INTERIM REPORT OF
SOIL RESEARCH RELATED TO REVEGETATION OF THE OIL SANDS AREA

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ABSTRACT

Monitoring was continued at instrumented sites which were selected in Spring 1976, at Mildred Lake, Supertest Hill, the GCOS dike, and near Richardson Tower. Because of budget limitations, sites at Richardson were only monitored occasionally. However, information was obtained at a number of temporary `outlying sites', which showed that conditions at the instrumented sites are fairly representative of those under similar vegetation in the surrounding area. Special emphasis in 1977, was placed on obtaining detailed information on moisture tensions using thermocouple psychrometers, and on aquiring accurate information on changes in moisture distribution during spring thaw. Growth of grasses and legumes in Tailings sand, and the effect of adding materials such as peat and glacial till to Tailings sand, were studied using lysimeters both indoors and in the field, and by establishing small plots, all of which were instrumented for gathering of physical and chemical information. Aspects of nutrient cycling such as nutrient inputs and outputs at forest sites, nitrogen mineralization and immobilization, retention of nitrogen by soil mixes, and decomposition of plant materials, were investigated with ^{15}N and ^{14}C. Laboratory studies were carried out on nitrogen and carbon cycling in Tailings sand and two overburden marerials. Much interpretation of information gathered over the year is still to be done and will be included in the next report.

ACKNOWLEDGEMENTS

The work of Ian Madsen (summer student) who took most of the field readings over the summer, is gratefully acknowledged. The project acknowledges the assistance of C. R. Jones, Dept. of Soil Science, who has performed all the ^{15}N isotope analysis and also Dale Kaliel, a summer student who helped both in the laboratory and in the field. K. Morency performed most of the Kjeldahl analyses on field samples, and M. Stanners has recently started work in our laboratory.

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1. INTRODUCTION

The purpose of this study, is to provide basic information on disturbed and undisturbed soils in the Oil Sands area, which can be applied to management programs involving revegetation of spoil piles, Tailings sand piles, and other disturbed materials.

The study was divided into four main parts, these are: (1) examination of the effect of clay lenses on water conditions in Tailings sand; (2) examination of chemical, physical and microbiological properties of Tailings sand in various combinations with overburden and peat; (3) examination of control areas to determine base-line soil characteristics; and (4) examination of nutrient cycling in fertilized and unfertilized soils and in the Tailings sand mixtures.

Lysimeters were installed at the University farm in 1976, to study movement of soil solutions through sand which had been modified by additions of other materials.

Selection of field sites for instrumentation was begun in Spring 1976. The purpose was to monitor water and temperature relations at disturbed and undisturbed sites in the Fort McMurray area as a basis for evaluation of reclamation projects. Sites established on the GCOS dike were expected to give some insight into problems peculiar to the Tailings sand.

Lysimeters and lysimeter - type plots were established at the AOSERP Mildred Lake Research facility during autumn 1976. The aim was twofold; first to investigate the effect of various amendments on water conditions, and second to obtain information on the physical environment and its effect on biological and chemical activities in mixtures of Tailings sand and amendment materials. The plots are being used for experiments on decomposition of plant materials using ^{15}N and ^{14}C techniques.

Analysis of samples, to determine base-line characteristics of soils within the Oil Sands area, is nearly complete. The data will be useful, when combined with nutrient cycling information, in calculating the long-term behaviour of mixtures of different materials.

Nutrient cycling studies undertaken on the GCOS dike and in the plot at Mildred Lake will provide information on the overall processes of nitrogen uptake by plants, its conversion to litter-nitrogen, and its subsequent decomposition and remineralization under field conditions. More specific information on the rapid dynamics of carbon and nitrogen in amendment materials will be needed later to determine how these materials affect biological activity.

Laboratory studies are being carried out on carbon and nitrogen cycling in amended and pure Tailings sand, till, and shale, and also in agricultural soil for comparison. This should further our understanding of the behaviour of amendments on Tailings sand.

2. RESUME OF CURRENT STATE OF KNOWLEDGE

In the first year of operation effort was put into installation of equipment rather than into obtaining experimental results. Soil samples were collected and analysed to provide base-line data on soil properties in the Oil Sands area. It was shown that problems with Tailings sand are related to the very high sand content, low organic matter content, high pH (9.2), poor wettability, low nitrogen content and low exchangeable cation content.

Sands in the study area were shown to drain rapidly following rain, until a tension of about 60 mbar is reached after which drainage is slow. This agrees with the range suggested by Russel (1961), Salter *et al* (1967) and Webster and Beckett (1971) for sands. At this tension, the moisture available to crops is fairly large in dike Tailings sand, but much less in some other sands. Adding till (20% by weight) to Tailings sand did not appear to increase available moisture significantly nor did it slow hydraulic conductivity. Peat additions however increased both the moisture available at 60 mbar and hydraulic conductivity.

Lysimeters, which are large tank type containers filled with soil and equipped with outlets at the bottom to collect drainage waters, showed that ions in solution are rapidly removed under intense leaching conditions and that the pH of Tailings sand or sand mixed with peat decreases rapidly. However, in Tailings sand mixed with glacial till, the surface soil pH decreased only slightly after eight months leaching and plant growth was relatively poor.

Use of peat to control erosion has been studied, and will be reported in a thesis by R. J. Logan who worked under the supervision of W. B. Mcgill and M. Nyborg at the University of Alberta. Two reports on revegetating steep sandy slopes have been published by Syncrude Canada Ltd., one written by Takyi *et al*. (Univ. Alberta) and the other by Rowell (Norwest

Soil Research Ltd.). These reports deal with a wide range of problems associated with establishing and promoting good growth of grasses on Tailings sand slopes. They were not designed to provide background information from which programs involving a wide range of conditions can be developed, nor can they be readily used in evaluating different reclamation alternatives. Apart from these reports, there is no information on erosion and nutrient cycling in connection with these sands either before or afer they have been mined.

A systems analysis approach was adopted for investigation of mineral cycling in order to provide a flexible means of integrating the various aspects of the study and of including information from the literature and other AOSERP projects as it becomes available. A soil-plant system is divided into compartments, which in simplest form consist of plant and soil. Inputs and outputs of nutrient elements between the compartments, and inventories within them are measured (Ulrich and Mayer, 1972). An example of division of the ecosystem into compartments is shown in Figure 1. It was decided that the base-line situation in forest and reclaimed soil sites should be studied according to this framework. Studies on nitrogen are being emphasized because of its quantitative importance and complexity in the ecosystem. Approaches to nitrogen study and experimental designs were introduced in the 1976-77 report (Cook et al in prep.).

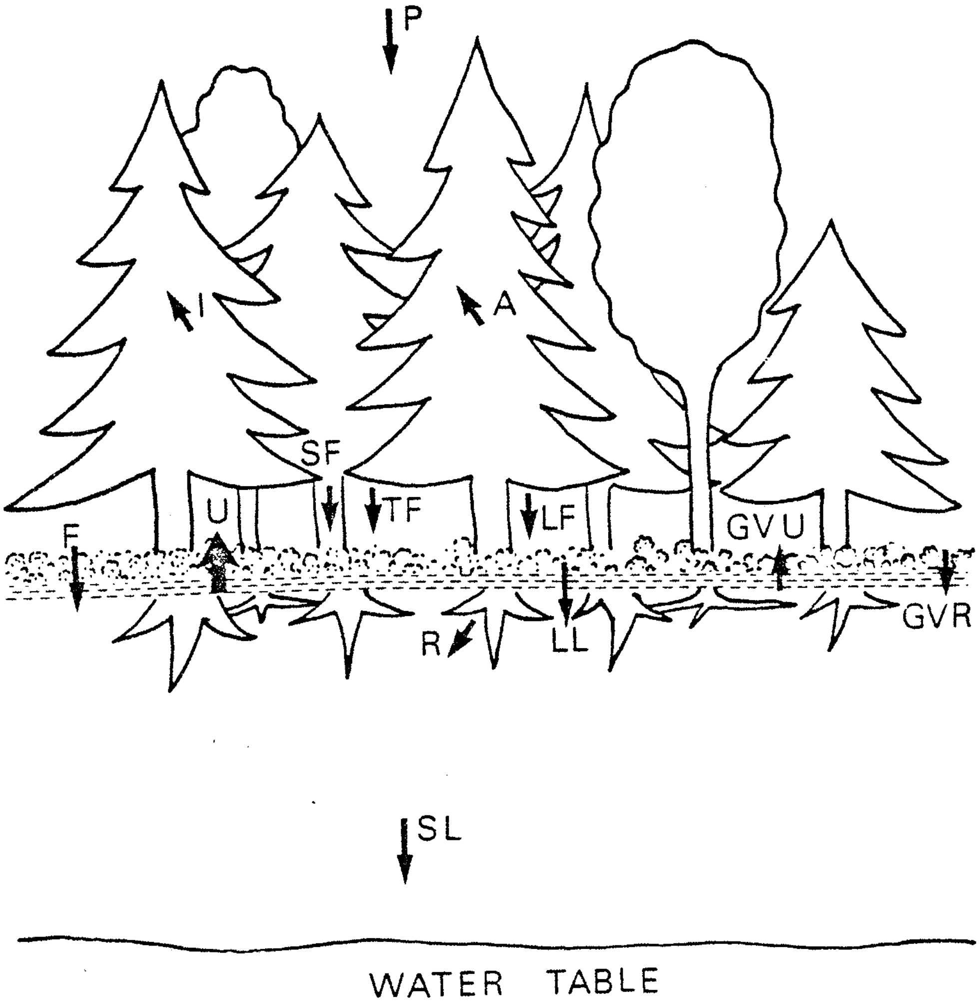


Figure 1. Compartments of the nutrient cycle at a forest site. The compartments are precipitation (P), canopy interception (I), stemflow (SF), fixation (F; in N cycle), litter leachate (LL), root slough (R), ground vegetation uptake (GVU), ground vegetation return (GVR), gross uptake (U) and accumulation (A). Adapted from Morrison and Foster (1974).

3. STUDY AREA

3.1. LOCATION OF FIELD SITES

A map of the AOSERP study area is shown (Figure 2). Selection of sites for permanent instrumentation within this area was made in Spring 1976. Selection was governed by the need to cover the range of vegetation types with emphasis on the dominant soil parent material which is sand, and also by accessibility. Sites on sand include all those within the Mildred Lake research facility boundaries and close to them (Figures 3 and 4) as well as 3 sites near Richardson Tower. The Richardson sites were designed to complement those of sub-project V.E. 6.1. The site on till at Supertest Hill was chosen because till is a constituent of many of the present overburden piles.

A nitrogen cycling experiment was carried out in the north east area of the GCOS dike, on the second berm (GCOS site 3). Sites of the experiment on nitrogen mineralization and immobilization from forest litters were located as follows:

Mildred Lake site 2 in jackpine (Figure 3).
Mildred Lake site 6 in aspen. Approximately 0.1 km N of Mildred L. facility boundary (Figure 3).
Mildred Lake site 7 in mixedwood. Approximately 100 m East of Mildred L. site 3 (Figure 3).
Mildred Lake site 8 in spruce. Approximately 0.5 km N of Beaver Creek, on the Fort Mackay road.

Ten lysimeters and three plots of Tailings sand mixes were established at the Mildred Lake field research facility.

In addition to the permanently instrumented sites, soil sampling was carried out and moisture determinations (neutron probe) were made at 32 `outlying' sites. The purpose was to obtain more information on the relationship between soil conditions (particularly moisture) and type of tree cover, and

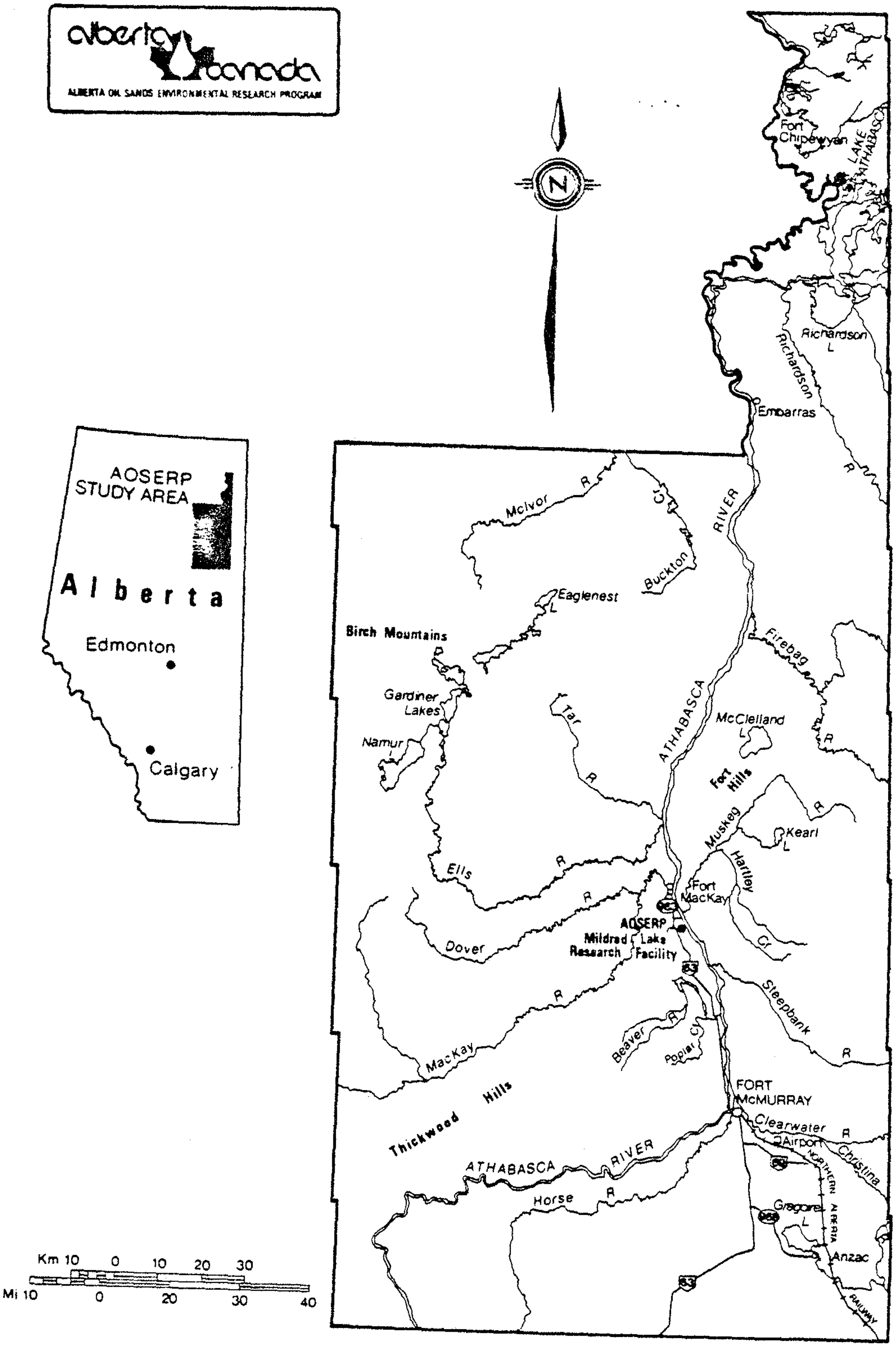


Figure 2. The AOSERP study area.

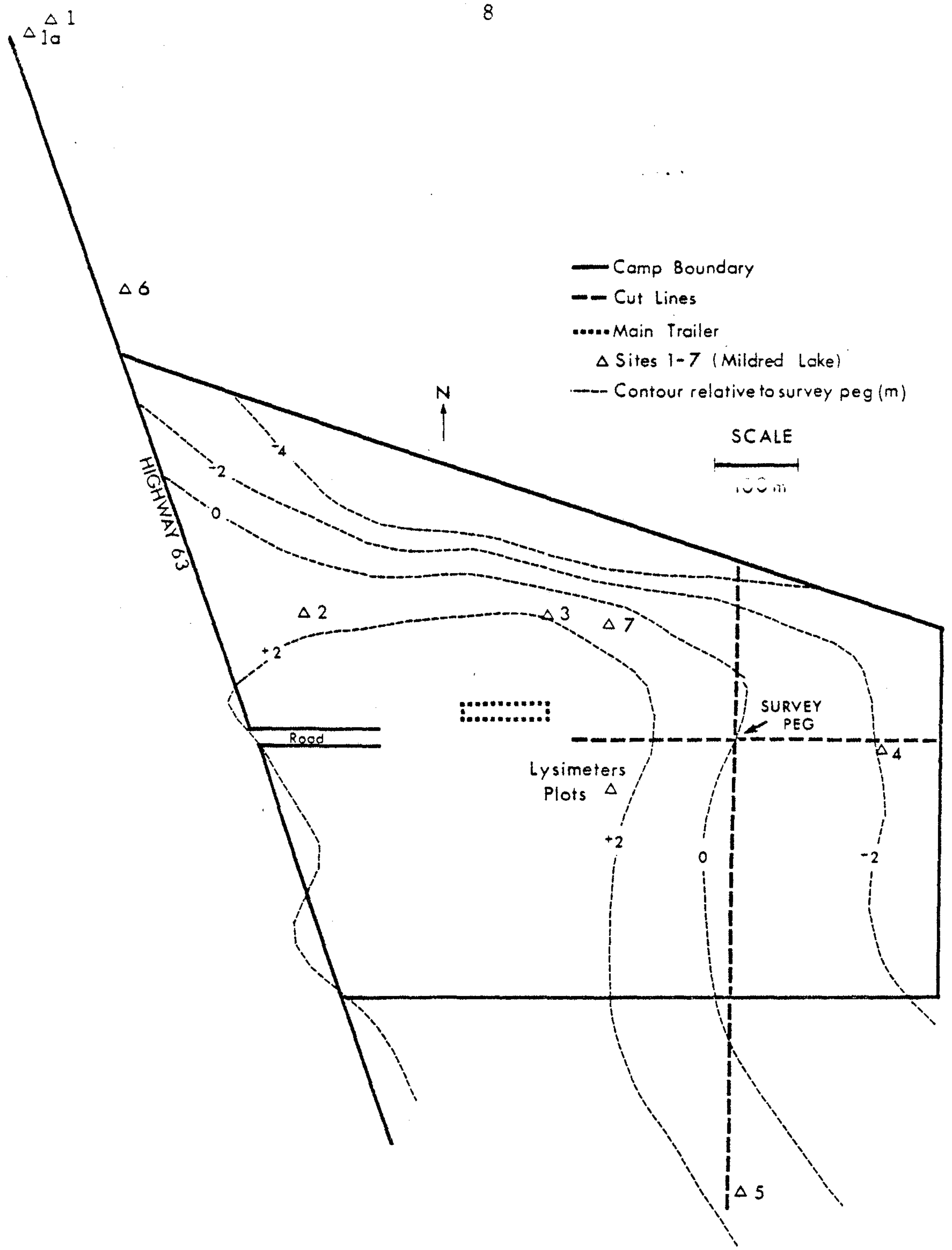


Figure 3. Map showing location of instumented sites within and near the AOSERP Mildred lake research facility.

