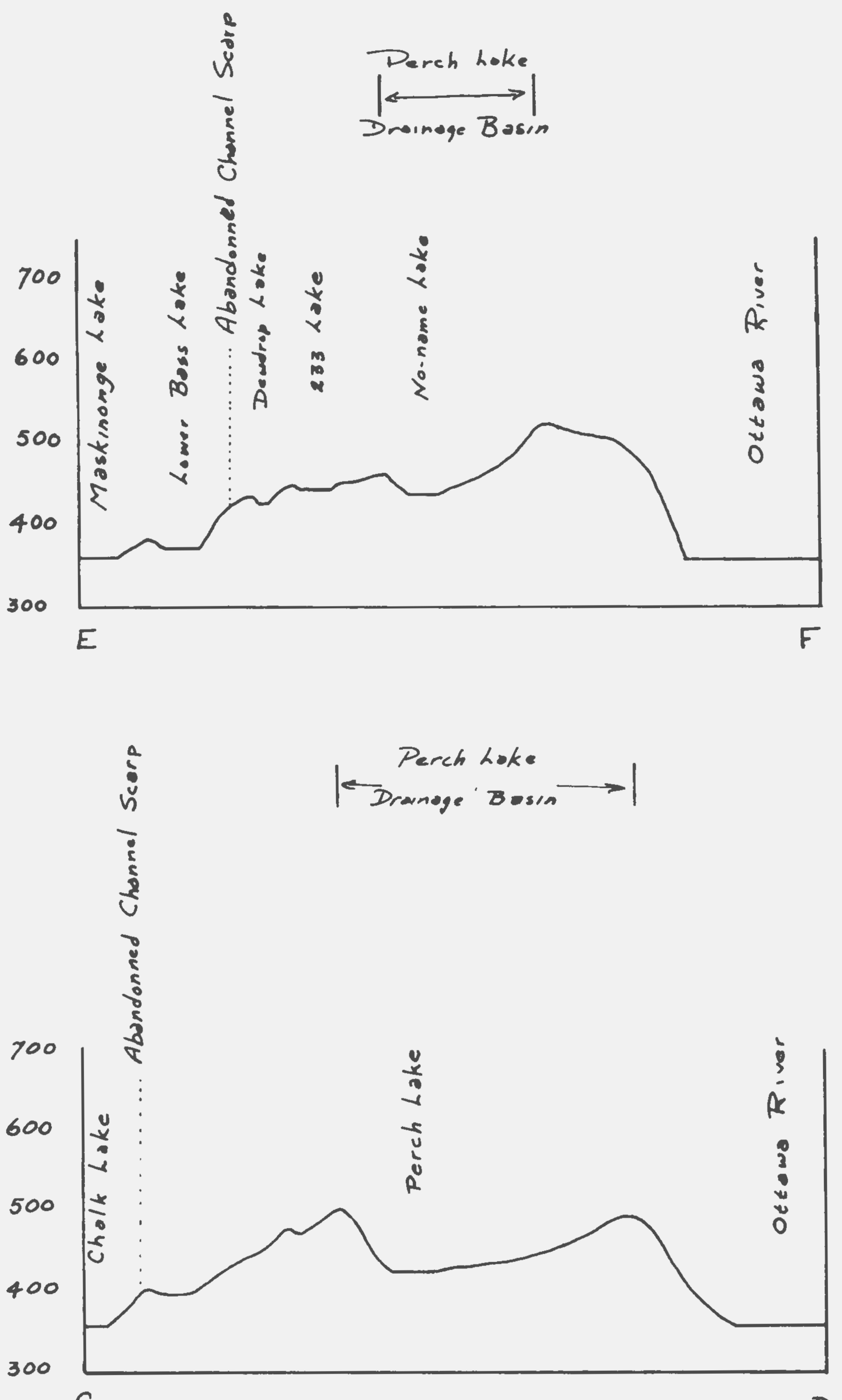

Figure 2: Profiles across 'peninsula' along CD and EF, showing depression of Perch Lake Drainage Basin

channel by direct run-off and by short streams. The extensive sand areas west of the Perch Lake drainage basin drain westward and southwestward into the abandoned river channel occupied by Maskinonge Lake. Several large springs and numerous seeps occur along the toe of the major scarp on the east side of the abandoned channel.