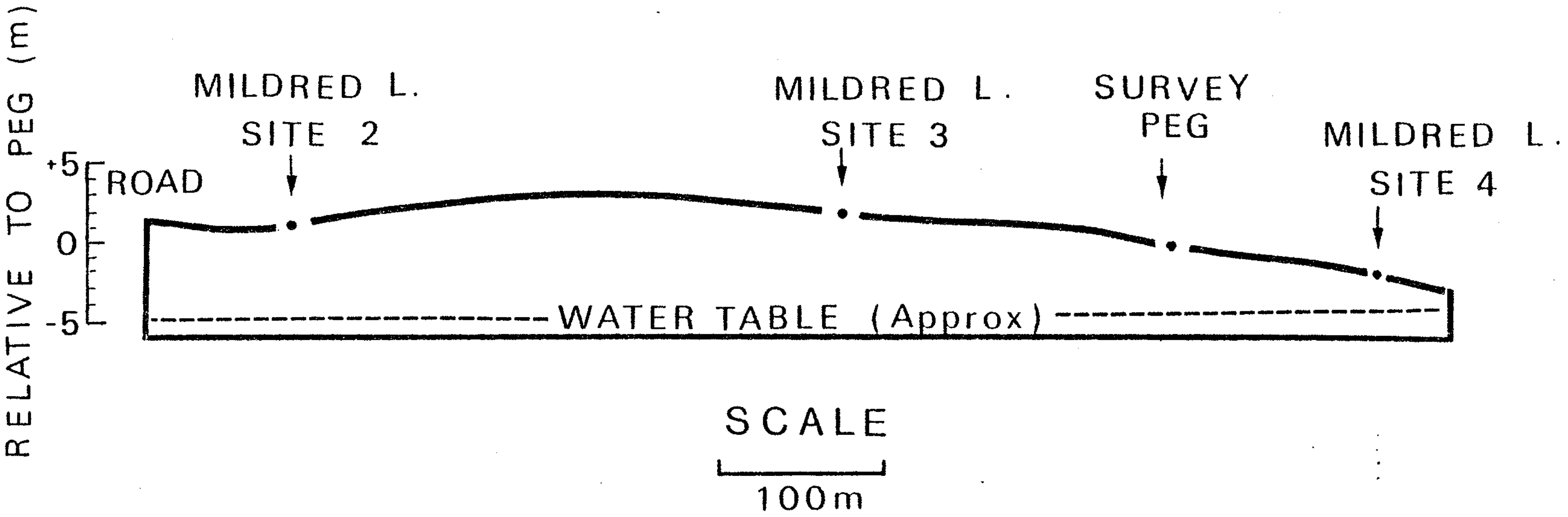


Figure 4. Vertical cross-sectional diagram showing location of Mildred Lake sites 2, 3, and 4 relative to the water table.

to see how conditions at the permanent sites relate to those of the surrounding area. The location of most of these sites is shown (Figure 5). Other sites not shown are listed in Table 1.

Table 1. Outlying sites not included in Figure 5.

Site No.	Location
30	32 km ESE of the G.C.O.S plant
31	2 km south of 30
35	Gordon Lake Airstrip. East side
36	Muskeg Mtn. Airstrip. West side
37	Richardson Airstrip. West end. South side
38	Bitumount Airstrip. West side
40	3 km North of Supertest Hill, in Jackpine
41	Near bend in the road between Firebag River and Richardson, 9 km North of Firebag River
42	1.7 km SW of 41, on the road.

3.2. SITE CHARACTERISTICS

At several of the instrumented sites (Mildred Lake 4, Supertest, GCOS 2 and Richardson 5), the water table averages within 3 m of the surface while at the others it is relatively deep (Table 2). Although the true water table at Mildred Lake site 3 is deep (Table 2) , layers of tar sand at 100 cm below the surface and deeper, create temporary perched water conditions.

Soils on the sands are mainly Eluviated Eutric Brunisols. The H layer and Ae horizon are very thin or almost absent at sites covered by Jackpine (Pinus banksiana), but are thick at the Aspen (Populus tremuloides), Birch (Betula papyrifera) and Spruce (Picea glauca) sites.

Profile characteristics and analyses of soils at various study sites appear in Appendix Table 1.

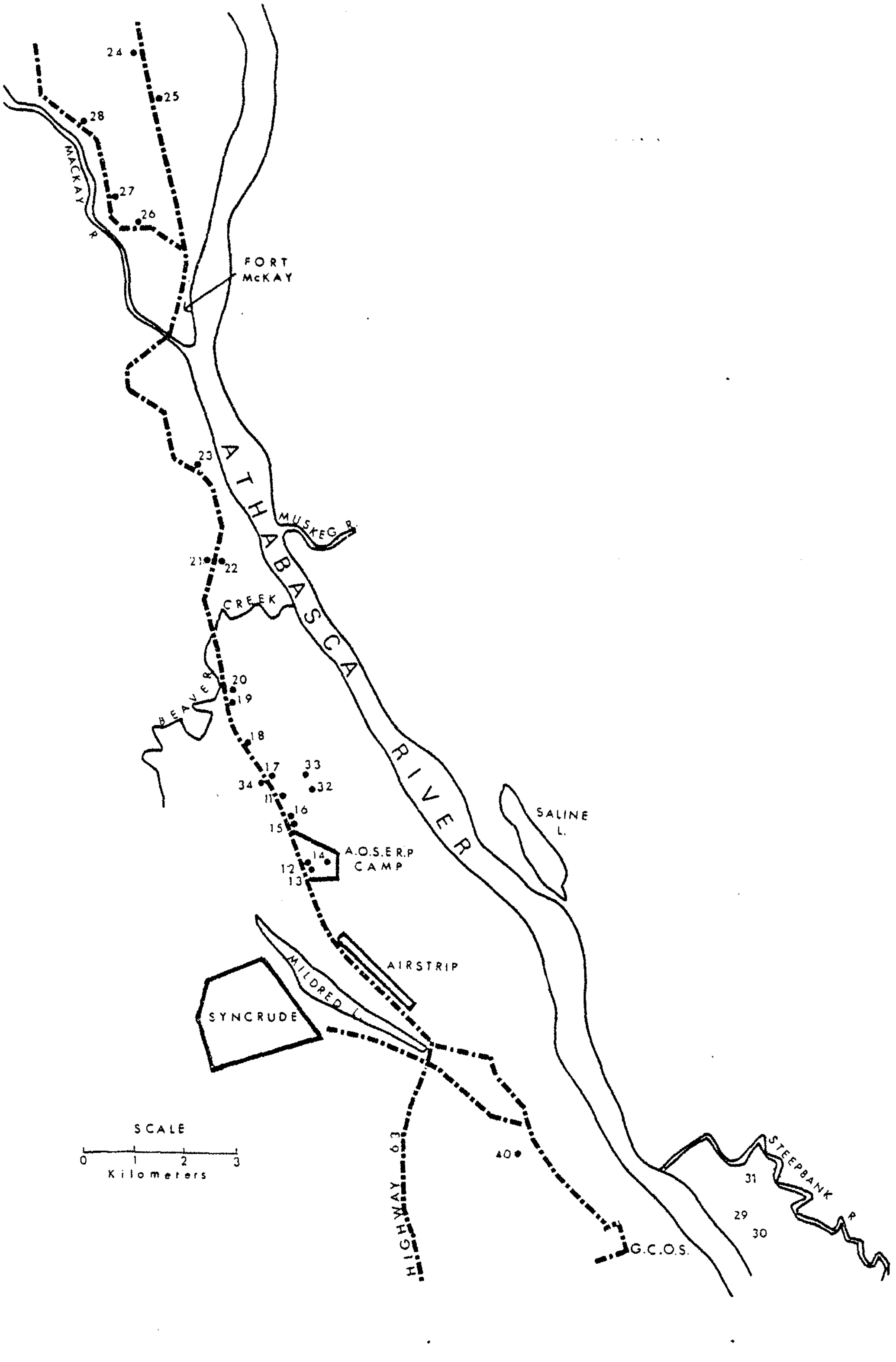


Figure 5. Map showing loacation of most of the 'outlying sites'.

Table 2. Instrumented site characteristics.

Location		Material	Dominant Vegetation	Aspect	Water Table (mean)
Mildred Lake	1	Sand	Aspen	SW	>6 m
	2	Sand	Jackpine	Flat	6 m
	3	Sand	Birch/Aspen	Flat	>6 m
	4	Sand	Mature Spruce	Flat	2 m
	5	Sand	Aspen	Flat	3 m
Supertest Hill		Till	Aspen	Flat	3 m
G.C.O.S. Dike	1	Sand	Grass	NW	>6 m
	2	Sand	Grass	SE	2 m
Richardson	4	Sand	Jackpine	Flat	>6 m
	5	Sand	Birch/Aspen	NE	2 m
	6	Sand	Birch/Aspen	NE	>6 m

4. MATERIALS AND METHODS

4.1. FIELD STUDIES

Of the instrumented sites (Table 2) 5 were monitored intensively (Mildred L. 2,3,4, GCOS 1,2), while for economic reasons, those at Richardson were monitored only occasionally and often with the help of sub-project V.E. 6.1.

4.1.1. Ground temperatures

Thermocouples installed at depth intervals down to 600 cm beneath the surface at the field sites and to 100 cm in the Lysimeters, were read using a simple microvoltmeter with a built-in reference junction. During winter an ice-water mixture in a vacuum flask was used for a reference junction.

4.1.2. Soil moisture tension

During summer 1977, great emphasis was placed on information from thermocouple psychrometers. About 150 of them were monitored. These instruments are very effective in the range 5 to 40 bars. Although readings can also be obtained between 1 and 5 bars, laboratory experience shows that the error is large within this range, especially at low temperatures. A relatively new design of single junction psychrometer, made by Merryll Inc., was used in addition to Wescor Inc. instruments. The thermocouples of the Merryll psychrometer are protected by a fine mesh metal screen rather than ceramic. In sands, where vapour movement is large, and quick response times are important, the more permeable barrier of the Merryll psychrometer should be an asset. All psychrometers were calibrated using three different salt solutions at two different temperatures. During installation, lead wires were buried in such a way as to minimize errors induced by thermal conduction. Merryll psychrometers were inserted at a depth of 5 cm at Mildred Lake sites 2,3, and 4 and GCOS sites 1 and 2, while both Merryll and Wescor psychrometers were installed at a depth of 10 cm. At greater depths and at Supertest Hill, only Wescor psychrometers were used. Because of large lateral variation, moisture tensions were based on the geometric mean (Webster, 1966) of readings from 3 to 5 psychrometers located at each depth, except at the Supertest Hill site which was given lower priority with only 2 psychrometers at each depth. Readings at the AOSERP field Research facility were taken almost daily while those on the GCOS dike were read approximately twice a week.

4.1.3. Soil moisture content

Aluminum access tubes for the neutron probe were inserted (by hammering where necessary) into auger holes which only slightly exceeded the diameter of the tubes. Two tubes were installed at each site, one to 6 m and the other to only 3 m so that duplicate measurements could be taken at the shallower depths. One tube was installed to a depth of 100 cm in each of the ten field lysimeters. Counts of 1 minute duration have been taken using either a Nuclear Chicago or Troxler probe. Calibration was carried out by augering holes, inserting an aluminum tube, taking probe counts and retaining the augered material for gravimetric moisture determination. All sands, including the Dike Tailings sand, gave essentially the same calibration equations using the Nuclear Chicago 5810 probe. Equation 1 relates volumetric moisture content (M) to count ratio (count / standard count),(CR) and depth (D) for depths greater than 10 cm , while equation 2 applies to the

1. $M\ \% = (CR + 0.0486 - (0.0477 \times \text{Log } D)) / 0.01801$

2. $M\ \% = (CR - 0.02794) / 0.007892$

At depths of over 150 cm, the value of D is 150.

10 cm sampling depth where much of the radiation escapes from the soil surface.

The equations used for the non-sand material at Supertest Hill differ slightly from those above. Equations relating counts between the different kinds of probe used were also obtained.

During the summer and fall, neutron probes give accurate moisture information and have the advantage over gravimetric sampling of consistent sample location and minimal site destruction. However, during spring thaw, the probes were found to vastly overestimate soil moisture content. At this time, soil almost saturated with moisture is in contact with soil which is almost dry. While probe readings within the saturated layer should theoretically be fairly accurate, those taken within adjacent dry soil are erroneous, because the sphere of influence is related to dryness and expands to include moisture in the wetter soil. Gravimetric moisture determinations alone suffer from considerable sampling error unless an impractical number of samples are included (Table 3). Although a thermal method of soil moisture determination was investigated under sub-project V.E. 6.1, it did not satisfactorily cover the range of moisture needed. The method adopted during the thaw period was therefore as follows. Auger samples were taken within 1 to 2 m of each probe tube and these were used to show the boundaries between wet and dry soil. The moisture content of the wet soil was obtained from the probe readings and that of the adjacent dry material from the gravimetric samples. This method should theoretically give readings which are much more accurate than relying on probe or gravimetric readings alone and should be reasonably well related to changes in moisture indicated by the probe alone later in the season.

During winter, snow cover influences near-surface readings. Removal of snow from some probe tubes and its

Table 3. Statistics reflecting sampling errors associated with Gravimetric sampling.

Sample location		Sample size	Mean	Median	Standard deviation
M.L.2.	0-5	10	10.0	9.3	2.2
	10	10	8.8	8.9	1.8
	20	10	8.7	8.7	1.3
M.L.3.	H	6	20.3	20.6	6.0
	0-5	6	13.9	12.1	4.3
	10	6	11.4	11.3	1.1
	20	6	11.2	11.0	1.4

replacement after counts were taken was necessary for moisture determinations at this time of year so that effects of the snow cover could be assessed.

The changes in soil water content can be combined with measurements of non-intercepted precipitation to obtain estimates of water drained combined with that removed by vegetation. Separation of these two components is more difficult but several approaches are possible. During thaw, the water drained may be calculated from the 'bulge' in moisture content which moves downwards through the profile as the season progresses. Following complete thaw, drainage can be calculated from the relationship between moisture content and the hydraulic conductivity of material beneath the rooting zone, and tensiometer readings (Rose and Stern, 1965). During winter, moisture readings below the frost zone and inferred tensions can be used for drainage calculations.

Moisture conditions were determined at a number of 'outlying sites' early in June. Neutron probe measurements were made using a temporary access tube in an augered hole. The readings were adjusted for the effects of lack of back-filling; these effects having been determined elsewhere.

4.1.4. Soil water sampling

Commercial suction-type ceramic water collectors (Figure 6) were installed in duplicate at two meter depths at the two forest sites, Mildred Lake 2 and 3. One was installed at a depth of a meter in each of the ten outdoor lysimeters and the three plots. Collectors were also installed at a depth of a meter at GCOS sites 1 and 2. In each case the holes were backfilled with the original material. The collectors slowly gather water when a permanent suction is applied.

4.1.5. Leaf litter collection

Leaf litter was collected on 1 sq. m nylon mesh screens attached to a wooden frame with 40 cm legs. Three of these were placed at each of Mildred L. sites 2 and 3. Leaf litter was collected every one to two weeks during the period of maximum leaf fall in the autumn.

Since the screens were set above the soil surface and above a low forest understory of blueberry, (*Vaccinium myrtilloides*), cowberry (*Vaccinium vitis-idaea*) and other species, these low shrubs were harvested before leaf fall; the leaves were separated from the stems, dried, weighed and retained for analysis. Evergreen species such as bearberry (*Arctostaphylos uva-ursi*) were not collected.

4.1.6. Rainfall measurement and forest throughfall colection.

Throughfall is the precipitation which falls through a forest canopy and reaches the forest floor. The nutrients dissolved in the precipitation, picked up both from the atmosphere and from the forest canopy, constitute one part of the soil nutrient input.

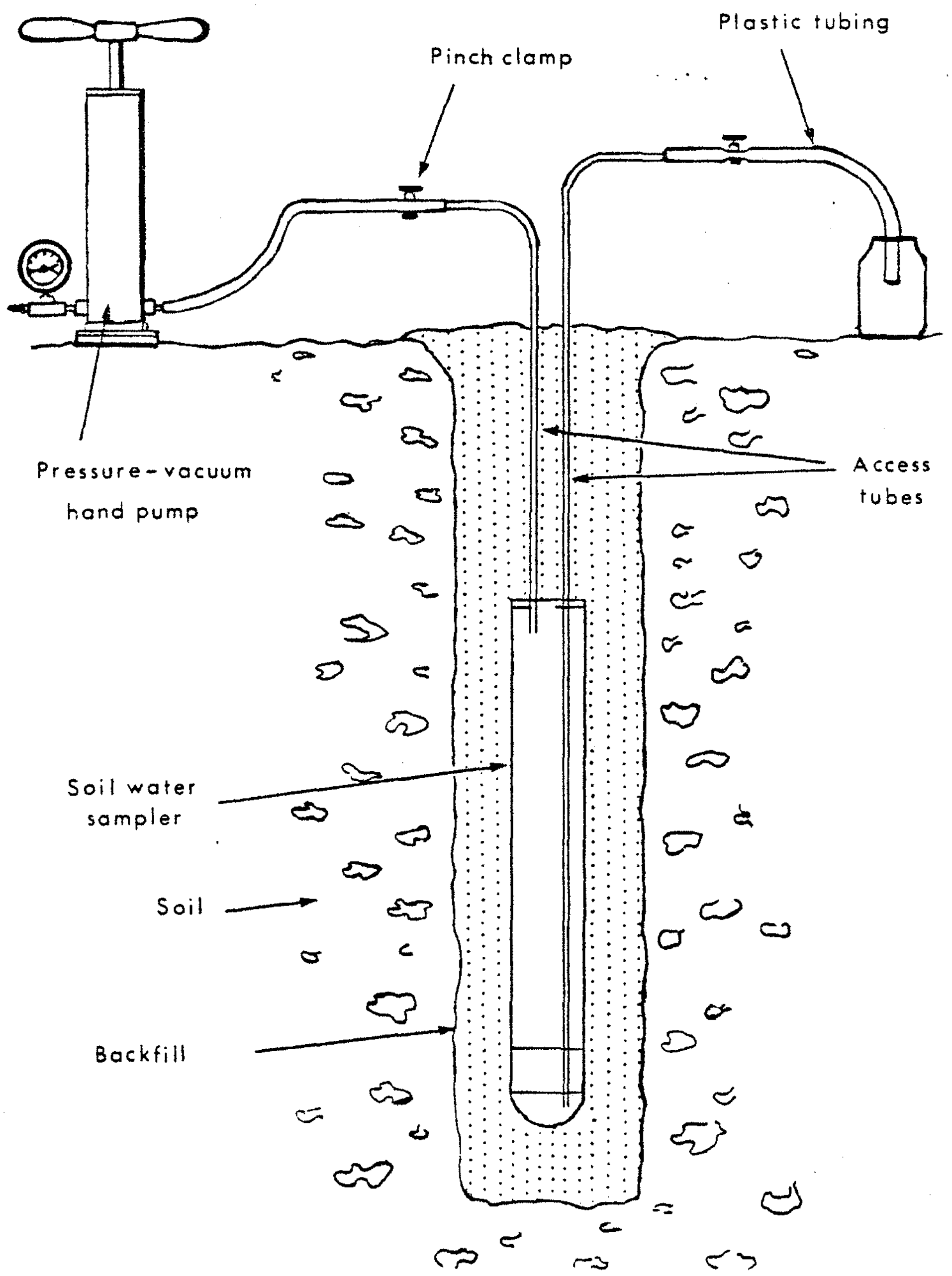


Figure 6. Cross-sectional diagram of soil water sampler.

Wooden boxes were constructed so that four liter plastic bottles fitted snugly into them. These were mounted on posts about one meter above the soil surface. A plastic funnel (22 cm diameter) was set into each plastic bottle and secured to the top of the post.

Eight collectors were randomly placed at Mildred L. site 2 and seven at Mildred L. site 3. One collector was placed in an open area at the plot site. At Mildred L. site la, three collectors were positioned at inner, middle, and edge positions beneath each of three pine trees. These were originally installed by sub project VE 4.2 in 1976 (Cook et al in prep.). Collections of throughfall were made approximately every two weeks from the time of installation in May until November 1.

Although it is realized that some loss occurs as a result of splash, and contamination by way of the open funnels is possible, the results should, in combination with information on soil moisture, and litter and soil leachate determinations, allow reasonable estimates of nutrient cycling to be calculated.

4.1.7. Stemflow measurement collection

Two pine trees at Mildred L. site la were fitted with stemflow collectors by Project VE 4.2 in 1976 (Cook et al in prep.). Collections of stemflow from this site were continued by Project VE 4.1 in 1977.

4.1.8. Litter leachate

Eight litter leachate collectors were installed at Mildred L. sites 2 and 3. The purpose was to determine the proportion of throughfall that is intercepted and turned over in the lichen and litter layers. The waters that percolate through the litter dissolve nutrients and organic compounds and leach them into the soil horizon below.

Litter leachate was collected in a kind of lysimeter consisting of one plastic bucket (21 cm diameter X 15 cm deep) nested in a second bucket (Figure 7). The bottom of the top bucket was lined with a nylon mesh screen and with polyester cloth. Soil litter layers were then carefully cut to the same diameter (21 cm) as the buckets and placed on top of the polyester cloth. A thin (<1 cm) layer of the Ae horizon of the soil was also incorporated with the litter. A plastic apron was taped around the upper bucket and draped over the lower bucket to prevent soil, insects, and precipitation from entering it. Each collector was installed in a hole in the soil such that the surface of the litter in the bucket was level with the natural soil surface. Precipitation falling into the buckets percolated through the litter layer and was collected in the lower bucket. The collected water was removed after heavy rainfalls or at two to three week intervals.

4.1.9. Rate of N turnover through established grasses on steep slopes of Tailings sand (GCOS dike)

The objectives and methodology of this experiment were described in the 1976-77 VE 4.1 report. Samples had been taken on four dates in 1976 and on two dates, in June and in September, 1977. The remaining eight cylinders on the dike are to be sampled in 1978, probably again in June and September. All samples have been air-dried and are now in storage. No nitrogen analysis has been initiated to date.

4.1.10. Decomposition of plant materials in the field

Decomposition of plant materials in reclaimed Tailings sand with a sand-peat surface mix in the top 25 cm, is being studied by determining the fate, over time, of ^{14}C and ^{15}N labelled grass shoots and roots added to surface soil in a field plot. In May 1977, forty cylinders (20 cm diameter x 60 cm) were distributed evenly throughout a 8 m x 5 m section of

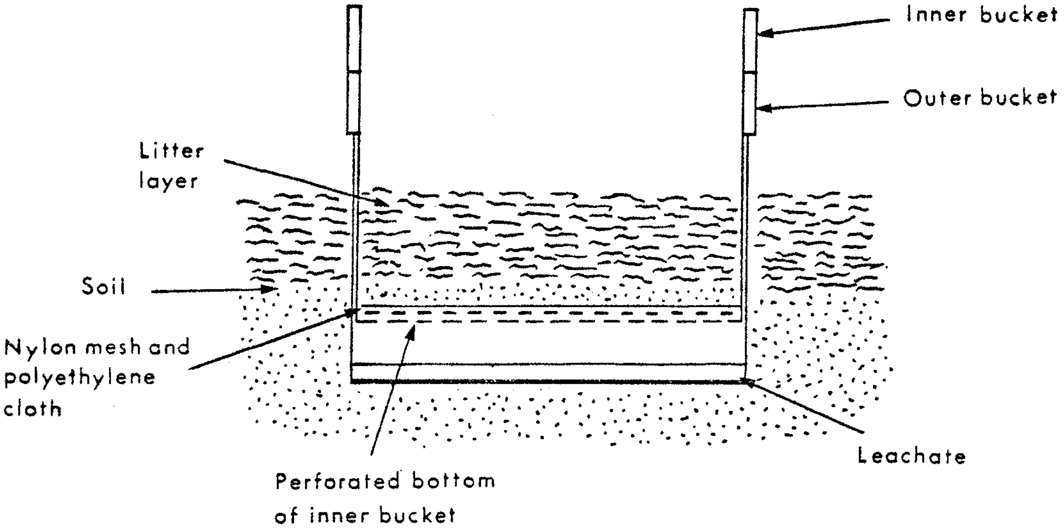


Figure 7. Cross-sectional diagram of litter leachate sampler.

the plot, and pushed into the soil leaving about 5 cm protruding above the surface. Brome grass plants which had been grown in a ^{14}C CO_2 atmosphere and fertilized with ^{15}N $(NH_4)_2SO_4$ were harvested and separated into green tops (G), brown tops (B), and roots (R). Weighed quantities of green and brown tops were placed on the soil surface within the cylinders, distributed evenly and covered with a nylon mesh screen to prevent removal by wind. Weighed quantities of roots were mixed into the top 2 cm of soil and covered with a nylon mesh screen. Treatments were randomized, and consisted of the three plant components, four replicates and four sampling dates, except for brown tops where there were only two sampling dates. Treatments and sampling dates were distributed randomly among the forty cylinders. The experimental layout and weights of added materials are shown in Table 4.

Table 4. Experimental layout of cylinders and weight of added material (g) in decomposition experiment

	1	2	3	4	5
1	R+ 0.29	G 1.56	B* 0.74	R 0.26	G+ 1.51
2	G 1.50	B+ 0.75	R 0.23	G* 1.49	R* 0.35
3	G 1.78	R+ 0.28	G+ 1.48	R 0.28	B* 0.70
4	G* 1.48	R* 0.32	B+ 0.74	G 1.51	R 0.34
5	R 0.30	B* 0.73	G+ 1.48	R* 0.26	G 1.54
6	B+ 0.72	R 0.32	G* 1.50	G 1.56	R+ 0.28
7	R+ 0.29	G* 1.57	R 0.32	B* 0.73	G 1.52
8	G 1.52	R* 0.31	G+ 1.59	R 0.30	B+ 0.71

* sampled July, 1977

\+ sampled September, 1977

G = Green tops, B = Brown tops, R = Roots.

Four replicates were sampled in July and September 1977. The remainder are to be sampled in summer and autumn, 1978. Samples were separated into 0-2, 2-6, 6-15, 15-30 and 30-55 cm depth layers. The samples were air-dried, weighed and subsampled for analysis.

Analysis of the samples will be initiated in early 1978. The analyses will consist of total C, total N, ^{14}C and ^{15}N determinations.

4.1.11. Natural mineralization and immobilization from forest litters

An experiment in which ^{15}N was added to the litter of different forest soils and the soils sampled at regular intervals was established in 1976. The experimental methods were described in the previous Annual Report.

4.1.12. Runoff plots On the GCOS dike

The plots were initiated on the Dike in 1975 by Robert Logan as part of his M.Sc. thesis work. The plots consisted of three kinds of peat treatment together with untreated Tailings sand. There are two replications. Runoff water from each of the plots is collected by ducts and directed into metal drums where it can be measured. It was agreed that measurements of this runoff would be continued during summer 1977 following heavy rainfalls. Considerable repair work, particularly to the ducts, was however necessary before readings could be taken, so measurements were not started until June.

4.1.13. Soil physical analyses associated with field studies

Determination of moisture retention curves was continued. The range 0.01 to 1 bar was determined using small intact cores which were inserted into individual pressure cells. Because liquid movement is slow in sands at low moisture content, pressure plate results could not be used at tensions greater than 1 bar. Container thermocouple psychrometers (Korven and Taylor, 1959), which depend on vapour movement, were therefore used in the range 1 bar to 50 bars. Small `chunks' from the same cores used in the pressure plate cells were partially dried and then sealed in psychrometer containers. Microvoltmeter readings were taken periodically until they stabilized. The moisture content of the sand was then determined gravimetrically.

Saturated hydraulic conductivity was determined by the constant head method (Klute, 1965). Rings (2.6 cm diam., 6 cm long) were packed to a bulk density similar to that in the field, and saturated with distilled water under vacuum. Because of the high permeability of the sands, 0.05 mm opening wire mesh screens had to be used in place of paper filters at the ends of the cores, so as not to impede flow, while loss of fine material was minimized using micro-burettes at the inlet and outlet to reduce the quantity of flow.

Unsaturated hydraulic conductivity curves were derived from the moisture retention curves using the method of Millington and Quirk (1961). The curves were matched with the laboratory-determined saturation point. Since there are several versions of this method (Green and Corey, 1971), unsaturated hydraulic conductivity was also determined on some cores in the laboratory for comparison with theoretical results. The apparatus used was similar to that described by Elrick and Bowman (1964). Cellulose acetate filters of suitable pore size for the required pressure range were attached at either end of rings packed similarly to those used for saturated conductivity. Pressures were controlled by drilling numerous small holes in the ring wall and enclosing the whole apparatus in a pressurized container.

4.1.14. Chemical analyses associated with field studies.

All plant samples were passed through a Wiley mill and mixed thoroughly prior to taking subsamples for analysis. Mineral soil samples were ground with a mortar and pestle to pass a 100 mesh sieve prior to chemical analysis.

All lysimeter leachate, throughfall and other water samples were stored at 2-3°C after addition of a few drops of toluene to retard microbial activity. As the present interest in nutrient elements is in total quantities rather than the different forms, microbial growth should not affect results significantly. In the few water samples where microbial growth occurred, such as in some stemflow samples, homogenization with a Waring blender was carried out prior to chemical analysis.

Methods for determination of total, inorganic, and organic carbon, total nitrogen, pH, cation exchange capacity, exchangeable cations, electrical conductivity, soluble Ca, Mg, Na, K, Fe, Mn, chloride, sulphate and extractable phosphorus were described in the last annual report. Before determining total N, P, Ca, Mg, K and Na, aliquots of the water or weighed plant samples were oxidized with sulphuric acid and hydrogen peroxide, with lithium sulphate added to elevate the digestion temperature and selenium to catalyze the reaction (Parkinson and Allen, 1975). The elements were then determined by standard methods (McKeague, 1976).

4.2. INDOOR LYSIMETERS, FIELD LYSIMETERS, AND PLOTS

Construction and installation of these were presented in the last report (Cook et al in prep.).

4.2.1. Indoor lysimeters

Ten lysimeters were installed at the Soil Science farm at Ellerslie. The duplicated treatments are as follows:

Lysimeter	Treatment
1 and 9	Control - Tailings sand without treatment.
2 and 8	Glacial till mixed into top 15 cm at a 1:4 (w:w), till:sand ratio.
3 and 6	One subsurface till layer (2.5 cm) at 65 cm
4 and 10	Two subsurface till layers (1.25 cm) at 35 and 65 cm depths.
5 and 7	Mesic peat mixed into top 15 cm at a 1:20 (w:w) peat:sand ratio.

In 1976, one member of each duplicate (1 to 5) was sown to brome grass while the remaining lysimeters were used to study leaching without plant cover. Both sets were outdoors, receiving natural precipitation during summer, 1976. In November, 1976, all the lysimeters were moved indoors and a set of fluorescent lights was installed above them. All lysimeters were sown with brome grass in February, 1977. Leachate was collected monthly, although as the brome grass grew and water demand increased, leachate collections eventually dwindled until no water was obtained from any of the lysimeters. Distilled water was applied twice weekly at a rate of 2.4 liter per lysimeter (0.88 cm water). Fertilizer consisting of a 10:4:10:1 ratio of N:P:K:S was applied at a rate of 100 kg/ha N in mid March. A micronutrient solution containing Fe, Ca, Mg, B, Mn, Zn, Mo, Cu and Co was applied in late April. Tensiometer readings were made weekly and temperature data were obtained using a hi-low thermometer. The brome grass in the lysimeters was harvested on December 2, 1977. Plant growth in lysimeters was measured by harvesting the grass in each lysimeter and weighing after air-drying.

4.2.2. Field lysimeters and Plots

Installation of ten lysimeters and three small plots at the AOSERP Mildred Lake field facility was described in the last report. The lysimeters were sown on 6 May 1977, with grasses (creeping red fescue, brome grass and crested wheat grass) at a rate of 5 kg/ha and legumes (alfalfa and alsike clover) at a rate of 10 kg/ha. Fertilizer was added at rates of 50 kg N, 20 kg P and 5 kg K per hectare. Psychrometers, tensiometers and thermocouples were installed in both lysimeters and plots. Psychrometers were installed at a depth of 10 cm and tensiometers at a depth of 40 cm. Thermocouples were installed at 10 cm, 40 cm, and 100 cm. Neutron probe access tubes were installed to a depth of 1 m (lysimeters only) and soil water samplers were installed in September, 1976. Natural sand plots were established, without instrumentation, in May, 1977.

4.3. LABORATORY STUDIES

4.3.1. Carbon and Nitrogen recycling during incubation

In this experiment, carbon and nitrogen cycling were studied in three soil materials of relevance in tar sands mining and revegetation trials. After addition of ammonium nitrogen and glucose carbon, the soils were monitored for biologically available carbon and nitrogen fractions over a short term incubation.

4.3.1.1. Materials. The materials under study were Tailings sand, Clearwater formation shale and Supertest till. The shale and till are overburden materials in the oil sands area. As mentioned elsewhere in the report, various combinations of these overburden materials are being studied for revegetation potential. Breton Ap, the plow layer of a Gray Luvisolic agricultural soil, was included in the study as a biological control. Some characteristics of these soils are given in Table 5.

Table 5. Characteristics of incubated materials

Soil	pH	Clay (%)	Organic carbon (%)	N (%)	Field moist. capacity (% by wt.)
Breton loam	6.3	24	1.45	0.16	23
Tailings sand	8.3	2	0.24	0.01	9
Clearwater shale	6.0	60	0.42	0.06	24
Supertest till	8.3	26	1.54	0.04	15

4.3.1.2. <u>Sample preparation and innoculation.</u> Samples were air-dried and ground to pass a 2 mm sieve. 792 g air-dried soil were innoculated with 8 g air-dried Breton Ap loam and the two were well mixed.

Each soil, in four replications, received N, C and P additions prior to incubation. 3000 ppm glucose-carbon per g air-dried soil were mixed into the soil in powder form. The soils were then wetted to a moisture content approaching field capacity with a solution containing 200 ppm nitrogen, as ammonium sulphate, and 40 ppm phosphorus, as potassium phosphate, per g air-dry soil.

Analytical controls received the Breton innoculation but no nutrients were added. One analytical control was incubated for each soil.

4.3.1.3. <u>Incubation and sampling.</u> Soils were incubated in 2.8 liter plastic buckets, as a 4 to 7 cm soil layer depending on packing. The buckets were covered with plastic lids in which a central 4 cm diameter circle had been removed and replaced with cotton wool to allow air circulation. Water content of the soils was monitored and deionized water was added to maintain moisture content. Soils were incubated in the dark at 26 °C. Soil samples were removed for mineral nitrogen, water soluble carbon and "glucose carbon", hydrolysable amine and moisture content determinations after the following incubation periods: 1,3,5,7,10,15,21,30 and 107 days for treated soils; 1,7 and 107 days for analytical controls. Carbon dioxide production rate was measured daily during the first week. After this, it was measured on the sampling days mentioned above. It was measured in the analytical controls after 1,7 and 107 days.

4.3.1.4. Moisture content. This was determined by oven drying 10 g samples at 105 °C for 24 hours.

4.3.1.5. Carbon dioxide production rate. The carbon dioxide production rate per day provides a measure of bacterial activity and carbon loss from the soil due to mineralization. It was determined using a 24 hr soil incubation during which the CO_2 evolved was absorbed in an NaOH trap (Middleboe, 1976).

A 150 ml beaker containing 10-20 ml 0.2N NaOH was placed in a one litre mason jar. A wire grid was placed over the beaker and a 50 ml beaker containing 20 g soil was placed on the grid. The jar was sealed and incubated in the dark for 24 hr at 26 °C. The incubation was established as quickly as possible to prevent atmospheric CO_2 absorption in the NaOH. Contamination was measured through use of a blank.

After removal from incubation, 2 ml saturated $BaCl_2$, 20 ml CO_2-free water and 5 drops phenolphthalein indicator were added to the NaOH. The solution was titrated over a magnetic stirrer with 0.10N HCl to determine the amount of excess NaOH, from which the amount of absorbed CO_2-C was calculated. The soil sample used for determining CO_2 production was returned to the soil container for further incubation. The time of soil sampling for CO_2-C determination was similar each day, with a maximum of one hour variation during the first week.

4.3.1.6. Mineral nitrogen (ammonium- and nitrate-nitrogen). Nitrate nitrogen and ammonium nitrogen were determined to observe the fate of added NH_4-N, the subsequent mineralisation of NH_4-N through bacterial death and breakdown of soil organic matter, and nitrification of ammonia to nitrate.

A 20 g soil sample was first extracted with 100 ml 2N KCl and shaken for one hour. The mixture was allowed to settle, after which the supernatnant was poured off and refrigerated (or frozen if the intended storage period was greater than two days) until distillations could be performed.

When ready to distill, a 20 ml aliquot of sample at room temperature was pipetted into a distillation flask. Using the distillation method outlined in McKeague (1976), the sample was first steam distilled for NH_4-N using MgO to drive off the NH_3 and, immediately after, for NO_3-N by adding Devarda's alloy to reduce NO_3 to NH_4. Distillates were collected in 0.4% boric acid and titrated to pH 4.8 with 0.005N H_2SO_4 using an automatic titrator.

4.3.1.7. Water soluble carbon and glucose. Water soluble carbon and glucose carbon were determined to observe the fate of added glucose, the rate of carbon turnover and the breakdown of soil organic matter.

Soil samples were extracted and analysed for water soluble carbon using a method similar to that of Burford and Bremner (1975). 10 g soil were shaken with 20 ml deionized water for 15 minutes in stoppered polyethylene centrifuge tubes. The mixture was then centrifuged at 19,500 g with a Sorval RC-5 centrifuge for one hour. The supernatant was poured off and filtered with suction through a 47 mm 0.2 un Metricel membrane filter, which had been previously washed with 100 ml deionized water. The filtrate was frozen until analyses for both water soluble carbon and glucose could be performed.

Soluble carbon was determined by a modification of the dichromate oxidation method of Mebius (1960). 5 ml extract was treated with 5 ml 0.06N $K_2Cr_2O_7$ and 15 ml 98% v/v H_2SO_4 in a 125 ml Erlenmeyer flask. A 50 ml Erlenmeyer flask was inverted to rest on the opening, forming a simple refluxing unit. The mixture was heated at 120°C for 30 minutes. 100 ml deionized water and 5 drops 0.2% n-phenanthroline indicator were added to the cooled digest which was then titrated with 0.03N Mohr salt to determine the amount of unreduced dichromate.

Some time was spent in determining the optimal digestion temperature and calibrating hot plates to that temperature. The boiling state suggested by Burford and Bremner was found to cause sufficient thermal degradation of the dichromate to destroy sensitivity at the lower range of the scale. Consequently, lower temperatures were tried, to decrease thermal degradation using standard (0-100 ppm) recovery tests. At 120°C, thermal degradation is slight and consistent among the samples, and recovery of glucose standards is complete.

Differing amounts of dichromate (up to 25 ml) were tested for the cases where samples, which should have been diluted, immediately reduced all the dichromate added. With compensations for thermal degradation, this was found to make no difference to the analysis.