233 Lake has small inlet streams on the north, east and south that drain small areas of bog. It has no outlet, but tracing of movements of radioactive material has indicated that water flows underground from 233 Lake westward to the vicinity of Twin Lakes. Twin Lakes receive drainage from an extensive peat bog area in the northwest quarter of the map-area and discharge southward into a small depression whose south end is occupied by Dewdrop Lake. This system, also has no surface outlet, but discharges by seepage through the sands. In high stage Dewdrop Lake has had intermittent outlet flow southward across Fire Trail C-4 into a small depression, but surface drainage from the depression to the bog beyond is blocked by the prominent narrow dune ridge along the crest of the scarp that forms the eastern limit of the bog. Drainage of this bog is northward and westward into Lower Bass Lake and southward by a stream that enters Maskinonge Lake about a thousand feet southeast of the landing place.

Peat bogs between the abandoned scarp and the Bass Lakes receive water from springs and seeps along the toe of the scarp and drain southward into Lower Bass Lake as well as westward into Upper Bass Lake. The latter also receives drainage from an elongate bog in the northwest corner of the map-area as well as from minor seeps and springs in adjacent rocky slopes and gravel beds. The two Bass Lakes drain directly into Maskinonge Lake by short outlet streams.

A stream draining into the marsh at the north end of Toussaint Lake (east of the south end of Maskinonge Lake and draining ultimately into Chalk (Sturgeon) Lake originates in a depression among bedrock hills about a quarter mile west of Perch Lake and south of the HEPCO power line. The original maps of this area show a stream heading just west of disposal area "B", extending southward across the power line to join the drainage system that empties into Toussaint Lake. This has been changed on the geologic map because the channel and surface stream are not at the power line at this point, but rather about seven hundred feet to the northeast through bogs that connect into Perch Lake. The divide between the two streams is very low and a gap exists through which an intermittent stream might interconnect at times of very high water or as a result of snow-melt runoff in the spring. In dry season there is no stream in the gap, but there may be minor underground seepage through deposits of organic matter and sand.

Other small areas south and southwest of the Perch Lake basin drain to Chalk Lake and Chalk Bay. There is an abandoned early river channel southward from Perch Lake through a gap in the bedrock rim of the basin, which probably is due to faulting in the bedrock. Glacial till forms the surface drainage divide. The possibility of ground water movements southward through this break in the rim of Perch Lake Basin might be examined by drilling.

Another gap in the rim of Perch Lake basin occurs on Fire Trail A about one thousand feet south of Trail A1 that leads to the exhaust stack on the hillcrest west of the plant. This gap is plugged by glacial till that probably prevents drainage from the south and east of No-name Lake across to the east side of Fire Trail A. The hillside in the northeast part of the map-area drains partly into a shallow spruce and peat bog east of Fire Trail A that drains eastward to the Ottawa River. The outlet stream has been confined in buried culverts through the AECL plant area. The question of whether this confined stream carries water from the bog around No-name Lake is a function of the effectiveness of the plug of glacial till in the air-gap between the two shallow bogs.

GEOLOGY

Resume of Geologic History: The unconsolidated sediments are described below in their apparent chronological order, which is based on the order of superposition within the area. If the sediments preserved represent all the depositional environments of glacial and post-glacial time, then the interpretation of the record indicates a quite simple history for the area. Because no major erosional unconformities are recognized, the history outlined below is thought to be a true history of glacial and post-glacial sedimentation in the area.

Deep valleys were eroded into the Precambrian bedrock along planes of weakness afforded chiefly by faulting. The erosion, which probably was effective over an exceptionally long period of time, or at a number of different times, since the Precambrian, has removed most if not all consolidated rocks younger than Precambrian that may have existed in the region. The occurrence of sedimentary rocks in the so-called Brent Crater (Beals, 1958) [1] indicated that Palaeozoic seas probably submerged the Ottawa valley in the vicinity of

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(1) Beals, C.S. (1958) - "Fossil Meteorite Craters"; Amer. Sci. vol. 199, No. 1, July, 1958; p. 32.

Chalk River, but local evidence is lacking.

Further deepening of pre-glacial valleys occurred when Pleistocene ice sheets advanced from the north and east across the Chalk River region. Glacial striae on rocks along Highway 17 near the Petawawa Forest Experiment Station and on the shores of Chalk (Sturgeon) Lake show that at least part of the movement of glacial ice was directed by the valleys so that it moved directly down-valley, i.e. southeasterly. Regional movements, as indicated by lineations in the Algonquin Park area to the west, were south to southwest. Valleys transverse to the regional movements received thick accumulations of glacial till, thus most of the valleys and depressions in the bedrock of the map-area, which trend northwest, contain thick deposits of till.