Glucose was determined after a colorimetric method of Oades (1967). 2 ml extract or diluted extract was layered on 5 ml cold 0.2% w/v anthrone reagent in a test tube in an ice bath. The mixture was immediately mixed on a vortex mixer for 5 seconds, then heated in a boiling water bath for exactly 10 minutes and immediately returned to the ice bath. After cooling, the digest was returned to room temperature. Absorbance was measured at 625 mu using a Bausch and Lomb Spectronic 70 spectrophotometer. Glucose standards ranging from 0 to 100 ug glucose/ml were run during each analysis. The anthrone method does not strictly measure only glucose; other simple sugars are complexed during the digestion.

4.3.1.8. Hydrolysable amines. 1 g air-dried soil ground to pass a 106 um sieve was weighed into a 13 ml culture tube. 8 ml 0.5N HCl was added and the tube was capped with a teflon lined screw cap. The tube was shaken and left to sit until bubbling stopped. Prevention of overbubbling and consequent loss of soil-HCl mixture was accomplished by letting the samples sit for a few hours at room temperature prior to oven digestion and decreasing oven digestion time to compensate. The tubes were then digested for 16 hr in sand in a 105 °C oven. Cooled digests were centrifuged for 30 minutes at 2000 g. The supernatent was poured off, filtered through a glass membrane filter and stored for digestion. The remaining soil was then hydrolysed with 8 ml 6N HCl in the same tube following the same procedure.

Extracts were analysed for total N using a modified micro Kjeldahl digestion procedure (McKeague, 1976) to convert organic N to NH_3, neutralising the digested mixture, and steam distilling NH_3 into a 4% boric acid collector, which was then titrated colorimetrically with 0.01N H_2SO_4 to measure collected NH_3.

Problems in the analysis arose from poor sealing on some culture tubes, initially incomplete neutralisation of the H_2SO_4 prior to steam distillation of NH_3, sample volume, and the setting up of the still. Soil-HCl losses from the tubes ranged from 0 to 30 percent on samples which were retained for digestion. Acid added for Kjeldahl digestion was incompletely neutralised during the distillation step (due to technical error) yielding low NH_3 values. When the necessary amount of NaOH required to neutralise the H_2SO_4 was determined, the volume of solution in the distillation flask was so great that the samples had to be split in two, increasing the length of the analysis. The low results (Appendix Table 29) suggest that a combination of these problems led to considerable error, and consequently, the data on hydrolyzable amines are not discussed in subsequent sections.

5. RESULTS AND DISCUSSION

5.1. FIELD STUDIES

5.1.1. Ground temperatures at the instrumented sites

Changes in temperature over the year at 3 sites are shown (Figure 8). Details at all the sites are given in Appendix table 2. At the forested sites, periods of upward and downward thermal gradients are about equal, while at GCOS site 2, the period of upward thermal gradient predominates. Temperatures are also much higher at GCOS site 2 than at other sites, presumably because of the warmth of the groundwater only 2 m below the surface which originates in the Tailings pond. The strong thermal gradient at the dike sites is also shown by the mean annual ground temperatures (Table 6). In contrast, at the forest sites, little difference in mean temperature exists between depths. The low temperatures at Mildred Lake site 4 are presumably caused by heavy shading. Sites under more open Jackpine canopy (Mildred L. 2 and Richardson 4) show relatively high temperatures.

Table 6. Mean annual ground temperatures (°C) for the period November 1976 to November 1977.

Depth (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUP-TEST	GCOS 1	GCOS 2	RICH. 4
50	-	4.2	3.9	3.1	3.4	3.7	5.0	8.6	4.5
100	4.1	4.1	3.7	2.9	3.6	3.6	5.4	9.4	4.6
150	4.1	4.2	3.7	2.8	3.4	3.6	5.6	9.8	4.4
200	4.2	4.2	3.6	2.8	3.5	3.6	5.8	10.3	4.5
300	4.3	4.2	3.6	2.8	3.5	3.7	6.2	11.2	4.5
450	4.4	4.2	3.5	2.8	3.6	3.6	6.8	12.5	4.3
600	4.6	4.4	3.7	2.8	-	3.7	7.3	-	4.2

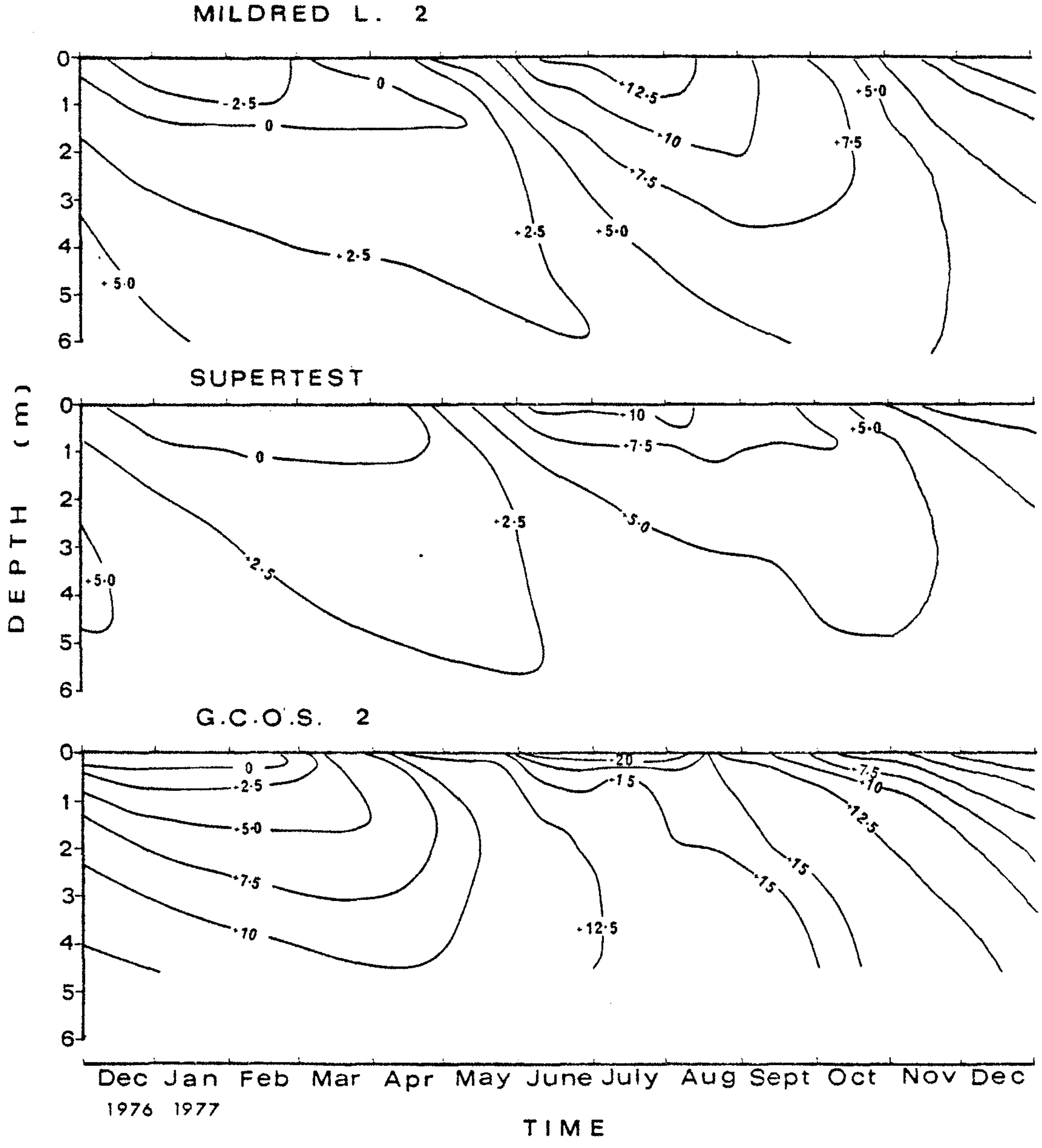


Figure 8. Isotherms in relation to time and depth beneath the ground surface for Mildred lake site 2, Supertest hill and GCOS site 2.

5.1.2. Soil moisture tension at the instrumented sites

Changes in moisture tension over the summer are shown (Figure 9a,b). The few results at Supertest Hill are omitted for clarity. Tensions were low in spring at the three forested sites at the Research facility, but they rose gradually through June. Heavy rains in July lowered tensions but they increased again to reach a final peak in late August before rain again caused them to drop. Tensions are fairly comparable at all three sites, in spite of the different forest vegetation and different moisture holding capacities. It appears that the type and density of vegetative cover have adjusted themselves to the soil parent material so that tensions rarely exceed 20 bars within the rooting zone. A complete contrast is however shown by the dike sites. Even in late spring, tensions of over 20 bars were realised. Although tensions were lowered by rains in early July, they became extreme in late August. Since most roots remain within the thin layer containing peat, it is suggested that poor growth of trees (particularly the spruce) may be the result of such high tensions. The cause of high tensions is perhaps a combination of factors. These could include run-off, and large water demand by fertilized brome grass (see section 5.1.12).

Moisture tensions at Supertest Hill (till) were fairly similar to the tensions at the forested sand sites, except that the high tensions of August persisted for longer into the fall than at the other sites, presumably because more rain was needed to replenish the larger moisture holding capacity of the clay-loam soil at this site.

5.1.3. Soil moisture content at the instrumented sites.

Full details of moisture readings obtained from both the neutron probe and by gravimetric sampling are given in Appendix tables 5 to 11. Particular attention was paid in Spring 1977 to obtaining detailed information on moisture

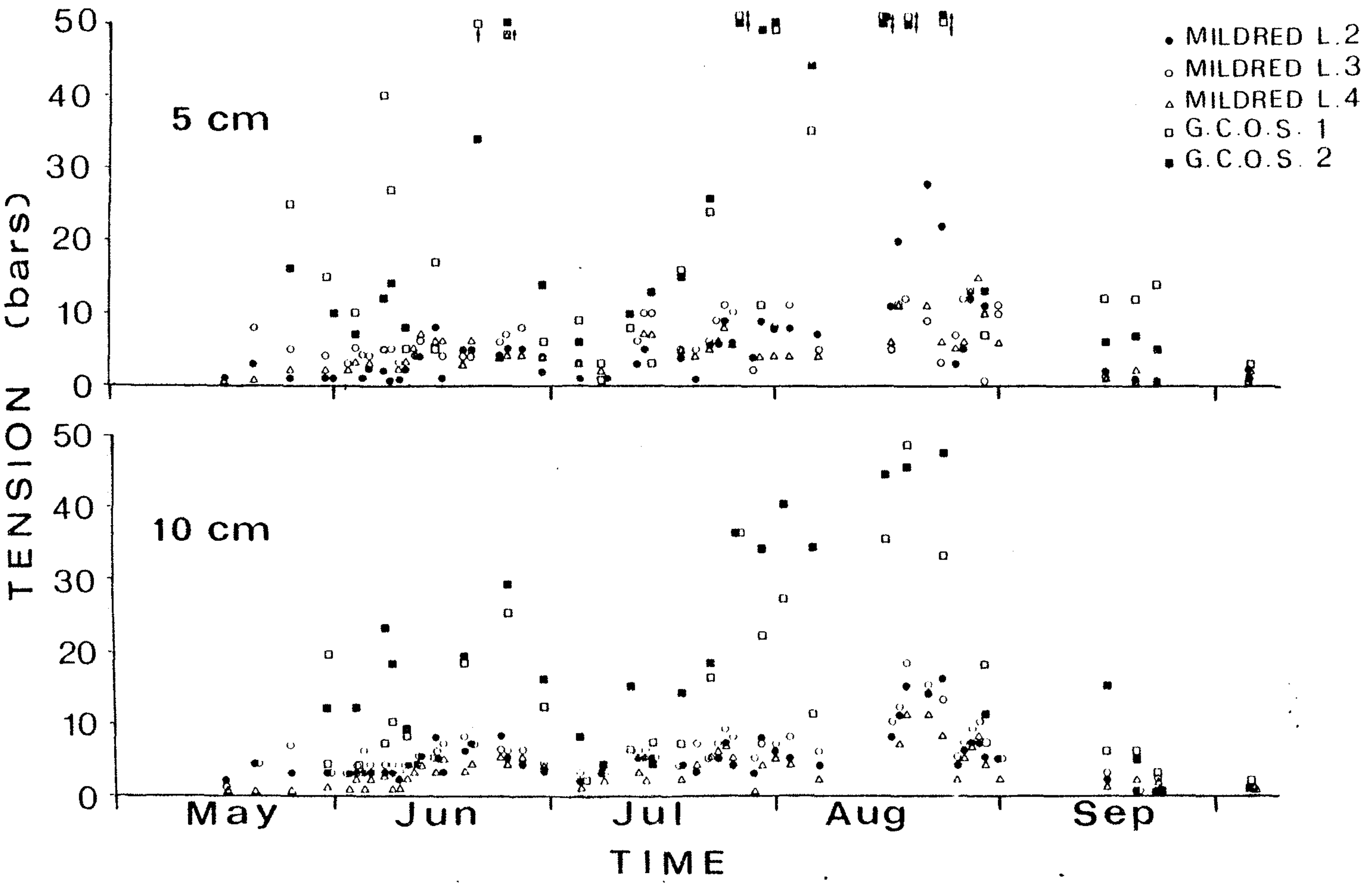


Figure 9a. Moisture tensions (geometric means) at depths of 5 and 10 cm, obtained with psychrometers during the summer at Mildred lake sites 2, 3, and 4 and at GCOS sites 1 and 2.

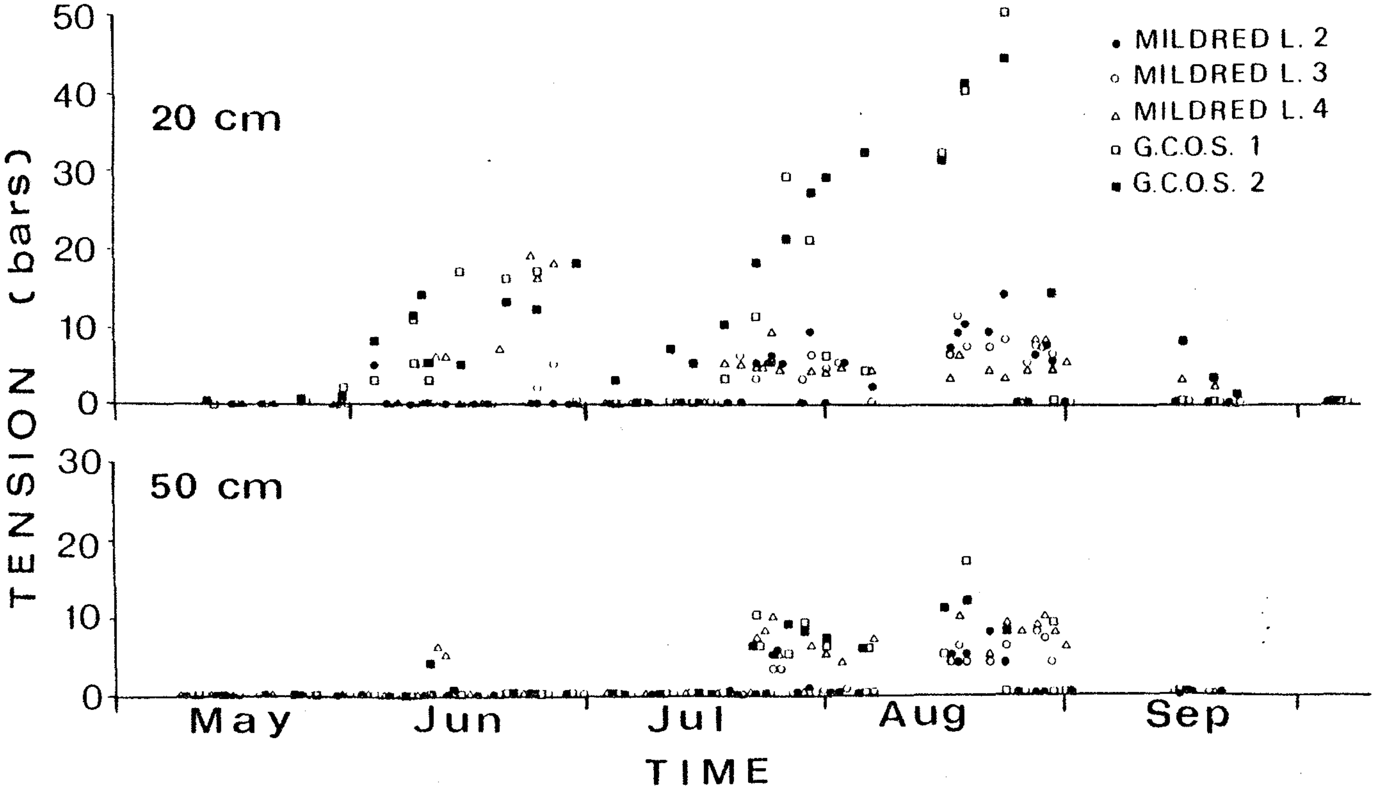


Figure 9b. Moisture tensions (geometric means) at depths of 20 and 50 cm, obtained with psychrometers during the summer at Mildred lake sites 2, 3, and 4 and at GCOS sites 1 and 2.

changes during the thaw period at Mildred Lake sites 2 and 3 by combining probe and gravimetric information. Although snowfall during winter 1976-77 was very light, and an almost complete thaw occurred exceptionally early in March, the downward progress of snow meltwater as thawing of the soil progressed was readily discernable and the effects of differences in the soil material were apparent (Figure 10). At site 2 the surface soil was saturated with moisture early in March, but as the soil temperature rose above freezing point, moisture from meltwater moved downwards and even by mid-June remained detectable as a bulge at depths between 200 and 300 cm. The water content of this bulge was 43 mm, and presumably most of it eventually reached the water table. At Mildred Lake site 3, there is a thin tar sand layer at a depth of 100 cm. Even early in March, water had accumulated at this depth, perhaps during the previous fall. As the thaw progressed, the moisture continued to accumulate above the tar sand layer and there was evidence of little movement through it. Moisture at this level however diminished with time either as a result of uptake by the vegetation or through lateral movement.

Detailed information during the thaw period was obtained at the sites on the Richardson Tower Hill, in connection with Sub-project V.E. 6.1. This information will be included in detail in the V.E. 6.1 report, however some of the results are of particular interest here. Changes in total water content to 6 m between 8 March and 15 April are shown (Table 7). Between these dates more moisture accumulated at the lower site than can be acccounted for by precipitation plus local meltwater while at the Upper site less water accumulated than expected. Although no significant water movement over the surface has been observed, it seems reasonable that early in the thaw period, when the surface is near-saturated with water and downward movement is impeded by frost, considerable lateral

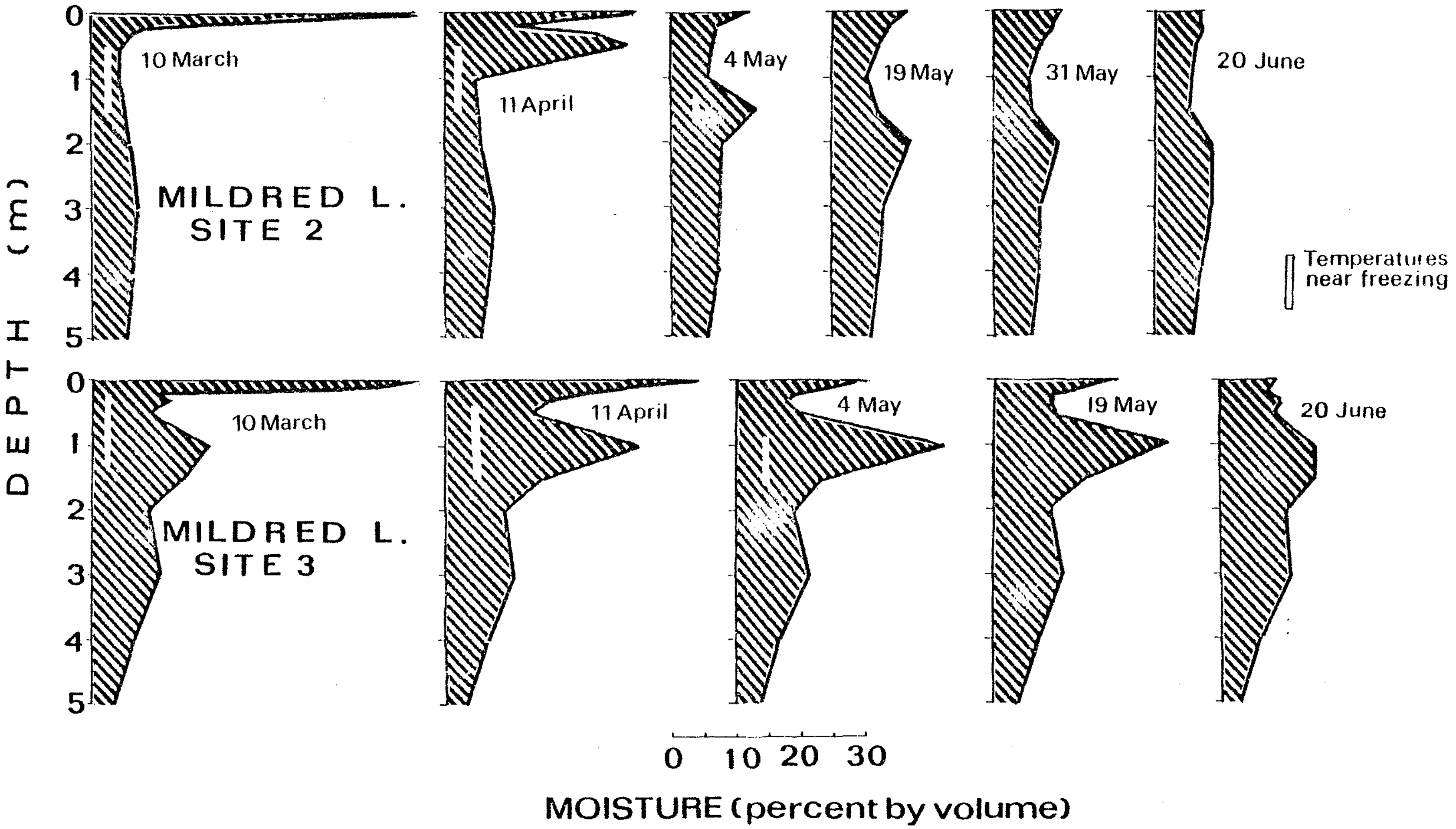


Figure 10. Moisture content profiles at different times following the thaw at Mildred Lake sites 2 and 3.

downslope movement occurs. A similar movement is also possible at Mildred Lake site 3.

Table 7. Total water to a depth of 6 metres below the ground surface on March 8th and April 15th 1977 and the expected total water on April 15th assuming all precipitation entered the ground and only a negligable amount of water drained below 6 m.

Location of water	Upper Site	Middle Site	Lower Site
Water (mm) in 6m soil on March 8	191	242	290
Water (mm) in Snowpack on March 8	14	51	46
Water (mm) Precip. March 8 to April 15	22	22	22
Total(above) = water expected in 6m soil on April 15	227	315	358
Water (mm) found in 6m soil April 15	161	302	397
Difference	-66	-13	+39

Changes in total water content of the top 5 m of soil between March and November are shown (Figure 11) for sites with deep water tables. 5 m was chosen rather than 6 m in order to avoid the water table. The larger water content at GCOS site 1 than at other sites is unlikely to be entirely a reflection of the materials' moisture holding capacity and is probably at least partly caused by moisture moving at depth from the Tailings pond. At all sites a decline in water occurs over the summer from the peak reached following the thaw. This decline, when added to total non-intercepted precipitation will give a value for moisture used by the vegetation plus water drained. Separation of these two components using hydraulic conductivity information and soil moisture tensions, will be discussed in the final report.

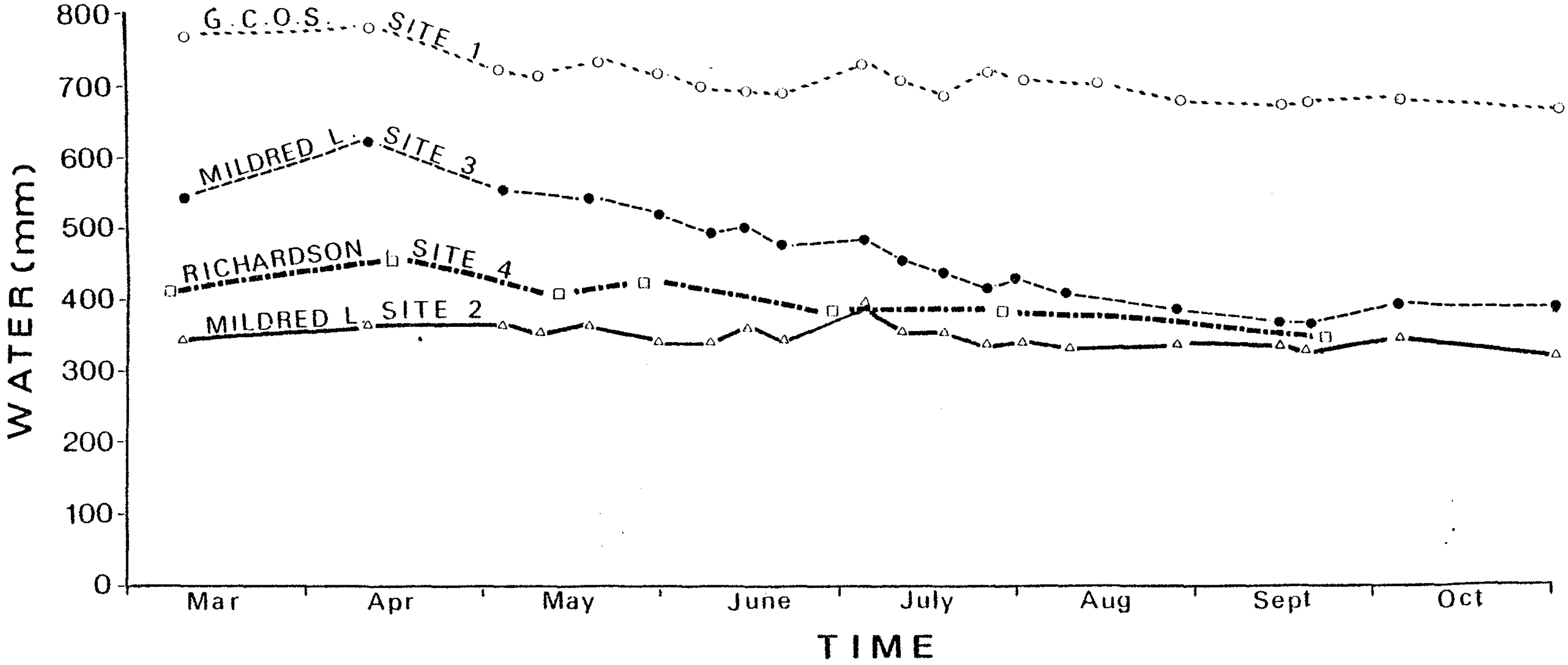


Figure 11. Changes in total water content within 5 m of the ground surface at Mildred Lake sites 2 and 3, GCOS site 1, and Richardson site 4.

5.1.4. Soil moisture content at the 'outlying sites'

The sites were classified into five vegetative categories: Jackpine, Aspen, Birch-Aspen, Spruce and other. Six sites on till rather than on the sand were eliminated, though it is noteworthy that this eliminated 4 Spruce sites leaving only two (14 and 25), one of which is a managed site (25). Three measurements of moisture conditions were investigated, percent moisture at 10 cm, amount of water in the surface 50 cm, and amount of water between 50 cm and 100 cm. The results (Tables 8 and 9) show that differences are greatest between pine and the other sites. Differences between the other

Table 8. Means and standard deviations of selected moisture conditions in sands under different vegetative types during June 1977.

Vegetation type	Sample size	Moisture at 10cm (%vol)		Water in top 50cm (mm)		Water between 50 and 100cm (mm)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Pine	12	9.5	2.8	42	9	37	8
Aspen	10	16.6	4.3	64	16	58	23
Birch	4	24.5	11.5	100	51	64	29
Spruce	3	21.4	7.2	46	31	44	4

Table 9. Analysis of variance of selected moisture conditions in sands under different vegetative types.

Source of Variation	D.F.	Variances and Significance		
		Moisture at 10cm	Water in top 50cm	Water in 50-100cm
Between vegetations	3	288**	3551**	1137**
Pine versus rest	(1)	669**	4980**	2688**
Error	25	30	517	485

**=99% probability

vegetative types are not pronounced except in the surface, and moisture in the surface is strongly influenced by organic matter and therefore by the vegetation itself. Differences in water content between depths of 50 cm and 100 cm presumably mainly reflect physical differences in the parent material. At this depth, a similarity between water content under Spruce and that under Jackpine (Table 8) has presumably resulted because most of the Spruce sites were on till and few are represented. Although the majority of sites on which Birch was dominant showed impeded drainage caused by Tar sand, the results of this analysis show that Birch occurs under widely varying moisture conditions in the area.

5.1.5. Throughfall

At Mildred Lake site 1a, it was found that the amount of water collected under three Jackpine trees was greatest at the edge position (Cook et al in prep). These results also showed a lower acidity at the edge position than at the inner position. A similar trend occurred in 1977 (Table 10), but the differences were not significant. The average pH of the throughfall at Mildred L. site 1a was about 6.1. The electrical conductivities were very low. Complete data for this site are presented in Appendix Table 13.

Table 10. Quantity, pH and electrical conductivity of throughfall at Mildred Lake site 1a

Position	Throughfall over season (cm)		pH		Electrical conductivity (umho/cm)	
	mean	s.d.	mean	s.d.	mean	s.d.
Inner	13.1	5.0	6.0	0.4	22.6	8.3
Middle	14.8	3.2	6.1	0.4	19.7	10.0
Edge	24.3	10.1	6.1	0.3	14.9	4.4

At Mildred L. site 2 (jackpine), with collectors randomly placed, the average pH range over the collection period was 5.7 to 6.9. The pH was highest at the end of the season, in November. Average electrical conductivity ranged from 10 to 19 umho/cm. Complete data are presented in Appendix table 14.

The pH range at Mildred L. site 3 (Birch/Aspen) was 5.7 to 8.5. As at Mildred L. site 2 the highest pH occurred at the end of the season. Since loss of pine needles is relatively high during the autumn, the decrease in acidity of throughfall at this time may be related to the reduced amount of plant material with which the precipitation comes into contact. The electrical conductivity of throughfall was very low, ranging from 5 to 14 umho/cm.

Precipitation was also collected in open land, at the lysimeter and plot site. The rainfall quantities obtained agree well with data from the Atmospheric Environment weather station at the Mildred Lake research facility. The rainfall pH ranged from 5.3 to 6.3. As with throughfall, its pH was lower early in the season (May) than in the autumn.

Comparison of throughfall and rainfall amounts showed that the proportion of precipitation intercepted and recycled in the canopy was 11 percent at Mildred L. site 2 and 14 percent at Mildred L. site 3. This water was returned to the atmosphere; the nutrients in solution are presumably either utilized by the tree or they enter the soil as a result of throughfall or stemflow during subsequent precipitation.

5.1.6. Stemflow

Amounts of stemflow collected at Mildred L. site 1a (jackpine) differed greatly between the two trees monitored (Table 11). A larger number of stemflow collectors would, therefore be required to obtain representative results. The pH of the water collected was lower than that of the throughfall

Table 11. Properties of stemflow at Mildred Lake site la

Date		Volume (ml)	pH	EC (umho/cm)
May 16 - May 31	1	8120	4.1	38.2
	2	3195	3.8	67.3
May 31 - June 21	1	1740	4.1	70.8
	2	380	4.0	72.5
June 21 - July 10	1	11250	4.4	24.2
	2	7680	3.9	55.2
July 10 - July 24	1	2930	4.4	24.2
	2	1780	3.9	58.6
July 24 - Aug 15	1	20	7.0	107.9
	2	5	-	-
Aug 15 - Aug 27	1	4640	4.1	46.4
	2	3290	3.7	82.9
Aug 27 - Sept 20	1	200	5.0	28.0
	2	10	5.1	10.4
Sept 20 - Oct 6	1	5600	4.0	58.0
	2	3000	3.7	107.3
Oct 6 - Nov 1	1	1460	4.2	26.1
	2	3100	3.8	58.6

at both Mildred L. sites 1a and 2. The pH ranged over the season from 4.0 to 7.0 for one tree and from 3.7 to 5.1 for the other. Electrical conductivity was also higher than that of throughfall, ranging from 10 to 108 umho/cm and averaging about 58 umho/cm for the two trees.

Stemflow represents a very small proportion of the total precipitation reaching the soil. Assuming 1000 trees per hectare, the stemflow volumes obtained would represent less than 2 percent of total throughfall per hectare. Bioelements such as sulphur in stemflow, however, would constitute a larger proportion since their concentration is higher in stemflow than in throughfall (Cook et al in prep.).

5.1.7. Litter leachates

The quantities, pH and electrical conductivities of litter leachates are given in Appendix Table 24. The pH range of averaged duplicates over the season was 5.6 to 5.9 at Mildred L. site 2. The conductivities ranged from 2 to 5 umho/cm. The ranges at Mildred L. site 3 were 4.7 to 5.1, and 3 to 20 umho/cm for pH and E.C. respectively. These values are lower than those of throughfall at the same sites. The acidity of precipitation thus increases as it falls through a forest canopy and again as it leaches through the soil litter layer. The total amount of water that leached through the litter layer was 67 to 68 percent of the throughfall at both sites. Approximately one third of the throughfall thus undergoes a turnover within the litter layer.

5.1.8. Litter-fall

A large component of the nutrient cycle of forests comprises those nutrients returned to the forest floor by fallen leaves, needles, branches and other plant parts. Litter-fall represents the annual addition to the leaf litter layer of a forest soil. Amounts of litter collected on 1 sq. m screens are given in Table 12. There have been no analyses conducted on the litter to date. The totals show that variation under pine was considerable, and ideally more collectors should have been used. There appears to be much less variation under birch/aspen.

Table 12. Litter-fall collected during autumn, 1977 (g/m2)

Date	Mildred Lake site 2 (Jackpine)			Mildred Lake site 3 (Birch/Aspen)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Aug 22	19.0	8.3	7.5	14.8	9.5	7.1
Aug 30*	15.6	6.3	12.3	33.7	41.4	25.7
Sept 12	nd+	nd+	10.1	34.1	63.0	48.5
Sept 20	9.2	5.9	29.7	150.2	115.7	114.9
Oct 5	27.8	5.3	32.8	4.5	7.5	4.9
Nov 1	15.4	11.9	18.5	-	-	-
Total	87.0	37.7	110.9	237.3	237.1	201.1

* includes leaves of low shrubs
\+ not determined due to collector damage

5.1.9. Soil leachate

Soil water collections, from collectors installed 2 m beneath the surface were attempted several times during the growing season at Mildred L. sites 2 and 3, but small samples were obtained on only three days from one of the two collectors at Mildred L. site 2, and on only one date from one collector at Mildred L. site 3. The reasons for this are presumably related to the very low water content during the growing season and poor ability of the instrument to extract water from sands. Nevertheless, some indication of soil pH and electrical conductivity was provided from these small samples (Table 13). Both pH and electrical conductivity are higher than those of litter leachate, indicating that cations have been dissolved by water percolating through the soil.

Table 13. pH and electrical conductivity of soil leachate from Mildred Lake sites 2 and 3

Site	Date	pH	EC (umho/cm)
ML2	Aug 5	6.9	33.6
ML2	Sept 20	7.4	25.5
ML2	Nov 1	7.4	18.0
ML3	Nov 1	7.8	41.2

5.1.10. Characteristics of GCOS dike leachate

Values of pH and electrical conductivity of leachates collected during 1977 at GCOS sites 1 and 2 are shown (Table 14). The pH range at GCOS 1 (north end of dike) was 8.1 to 8.4, while that at GCOS 2 (south end) was 6.7 to 8.6 (the low pH reading is probably erroneous). These pH values are slightly higher than those of most lysimeter and plot leachates. Electrical conductivities were also higher than in leachates from most lysimeters and plots, ranging from 487 to 950 umho/cm, which again suggests that leaching at a depth of 100 cm is only slight.

Table 14. pH and electrical conductivities of GCOS dike leachates

	Site	Date					
		June 27	July 5	Aug 5	Aug 30	Oct 5	Nov 2
pH	1	-	-	8.2	8.4	8.4	8.1
	2	8.0	8.3	6.7	8.3	8.6	8.3
EC (umho/cm)	1	-	-	487	580	603	650
	2	516	568	687	951	766	568

5.1.11. Natural mineralization and immobilization from forest litters

Analysis for nitrogen content and for ^{15}N abundance was initiated during 1977 but was not completed because of the large number of samples (over 750) involved.

A study to assess the fractionation of ^{15}N during sample preparation is complete. The data are reported in Appendix C. This study showed there was no significant nitrogen enrichment during sample preparation using the standard distillation and evaporation procedures in our lab. Early analyses of unlabelled samples, to obtain their background ^{15}N content show a negative delta ^{15}N value in some of the Mildred Lake profiles. Negative soil delta ^{15}N values have been reported only once before in the literature (Riga *et al*; 1971). Discimination between ^{14}N and ^{15}N during chemical, physical and biochemical transformations results in the ^{15}N content of soils usually being greater than that of air. ^{15}N is normally disciminated against during denitrification and is also lost more slowly during NH_3 volatilization than ^{14}N. Mineralization - immobilization processes may also affect the $^{15}N/^{14}N$ ratio in soil. If sufficient information can be found in the literature or from our experiments about factors affecting the $^{15}N/^{14}N$ ratio, then the delta ^{15}N value of a soil or plant sample should provide information on the relative balance between the processes in the system under investigation.

Relationships between ^{15}N content, delta ^{15}N and the mass spectrometer output are described in Appendix B.

5.1.12. Runoff plots on the GCOS dike.

Since our rain guage was not working, rainfall information was provided by Atmospheric Environment from records obtained at 'Top Gate' on the GCOS plant site. There were five main rain periods during the summer. These were June

27 to July 4, July 12 to 19, July 25 to August 7, August 24 and 25, and September 6 to 15. Amounts of water collected following each of these periods were, in almost every case, less than the calculated amount of water contributed by rain falling directly into the open ducts and collection drums. However, following the final rainfall period, there was a significant amount of water collected from the Tailings sand plot and the two southern mesic peat plots, and this water was presumed to be from runoff, though amounts of water were less than 25 percent of that from direct rain collection. Errors caused by open ducts and drums are therefore large, especially since losses due to raindrop bounce and evaporation are difficult to take into account. If this experiment is continued, drums and ducts should be covered.

The lack of observed erosion on the dike during summer 1977 however confirms the suggestion that runoff amounts were small. If this was so, then runoff cannot be the main cause of the larger moisture tensions that occurred on the dike than elsewhere. Instead, it seems likely that high tensions were caused by a large demand for moisture by fertilized Brome grass.