Meltwaters associated with advance and retreat of the ice sheet carried sediment, ranging from clay size to gravel, in rivulets, streams and ponds to deposit sands, gravels and silty clays (varved) in and upon the glacial till sheet. Resultant pockets and lenses of these materials are encountered in borings within the plant area.

Deep submergence of the area followed closely upon deglaciation;

water flooding the glacially depressed land may have carried away much glacial ice as icebergs. This is a suggested explanation of the apparently sudden marine flooding of glaciated areas in other parts of the St. Lawrence Lowland. Probably the Chalk River area was submerged by the northern extremity of the Champlain Sea, but here the valley received large volumes of meltwater that so diluted the sea water as to make it essentially fresh. Of the few deposits of massive clay and silty clay encountered in borings along the western flank of the 'peninsula' samples examined contain no diagnostic fossils, but the sediments are similar otherwise to the typical clays of the Champlain Sea.

During the same period of late-glacial submergence the ice front retreated from the Algonquin Park area far enough to uncover the Fossmill outlet of the Glacial Great Lakes (Chapman, 1954) [1]. This river (the ancestor of the

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(1) Chapman, L.J. (1954) - "An outlet of Lake Algonquin at Fossmill, Ontario"; Geol. Assoc. of Canada Proc., vol. 6, pp. 61-68.

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present Petawawa River), the North Bay-Mattawa channel (a younger outlet of the Glacial Great Lakes), and meltwater streams flowing from the waning ice sheet, delivered large volumes of sand to the Ottawa valley. This sand now occupies most of the surface area of the triangular region west of the Ottawa between Point Alexander and Petawawa and lying below 575 feet elevation. It is postulated that the sand was deposited as a compound delta or as valley fill in the northern tip of the Champlain Sea, when it stood at about six hundred feet above present sea-level.

Since that time some 8,000 years ago, land has risen relative to sea-level and large bodies of water have disappeared, exposing uncovered areas to erosion. During recession of the sea prominent ridges were exposed as islands and fine sediments were removed by wave action, leaving bare rock or lag concentrations of boulders and coarse stony gravel. On thick till deposits, wave action disturbed only a surface layer and concentrated coarse material as a veneer. In such places there is an abrupt gradation from loose gravel to compact till at three to five feet from the surface.

Some parts of the hills north of No-name Lake and south of Perch Lake may have existed as islands in the deep-water embayment. But as water levels lowered, the area described above as the 'peninsula' emerged as an island in the ancestral Ottawa River. When water levels stood somewhere below 450 feet, present elevation, currents in the river channels east and west of the island were sufficiently strong to transport the coarse gravel and sands of map-unit 4 that are found in the vicinity of Upper Bass Lake and Maskinonge Lake and that underly the site of the AECL plant.

Uplift in succeeding years has caused the replacement of the western river channel by the series of lakes between Balmer Bay and Chalk Bay and has reversed the northern part of the drainage so that some water now flows northward to the Ottawa at Balmer Bay. The channel remains quite well marked by the steep banks cut in sand, roughly parallel to the 500 foot contour, and by the bottom-sediment gravels in abandoned terraces below 500 feet elevation.

Present topography and drainage reflect the pre-glacial pattern. Many parts of the drainage system now occupy re-excavated pre-glacial channels and it is expected that surface and sub-surface drainage in the AECL plant area follow the bedrock topography except where glacial and post-glacial sediments are of such a character and so deposited as to modify flow.

Poor drainage of many upland areas has resulted in accumulation of large areas of peat (map-unit 5). A few marshy areas also designated as bog under map-unit 5 have been drowned and expanded by recent dam-building activities of the beaver that abound in this area.

Bedrock: Areas of bedrock outcrop and of bedrock thinly veneered by surficial deposits are mapped as a single unit, (map-unit 1). There are no apparent physical differences in the rock types of the area that would seem to be significant in the problem of waste disposal in the ground, thus the rocks are not mapped in detail. Rocks observed in the map-area are Precambrian and most are granitic; pink, red, grey granites, granite gneisses, paragneisses, aplites, and pegmatites; many of these rocks are garnetiferous. Small outcrops of greenish grey metamorphic rocks of granitic composition and dark green to black amphibolite also occur. All are hard, siliceous crystalline rocks that are, of themselves, impervious to movements of ground water.