5.1.13. Soil physical investigations related to field studies.

Moisture retention curves for Mildred Lake site 2 are shown (Figure 12). They differ only slightly from those for Mildred Lake site 3 given in the last annual report. Those for several other materials including the peat-Tailings sand mixture of the GCOS dike surface are shown (Figure 13). The curve for Supertest Bt confirms that relatively little moisture is available at low tensions in materials high in clay. Some unsaturated hydraulic conductivities have been determined for Mildred Lake site 3 C-horizon material, and these show a reasonable approximation to values derived from the moisture

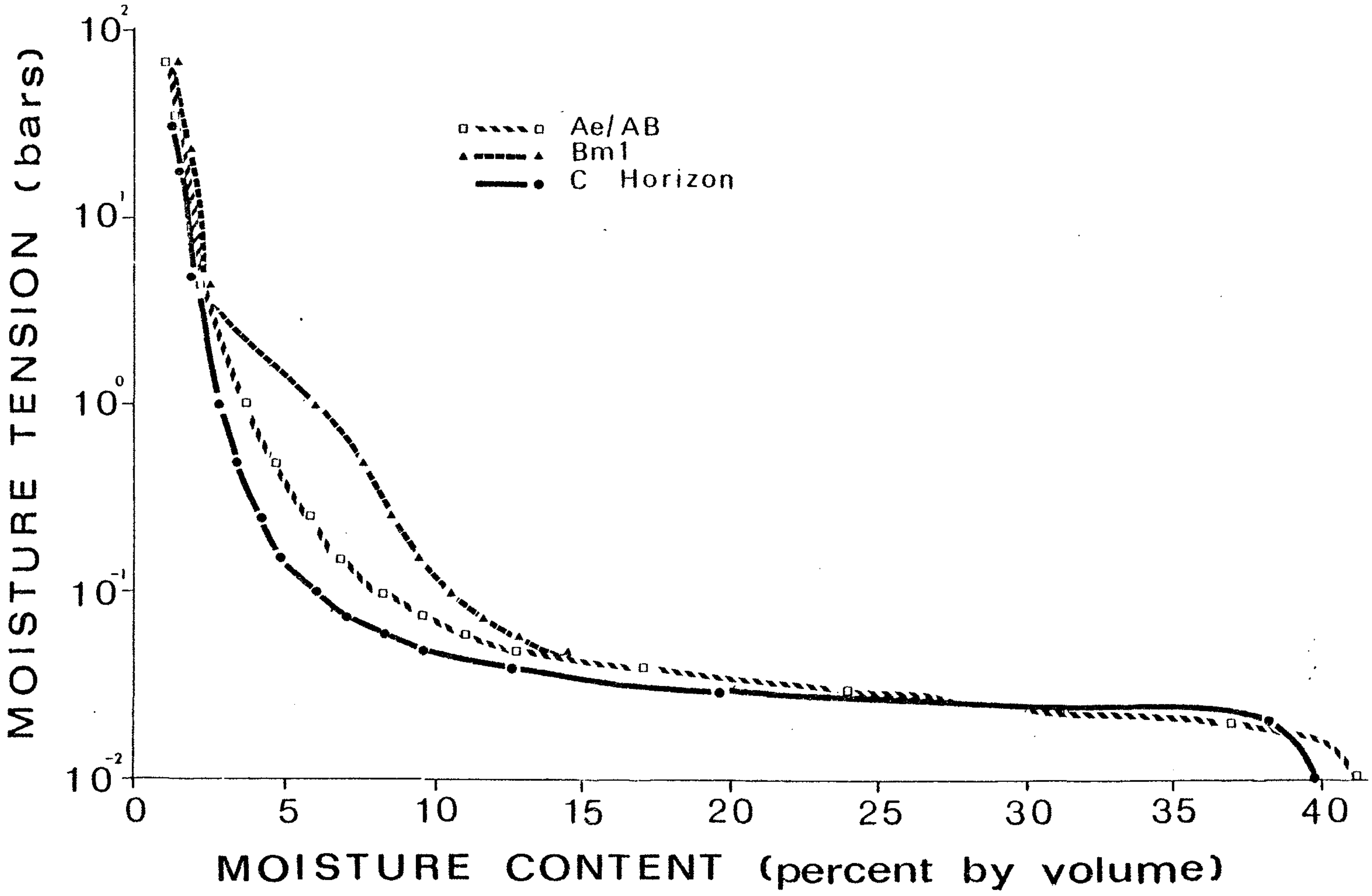


Figure 12. Moisture retention curves for different soil horizon samples from Mildred lake site 3.

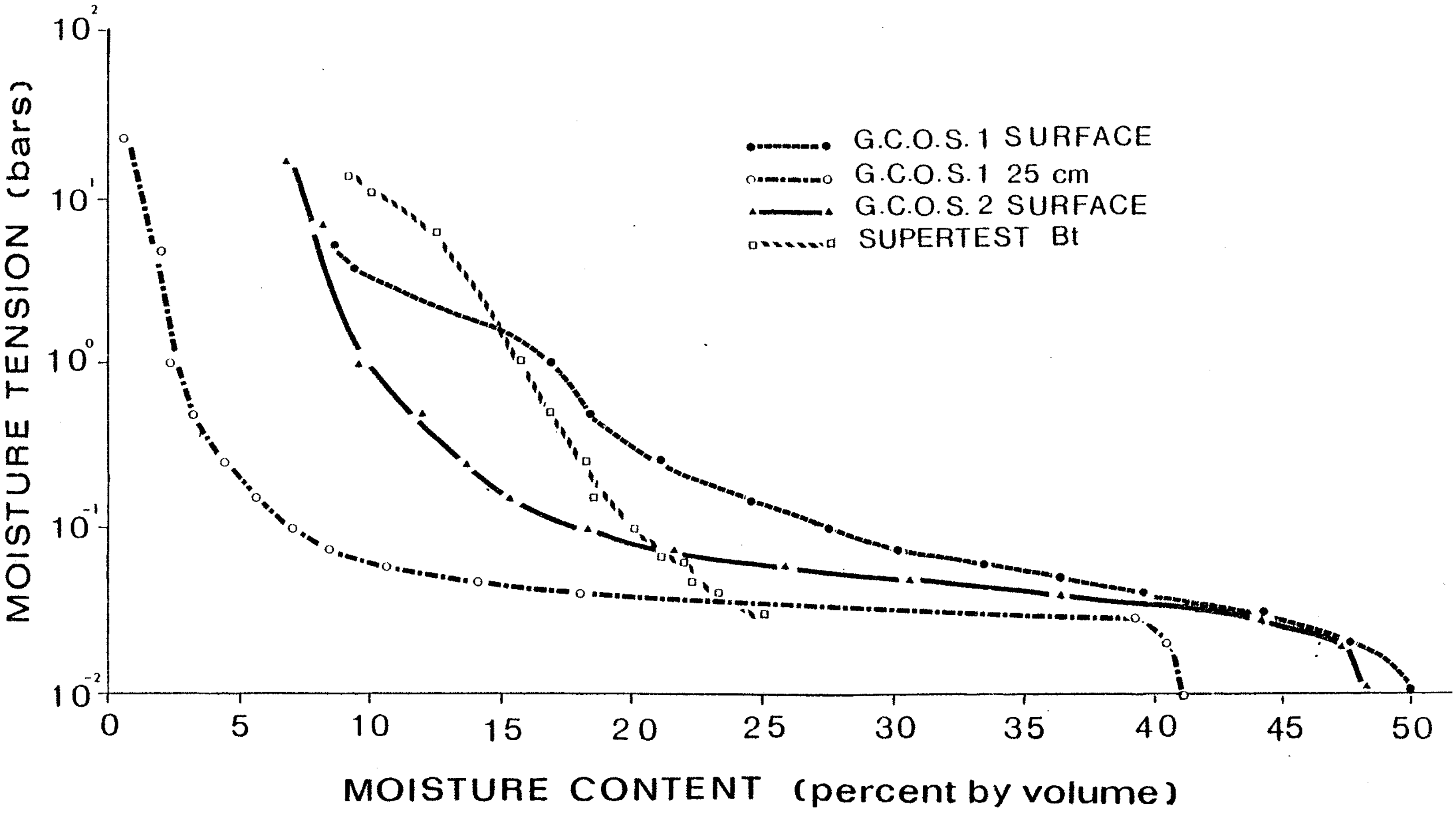


Figure 13. Moisture retention curves for GCOS dike materials, and Bt horizon material from Supertest hill.

retention curve using the Millington and Quirk (1961) equation (Table 15). Since the laboratory determination of unsaturated hydraulic coductivities is extremely time consuming, such values derived from field determinations of moisture tension and moisture content will have to be used in most calculations of soil-water movement.

Table 15. Measured and derived hydraulic conductivities in C-horizon sand from Mildred Lake site 3.

Moisture tension (mbar)	Moisture content (%vol)	Hydraulic conductivity Measured (mm/hr)	Hydraulic conductivity Derived (mm/hr)
Sat	40.3	120.0	-
50	27.6	8.9	18.0
60	16.1	0.81	1.1
75	10.0	0.16	0.09
100	7.0	-	0.006
250	4.1	-	0.00002

5.2. INDOOR LYSIMETERS, FIELD LYSIMETERS AND PLOTS

5.2.1. Indoor lysimeters

5.2.1.1. Leachate and soil analysis. Leachate analysis data are presented in Appendix Table 18. The general trend in all lysimeters was a gradual reduction in pH and conductivity with addition of water. The trend was reversed in some cases, however, as the amount of leachate diminished. The concentrations of C, Ca and Mg increased with the decreasing amount of leachate obtained. However, Na and K either decreased with time or remained relatively constant. No data for 1977 are available for sulphate.

The pH of the soil surface (Table 16) was highest in the glacial till surface mix treatment, presumably because of carbonates in the till, and lowest in treatments with non-amended surfaces.

5.2.1.2. Plant growth. Weights of harvested grass after air-drying are shown (Table 16). Duplicate 1 in each treatment was cropped in both years whereas duplicate 2 was only cropped in the second year. The yield from the till surface mix was lower than that of the other treatments in the first year, but by the second year, differences between treatments appear insignificant.

5.2.1.3. Soil moisture tension. Soil moisture tensions in lysimeters through the growing season are presented in Appendix Table 19. The data for two dates in September are given in Table 17 because they demonstrate the high soil moisture tensions during the later stages of plant growth. There is a suggestion of lower tensions, and therefore higher moisture content, in the single till layer treatment than in

Table 16. Dry matter production and pH of soil surface in indoor lysimeters

Lysimeter treatment	Duplicate	Weight of brome grass (g) Oct 76	Weight of brome grass (g) Dec 77	pH Oct 76	pH Dec 77
Tailings only	1	116	109	7.0	6.7
	2	-	114	-	6.4
Till surface mix	1	62	113	8.0	8.3
	2	-	98	-	8.7
One till layer	1	106	117	6.8	5.7
	2	-	113	-	5.6
Two till layers	1	116	116	6.7	6.3
	2	-	111	-	5.9
Peat surface mix	1	128	102	6.0	6.1
	2	-	134	-	6.1

Table 17. Soil moisture tensions in indoor lysimeters for selected dates in September, 1977

Treatment	Duplicate	Depth (cm)	Tension (mbars) Sep 8	Tension (mbars) Sep 13
Control	1	10	690	724
		20	452	542
		50	156	144
	2	10	764	728
		20	-	514
		50	278	382
Till surface mix	1	10	-	48
		20	682	650
	2	10	-	-
		20	586	596
One till layer	1	10	90	70
		20	50	50
	2	10	120	90
		20	86	72
		50	82	90
Two till layers	1	10	786	562
		20	-	604
	2	10	672	532
		20	-	452
		50	546	608
Peat surface mix	1	10	120	106
		20	274	332
	2	10	230	730
		20	-	-

treatments without such layers. However the double till layer treatment does not show the same effect. Evidence from indoor lysimeters is therefore inconclusive regarding the effects of a till layer on soil moisture storage.

5.2.2. Field lysimeters and plots

5.2.2.1. Leachate and soil analysis. Only pH and electrical conductivity measurements have been made on lysimeter leachates so far (Tables 18 and 19). The pH values of leachates from all the lysimeters were generally near 8. The similarities among treatments are expected at this early stage as the samples were collected well below the surface, at a depth of 100 cm. Conductivity measurements were generally in the range 200 to 400 umho/cm. In the plots, most pH values were in the range of 7.0 to 7.5, while electrical conductivity measurements were mainly 400 to 600 umho/cm.

Surface pH values for samples from the top 15 cm of lysimeters and plots collected in June, 1977 are listed (Table 20). Addition of peat to Tailings sand had the effect of lowering the pH from 9 to about 6. The pH remained high where till was added to Tailings sand. Where both till and peat were present the effect was intermediate. The results are similar to those of the indoor lysimeters. The high pH in non-amended Tailings sand and in the Tailings-till mixes, could be responsible for the poor plant growth.

5.2.2.2. Plant growth. Plant growth in lysimeters was measured as dry weight of harvested plant tops (Table 20). The weights were low, reflecting poor germination and slow growth during the summer. This is particularly evident in the "Tailings only" treatment. Treatments with peat and peat + till surface mixes produced most growth, but till additions alone seemed to have some benefit.

Table 18. pH of leachates collected from field lysimeters and plots.

Treatment	Lys/plot No	pH May 21	Jun 4	Jul 15	Aug 5	Sep 20	Nov 1
Tailings only	1	-	8.0	8.3	8.1	8.0	7.9
	9	-	8.1	-	8.2	8.9	8.5
Till surface mix	2	7.1	7.1	7.6	7.5	7.8	7.7
	10	7.4	7.9	-	-	8.1	8.5
Peat surface mix	3	-	8.3	-	7.9	-	8.2
	6	7.6	7.6	7.6	7.8	7.7	7.8
Peat +till surf. mix	4	-	8.1	7.9	8.2	8.4	8.6
	7	-	8.3	7.8	8.2	8.2	8.6
Peat surf. mix +	5	-	7.6	7.8	7.8	7.8	8.3
till layer	8	-	8.0	-	7.9	8.3	8.6
	Plots						
Peat surface mix	1	7.0	-	-	6.9	7.0	7.2
	-	-	6.7	-	7.8	8.1	8.5
Peat +till surf. mix	2	-	7.4	7.2	7.6	7.9	8.1
Peat surf. mix +till layer	3	-	7.8	7.1	7.0	7.3	7.9

Table 19. Electrical conductivity of leachates collected from field lysimeters and plots.

Treatment	Lys/Plot no	Electrical conductivity (umho/cm) May 21	Jun 4	Jul 15	Aug 5	Sep 20	Nov 1
Tailings only	1	-	216	231	210	218	220
	9	-	196	-	277	290	319
Till surface mix	2	204	302	351	360	389	406
	10	214	270	-	259	264	314
Peat surface mix	3	-	252	-	194	-	301
	6	266	313	305	306	278	197
Peat +till surf. mix	4	-	209	215	258	262	219
	7	-	249	263	224	232	217
Peat surf. mix +	5	-	243	303	312	364	354
till layer	8	-	223	-	277	266	280
	Plots						
Peat surface mix	1	441	-	476	383	559	551
		-	362	471	603	661	632
Peat +till surf. mix	2	-	440	-	493	505	499
Peat surf. mix +till layer	3	-	221	-	441	493	522

Table 20. Dry matter production and pH of soil surface in field lysimeters

Lysimeter treatment	Mean weight (g)	Mean pH
Tailings only	2.7	7.9
Peat surface mix + till layer	34.8	5.9
Peat surface mix	46.2	6.1
Till surface mix	14.7	8.7
Peat + till surface mix	46.7	7.5

In plots 2 (peat + till surface mix) and 3 (peat surface mix and till layer at 50 cm), plant growth was measured as lengths of dominant grasses, legumes, legume - grass mix or bare soil along a tape stretched across the plot. Measurements were repeated six times for each plot. The results, (Table 21), show that total cover was similar but legumes made more growth in plot 2 than in plot 3. Possibly, the glacial till in the surface mix of plot 2 provides micronutrients required by the legumes. A check of some uprooted alfalfa and clover plants showed that they were nodulated.

In the natural sand plots, growth was visually greater in the peat-amended sand than in the non-amended sand. Since the plants were still quite small in September, a method, using a 20 cm X 20 cm grid (divided into 1 cm squares), was used to estimate growth. The grid was tossed ten times into different areas of the plot. On each toss, the number of squares in which a grass, legume, or both together occurred was recorded. The results (Table 21) show greatest cover on the peat-amended plot, again pointing to the value of peat in reclaiming sandy soil materials. Differences between species were not investigated.

Table 21. Area of vegetative cover in Plots 2, 3, and natural sand.

Plot	Treatment		% Cover			% Bare soil
			Grass	Legume	Shared	
2	Peat + till surface mix	mean	32	25	18	25
		s.d.	12	15	10	8
3	Till surface mix + till layer	mean	55	9	16	20
		s.d.	9	3	5	7
	Natural sand	mean	17	2	3	78
		s.d.	13	2	3	
	Natural sand + peat	mean	21	11	32	36
		s.d.	15	11	26	

5.2.2.3. Soil temperature. Soil temperatures are presented in Appendix Table 20. Temperatures at any given depth are generally similar between treatments. Maximum surface temperatures occurred in both June and July. Temperature maxima at depths of 40 and 100 cm occurred in July and early August.

5.2.2.4. Soil moisture tension. Readings from tensiometers installed at a depth of 40 cm (Appendix Table 21) were low throughout the summer, probably as a consequence of sparse plant growth. Agreement between readings was fair except in the controls where Lysimeter 1 usually showed greater tensions than lysimeter 9. The tensiometers in Lysimeters 2 and 10 are positioned just above a buried till layer (45-50 cm depth), but readings did not show a higher water content in this region. Tensions were only slightly lower than those of other lysimeters in August, the driest month. There is therefore no evidence from the tensiometers that a buried till layer significantly increases the water content in the layers above it.

5.2.2.5. Moisture content. Soil moisture contents at various depths in the lysimeters were determined regularly during the growing season using a neutron probe (Appendix Table 22). As has already been suggested by soil moisture tension measurements, water conditions in the "Tailings only" treatment were very different from the others. Higher water contents occurred in the peat and till surface mixes compared to the control (Tailings only). A bulge in the water distribution pattern occurs at a depth of 50 cm in the treatment with a till layer (45-50 cm). The water content also was generally greater in the 0-50 cm depth interval of this treatment than in other treatments. However, since differences in tensions did not occur, the greater moisture content probably resulted from the larger moisture holding capacity of the till itself, rather than from an increase in moisture content in the layers above it.

5.3. LABORATORY INVESTIGATIONS

5.3.1. Carbon and Nitrogen recycling during soil incubation.

CO_2-Carbon production rates per day for treated soils and analytical controls are listed in Appendix Table 23. Means and standard deviations for treatment replicates are listed in Table 22. The CO_2 peak in the Breton Ap appeared earlier than expected and the amount of NaOH used in the CO_2-C determination was not sufficient for the CO_2-C evolved. The values obtained were thus immeasurably lower than the actual production rates. Later work suggests that twice the value would be a more accurate figure.

High CO_2 production rates were accompanied by fungal growth in all of the soils.

Mineral nitrogen determinations for treatment replicates and analytical controls are listed in Appendix Tables 24 and 25. Means and standard deviations for treatment replicates are listed in Tables 23 and 24.

Soluble carbon and "glucose-carbon" determinations for treatment replicates and analytical controls are listed in Appendix Tables 26 and 27. Means and standard deviations are listed in Tables 25 and 26.

Moisture content determinations for treatment replicates and analytical controls are listed in Appendix Table 28.

A complete factorial analysis to determine the variance accorded to replicates, to soil differences and to incubation periods, was performed on the raw data for each of the following analyses: water soluble carbon, glucose carbon, ammonium nitrogen, nitrate nitrogen and carbon dioxide production.

Table 22. Mean CO_2 production rates over incubation period

Incubation period (day)	CO_2-C (ug/g oven-dried sample/day)							
	Breton Ap(control)		Tailings sand		Clearwater shale		Supertest till	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
0-1	747.8	12.3	7.5	3.0	12.3	2.2	55.8	4.3
1-2	382.0	68.8	7.5	1.7	759.5	77.2	801.5	27.5
2-3	232.0	35.4	63.8	24.5	507.5	103.4	485.3	28.1
3-4	168.8	24.8	6.0	4.2	221.5	20.8	216.3	14.2
4-5	117.8	11.2	25.0	11.5	126.8	11.1	150.8	11.5
5-6	62.5	6.6	117.3	102.6	44.0	21.6	106.3	24.3
6-7	48.7	29.8	908.0	105.8	55.0	8.8	71.5	4.4
7-8	82.5	8.6	436.0	35.0	51.8	6.8	74.8	7.3
10-11	67.5	12.8	123.5	81.8	29.8	3.5	43.5	9.7
15-16	185.0	224.8	24.5	7.2	19.8	8.3	20.8	4.8
21-22	62.0	5.6	28.3	10.6	23.5	8.1	25.0	3.8
30-31	15.8	5.2	29.8	7.5	4.0	3.3	22.3	2.6
107-108	2.3	3.3	15.0	10.4	5.5	2.5	16.0	11.3

Table 23. Mean NH_4-N determinations over incubation period

Incubation period (day)	NH_4-N (ug/g oven-dried sample)							
	Breton Ap(control)		Tailings sand		Clearwater shale		Supertest till	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
1	25.0	6.8	175.9	16.8	159.8	12.0	95.8	8.0
3	15.8	5.0	161.3	4.8	3.7	5.4	0.1	0.2
5	36.3	5.0	177.0	6.0	13.2	2.9	4.0	1.5
7	52.4	5.6	19.1	8.9	15.4	2.7	9.0	4.1
10	60.1	6.9	9.0	0.9	26.3	5.0	14.4	2.2
15	77.8	6.5	10.3	3.9	32.9	3.9	20.9	2.7
21	68.9	11.7	23.4	20.9	43.4	3.9	22.9	3.9
30	28.8	0.8	17.6	7.0	47.9	11.6	14.9	5.2
107	1.5	0.6	57.0	40.1	54.5	6.8	0.2	0.2

Table 24. Mean NO_3-N determinations over incubation period

Incubation period (day)	NO_3-N (ug/g oven dried sample) Breton Ap(control)		Tailings sand		Clearwater shale		Supertest till	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
1	0.1	0.2	0.6	0.4	0.1	0.2	0.2	0.2
3	0.9	0.8	0.8	0.3	0.0	0.0	0.2	0.4
5	0.3	0.4	0.6	0.3	0.4	0.5	0.4	0.1
7	0.9	0.8	1.0	1.1	0.4	0.3	0.8	0.3
10	0.7	0.3	0.5	0.5	0.9	0.9	1.6	0.5
15	2.3	0.7	0.4	0.3	0.1	0.3	0.3	0.2
21	5.9	2.6	0.5	0.2	0.1	0.2	4.6	1.3
30	32.0	6.0	0.7	0.2	1.9	0.6	19.4	6.1
107	122.7	9.0	0.2	0.2	0.3	0.5	42.1	1.7

Table 25. Mean "glucose-C" determinations over incubation period

Incubation period (Day)	"Glucose-C" (ug/g oven-dried sample) Breton Ap(control)		Tailings sand		Clearwater shale		Supertest till	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
1	839.3	74.0	2479.4	181.8	2953.6	89.0	2633.3	340.2
3	120.7	7.2	2715.1	40.8	33.5	8.6	50.2	1.6
5	43.2	8.8	2020.0	85.4	12.9	3.4	32.3	2.3
7	33.3	3.6	536.7	38.0	6.6	0.3	16.8	0.8
10	27.4	7.4	24.2	5.4	15.2	2.5	14.0	3.5
15	23.3	3.0	17.7	2.3	15.8	5.0	11.9	4.6
21	6.2	4.0	19.6	2.0	14.4	2.8	5.0	2.0
30	2.7	2.0	16.1	1.4	13.1	5.0	3.9	3.2
107	5.1	1.8	4.7	3.6	5.4	1.3	1.5	0.5

Table 26. Mean soluble carbon determinations over incubation period

Incubation period (day)	Carbon ug/g oven-dried sample Breton Ap(control)		Tailings sand		Clearwater shale		Supertest till	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
1	2670.0	338.5	2625.1	165.5	3031.5	175.1	2552.3	60.3
3	259.2	81.0	2783.4	14.4	380.3	74.1	408.2	97.2
5	158.7	62.7	2818.2	119.4	121.7	37.9	223.4	51.6
7	136.7	23.3	913.2	284.8	62.3	12.5	111.2	16.4
10	98.9	31.3	122.0	27.3	37.8	19.2	52.1	19.5
15	135.7	18.8	115.2	14.3	114.5	26.4	64.6	17.4
21	54.5	16.5	105.4	3.4	64.6	17.4	73.1	6.6
30	13.7	14.3	94.2	7.0	25.6	8.8	21.7	7.6
107	18.2	7.2	41.1	11.2	28.7	7.4	12.1	5.6

Significant differences were found at the 0.05 level between both soil and incubation periods for all chemical determinations. Variation between replicates was only significant for ammonium nitrogen (0.05 level).

All four soils exhibited the same processes (with the exception of nitrification) but at different rates and to different degrees. Generally the Breton loam soil was the most dynamic followed by the Supertest till and Clearwater shale. Activity in the Tailings sand was generally much slower than in the other materials. Stabilization of synthesized biomass was most evident in the Clearwater shale but was almost non existent in the Tailings sand.

The uptake of carbon and nitrogen followed nearly identical patterns in all four soils, demonstrating the very close interrelation of these two elements in soil (Figure 14). Nitrogen uptake proceeded slightly faster than carbon uptake (from glucose). This may not be too surprising since the Ks

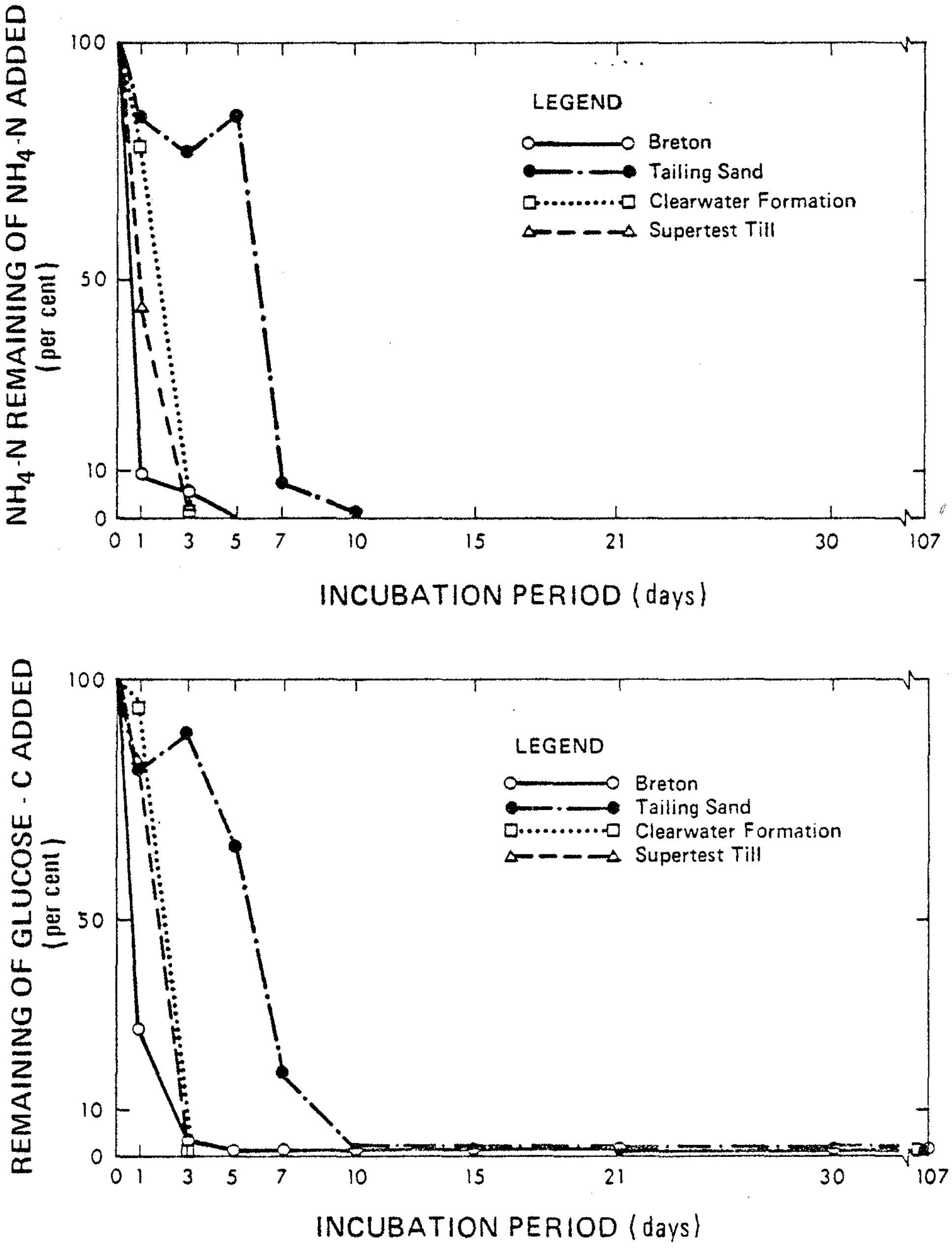


Figure 14. a (above). Percent added ammonium nitrogen remaining in incubated materials over incubation period.

b (below). Percent added glucose carbon remaining in incubated materials over incubation period.

for microbial growth as limiting substrate is 10^{-5}molar (Pirt, 1975) whereas the corresponding value when NH_4 is limiting is $5x10^{-7}$molar (Herbert, 1958; p388,385). Most of the mineral nitrogen had been consumed in one day in the Breton soil and in three days in the Clearwater shale and Supertest till, whereas substantial amounts of NH_4-nitrogen persisted in the Tailings sand for about a week (Table 23). In the Supertest till and Breton loam, the "glucose-carbon" content equilibrated at about 1-5 ug C/g soil after one month of incubation (Table 25). In the Tailings sand and Clearwater shale, the levels remained a little higher but by 107 days had reached the same level as in the other soils. It would appear that a quantity of anthrone reactive-carbon (mainly hexoses), equal to about 1-5 ug C/g soil remains in a dynamic equilibrium in the soil solution - at least as measured using a 2:1 water:soil extraction. Although soluble carbon has been proposed as an important pool from which microbes feed, very little data on this pool are available. This pool of energy is also rapidly replenished and the rate of turnover of carbon in it is therefore as important as the total quantity. It can be considered the main conveyor belt feeding soil microbes.

Remineralization of immobilized nitrogen and its subsequent oxidation to nitrate in the Breton loam follows the pattern normally observed in soils. A rapid loss of NH_4-N is followed by an increase in NH_4-N and its subsequent loss and replacement as NO_3-N (Figure 15). The pattern was the same in the Supertest till as in the Breton loam, but the amount of NH_4-N released was less (Figure 15). In both the Breton loam and the Supertest till, essentially all of the remineralized nitrogen was converted to NO_3-N (Tables 23 and 24). This was not the case, however, in the Clearwater shale and the Tailings sand (Figure 15). Although remineralization of immobilized nitrogen in the Clearwater shale and Tailings sand was as great as in the Supertest till (Tables 23 and 24), there was no

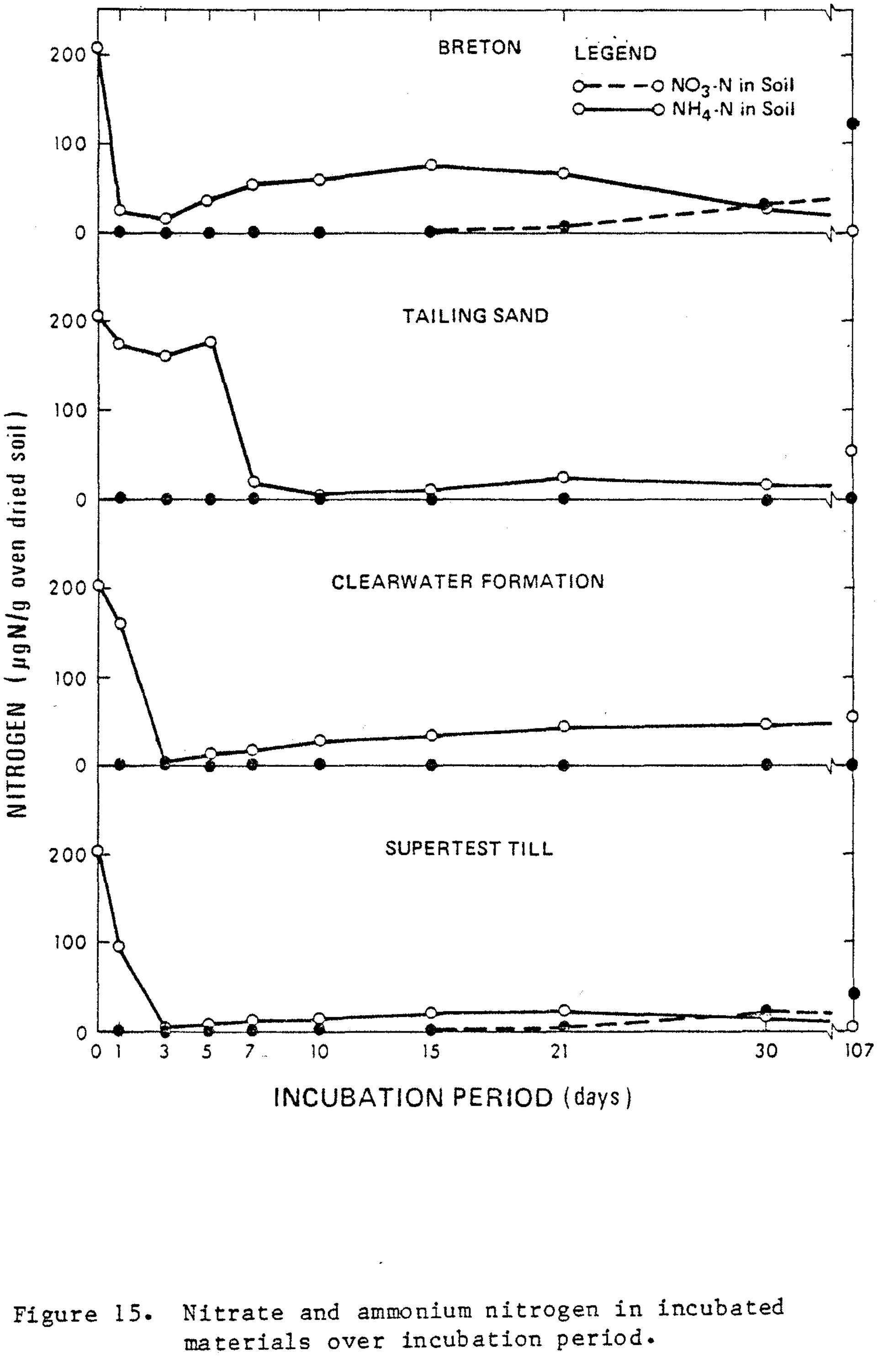
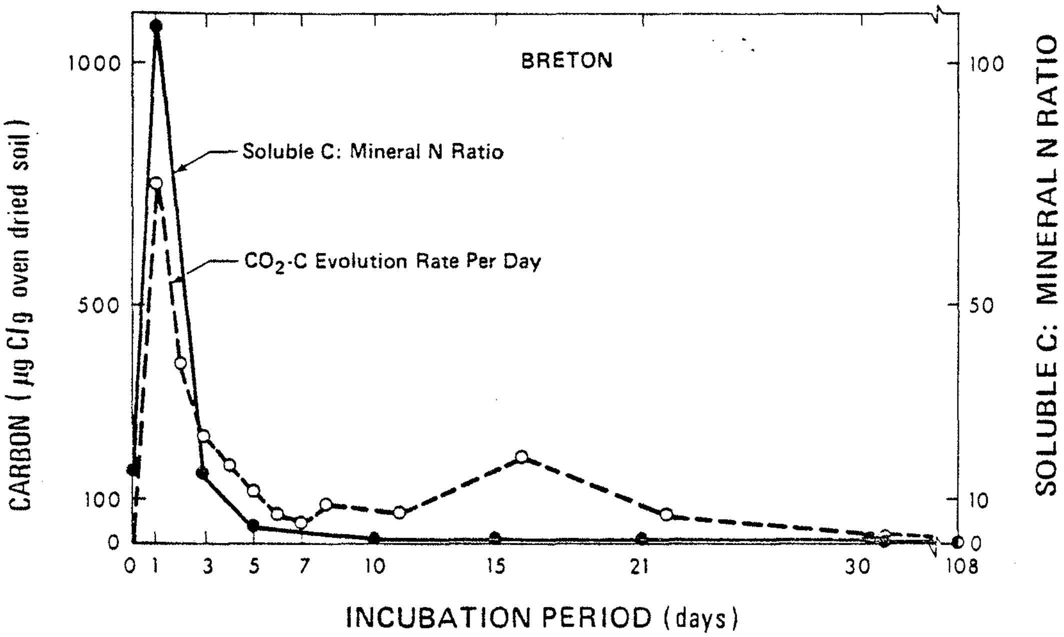


Figure 15. Nitrate and ammonium nitrogen in incubated materials over incubation period.

significant production of NO_3. Evidently some componenent of these materials has inhibited nitrification by the added nitrifiers and their proliferation during incubation. Reeder and Bing (1977) have similarly reported the absence of nitrification in Cretaceous shales and coal mine spoils near Hayden, Colorado. Nitrification, however, was rapid in vegetated spoils. R. J. Logan, in his M.Sc. thesis, has also reported substantial nitrification in peat amended Tailings sand on the GCOS dike. The inhibitory effect on nitrification, at least by Tailings sand, would thus appear to be temporary.

Nitrification is carried out by two main bacterial genera (Nitrosomonas and Nitrobacter). These data indicate that processes which can be conducted by a wide range of organisms (mineralization and immobilization) are not seriously affected in these overburden and mine waste materials. Very specific processes, however, where the genetic pool is small, are more susceptible. Between 19 and 25 percent of the immobilized nitrogen was remineralized during the 107 days of incubation. Although some of this may have been derived from organic matter already present in the Clearwater shale, the amount is probably small. Reeder and Bing (1977) found no nitrogen mineralization from their shale during a 160 day incubation although it contained 0.11 percent N.