The most significant feature of the bedrock is its physical state. Few large masses of unfractured rock occur. Generally the bedrock of the area is much faulted and fractured. Major faults trend northwesterly parallel to the Ottawa river in this vicinity, and constitute the principal topographic control. There are numerous cross-fractures. Therefore, one should expect to encounter a large number of interconnecting fractures in the bedrock of the area.

It is not known whether fractures in the bedrock of the AECL plant area actually transmit ground water in important quantities. However, it is reasonable to make an analogy with surrounding rural areas where it is known that diamond drill borings into the bedrock serve as wells for private use. The well water must necessarily be furnished through fractures in the rock. Bedrock under the plant area may be expected to contain water-bearing fractures, some of which may connect directly with the Ottawa River system.

Surface Deposits

Glacial Till: Map-unit 2 covers areas underlain by glacial till. Although the material is widespread in the area, it is seen rarely at the surface. Yet it is more significant in this study than the secondarily derived materials that overly it in the areas of occurrence shown on the map.

Glacial till generally is the heterogeneous material abraded from the bedrock, more or less pulverized and deposited by the continental glaciers. It contains chiefly local bedrock material, but includes some material transported from distant sources. In the Chalk River area the glacial till is composed chiefly of granitic material similar to the bedrock described above. The material ranges in size from fine silt to large boulders of five feet or more in diameter. The resultant mixture, being highly compressed and very dense, constitutes a tough, gritty material that, in its natural moist state drills at a rate similar to that for limestone, and that dries in air to the consistency of a soft sandstone. Granite boulders within the till are a serious drilling problem.

Borings in the map-area have revealed a discontinuous till sheet that ranges in thickness up to about one hundred feet, the thicker sections being in broad depressions between ridges. Many of the ridges are bedrock that remained bare after glaciation or that have been uncovered by erosion since the period of glaciation. Commonly the till rests directly on bedrock. It contains a few layers of sand, gravel and varved silt, but no persistent break in the glacial till sheet has been recognized. It is, therefore, assumed that water-laid sediments associated with the glacial till are normal melt-water sediments that form small discontinuous lenses within the till sheet.

Except for the few places where glacial till outcrops, the areas shown as map-unit 2 have a surface cover of coarse gravel and boulders that grades downward into glacial till or rests directly on bedrock. In these areas lag gravel deposits derived from underlying till by wave action and slope-wash range in thickness up to about five feet. A concentration of boulders, ranging over five feet in diameter, distinguishes these sediments from the transported alluvial gravels of unit 4.

Massive Silty Clay: Soft, sensitive, grey silty clays ranging to twenty-eight feet thick have been encountered in at least four borings within the AECL plant area (Gadd, 1958, Figure 3). They are not exposed in the map-area and therefore not shown on the map. These clays are similar in physical characteristics to the marine clays common farther downstream in the Ottawa River system. To date, they have not been encountered within the Perch Lake drainage basin, but seem to be part of a valley-filling deposit that once occupied the abandoned valley on the west side of the 'peninsula' (see above). Similar clay probably filled or partially filled most deep post-glacial depressions below, say, six hundred feet elevation. In the Chalk River region such valleys have been occupied by modern streams whose erosional activity has removed all but small masses of clay that hang on the flanks of existing valleys.

Sand: Uniformly fine-grained yellow-buff and rusty (weathered) to grey (unweathered) sand is present in most of the area as a thick mantle over older sediments and over bedrock. Part of this sand is wind-blown and occurs in characteristic dunes, now mostly stabilized by vegetation, but most of the sands of the area occur in thin, nearly horizontal layers whose structure indicates deposition by water currents. The uniform grain-size, the bedding structure, and the distribution of the sediment over a broad triangular area along the Ottawa River indicate a deltaic origin for the sand.

Alluvial Graval: Coarse gravels with few boulders over five inches in diameter and associated coarse sands (map-unit 4) occupy abandoned terraces of high-level stages of the modern drainage system. Such deposits are known to be five to ten feet thick in the vicinity of Upper Bass Lake. Others have been exploited for material used as road ballast in the plant area. Well-rounded pebbles of granite and granite gneiss constitute the bulk of the sediment.

Peat: Bogs containing accumulations of peat attain thicknesses of ten feet or more in many areas and occupy large surfaces within the map-area (map-unit 5). Most apparently are underlain by sand, but, drainage is poor because of irregularities in topography and the existence of natural barriers that resist erosion.