The rapid uptake of nitrogen by growing microbes quickly depleted the mineral N pool in all materials and a very high soluble carbon to mineral-nitrogen ratio developed (Figure 16a,b). The rate of CO_2 evolution started to drop off when the C:N ratio in the substrate became very high. This was most noticeable in the Clearwater shale and Supertest till (Figure 16). The C:N ratios of the readily available substrate reached as high as 1360 in the Supertest till. The lowest ratio (450) occurred in the Tailings sand. In all cases the increase in ratio appears to have been caused by the soil organisms and not



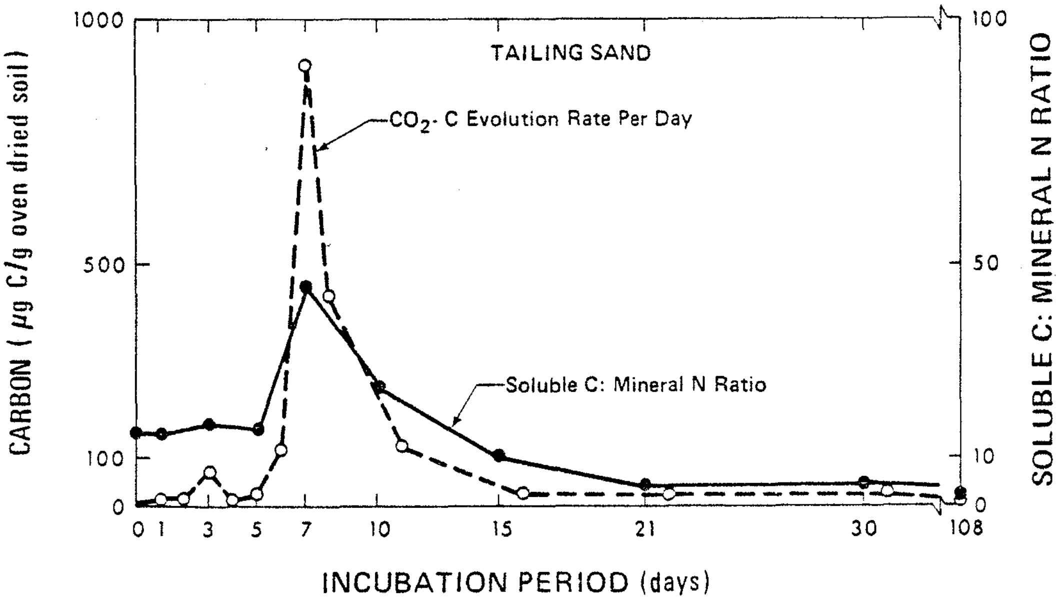


Figure 16a. Ratio of soluble carbon to mineral nitrogen, and carbon dioxide production rate in Breton loam and Tailings sand over the incubation period.

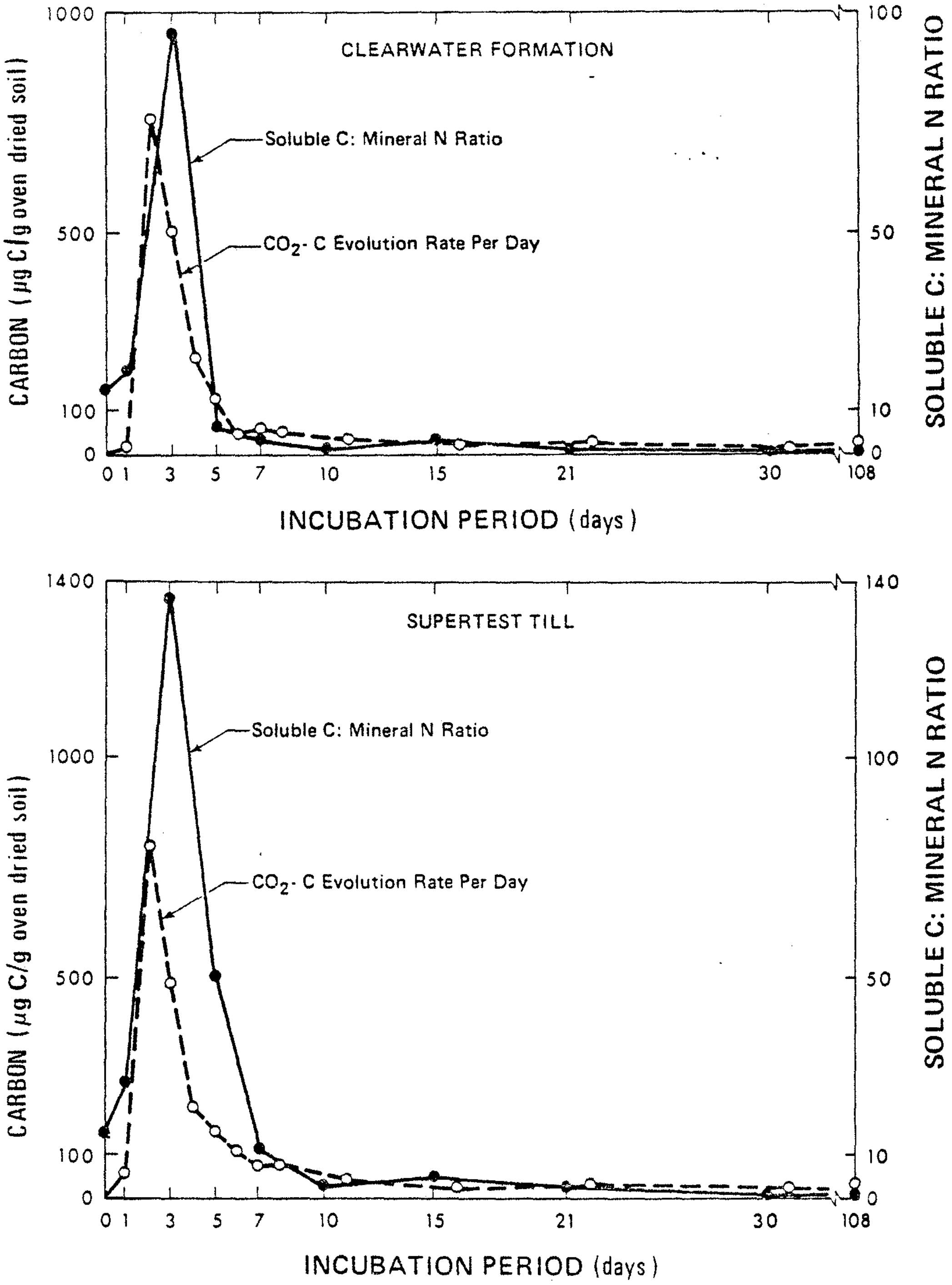


Figure 16b. Ratio of soluble carbon to mineral nitrogen, and carbon dioxide production rate in Clearwater formation shale and Supertest till over the incubation period.

by chemical or physical processes in the material. The same relationship of high CO_2 production rates producing high C:N ratios in the residual substrate occurred in all materials.

In all materials, the rapid depletion of the added glucose supply was associated with an increase in the total amount of non glucose soluble carbon in soil (Figure 17a,b). The source of this carbon is not certain and can only be determined with C-14 tracers. Two sources are the most likely: a) extracellular metabolic products synthesized and shunted through the cell when nitrogen supply became limiting; and b) carbon hydrolysed from stable organic compounds originally in the materials, by recently produced extracellular enzymes. Both mechanisms are probably operative. Except in the Clearwater shale, non "glucose carbon" (non anthrone-reactive-C) dominated after the first few days of incubation. In the Clearwater shale, however, the proportion of simple carbohydrate appears to have been substantial on occasion.

The close relationship between respiration rate and soluble carbon supply is evident in all soils (Figure 18a-d). In every soil CO_2 evolution rate dropped off quickly once soluble carbon dropped off. This suggests that for most practical purposes the soluble carbon pool is the immediate carbon source for soil microbes. The relation held in all materials, regardless of past history. It is significant that "glucose-C" usually drops to very low levels before the respiration rate or the total soluble carbon drops to low stable levels. It would appear from these preliminary results that this pool of carbon could be used as a useful measure of potential for microbial activity in these materials during revegetation. This information will be useful in constructing a model of the system during reclamation.

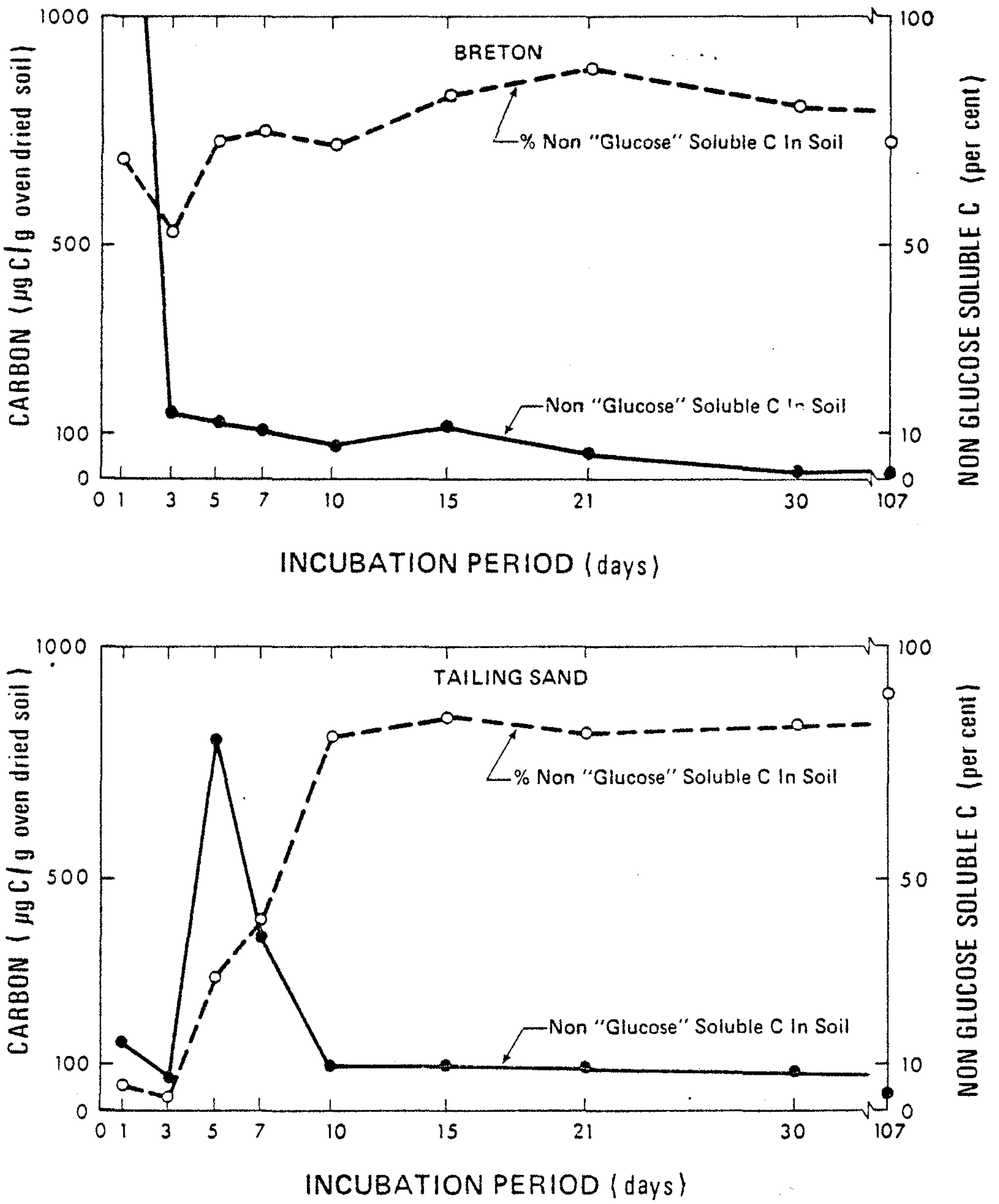


Figure 17a. Non "glucose" soluble carbon as total quantity and as percent of total soluble carbon in Breton loam and Tailings sand over the incubation period.

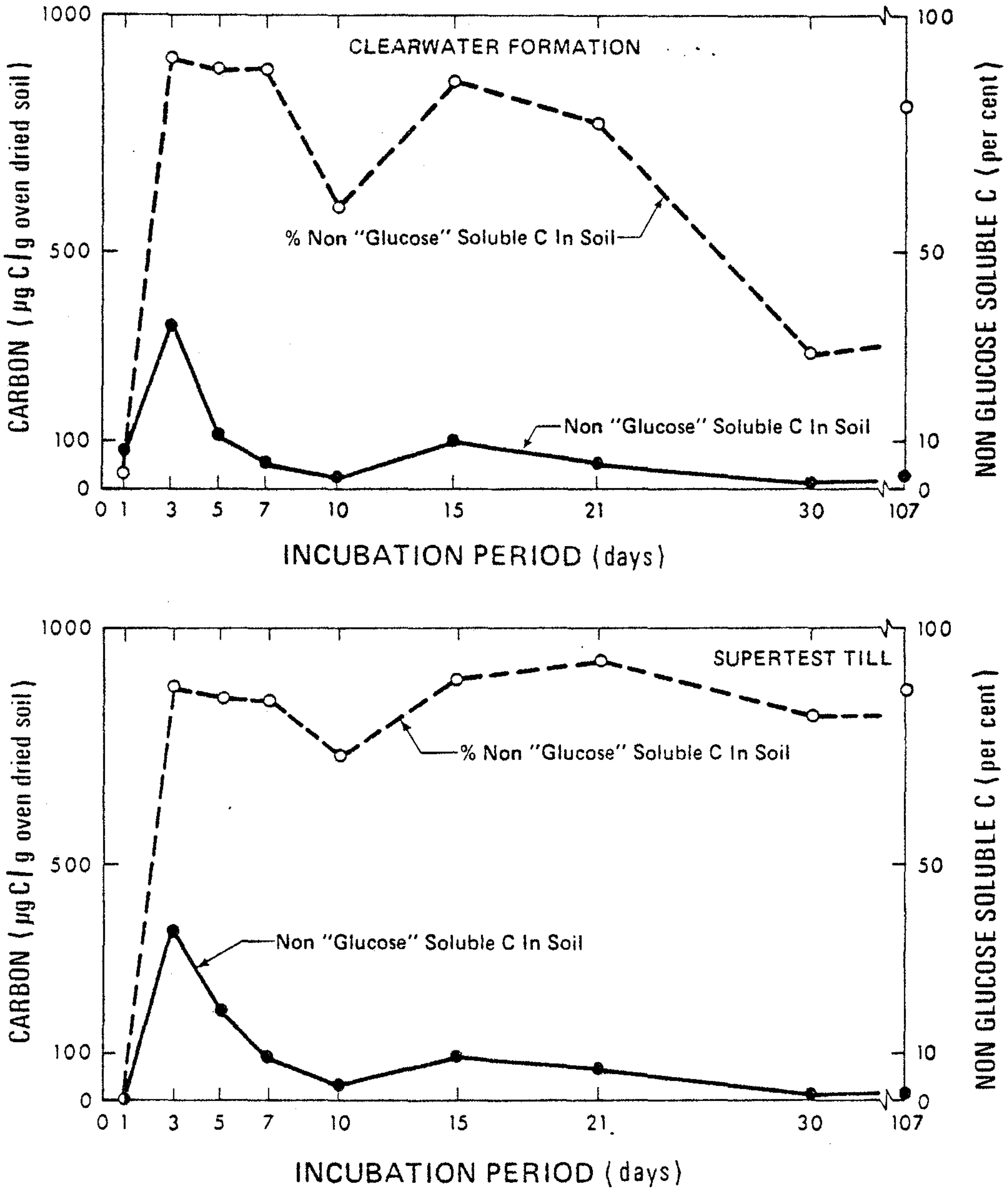


Figure 17b. Non "glucose" soluble carbon as total quantity and as percent of total soluble carbon in Clearwater formation shale and Supertest till over the incubation period.

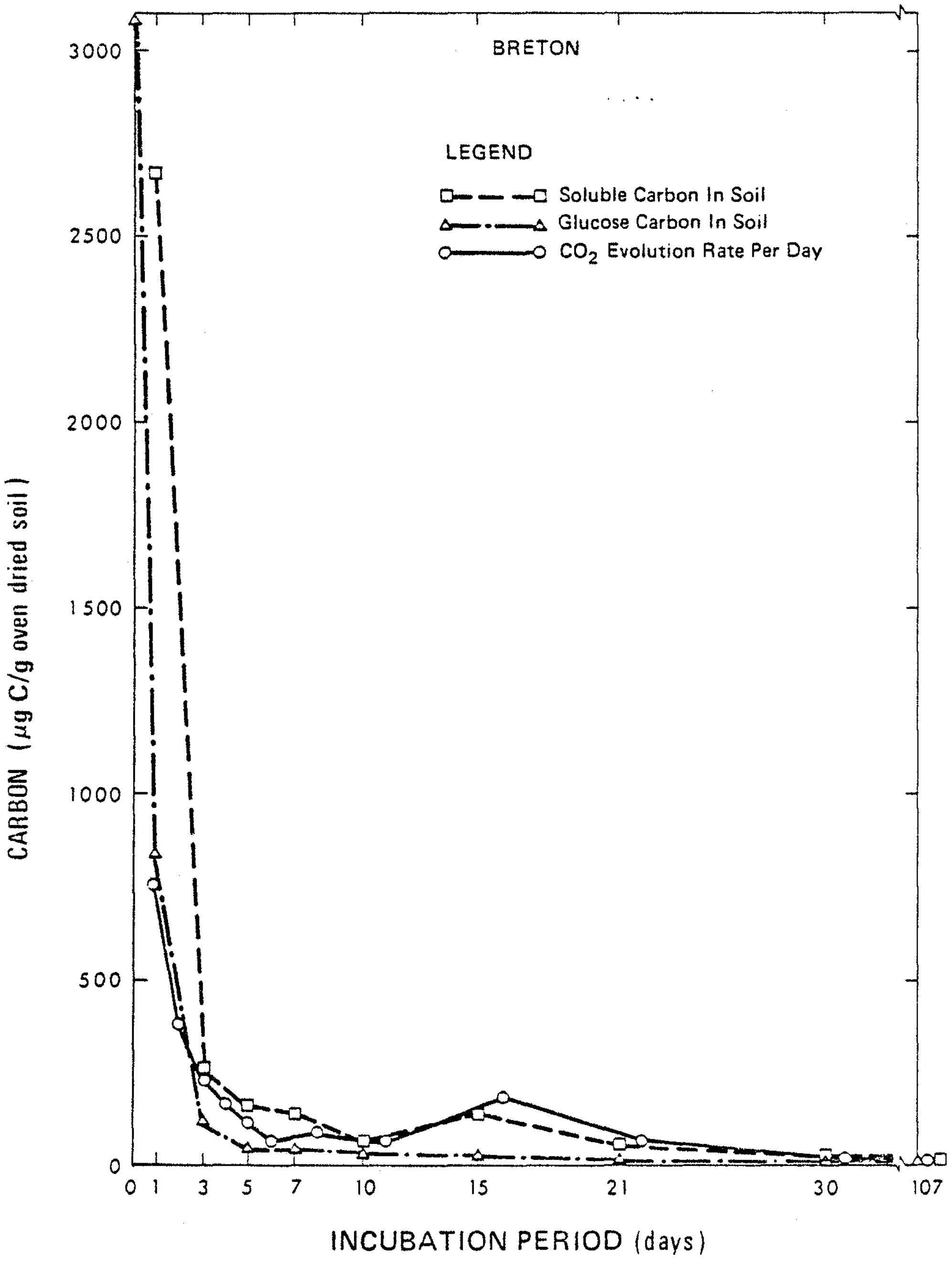


Figure 18a. Carbon dioxide production rates, soluble carbon and glucose carbon in Breton loam over the incubation period.

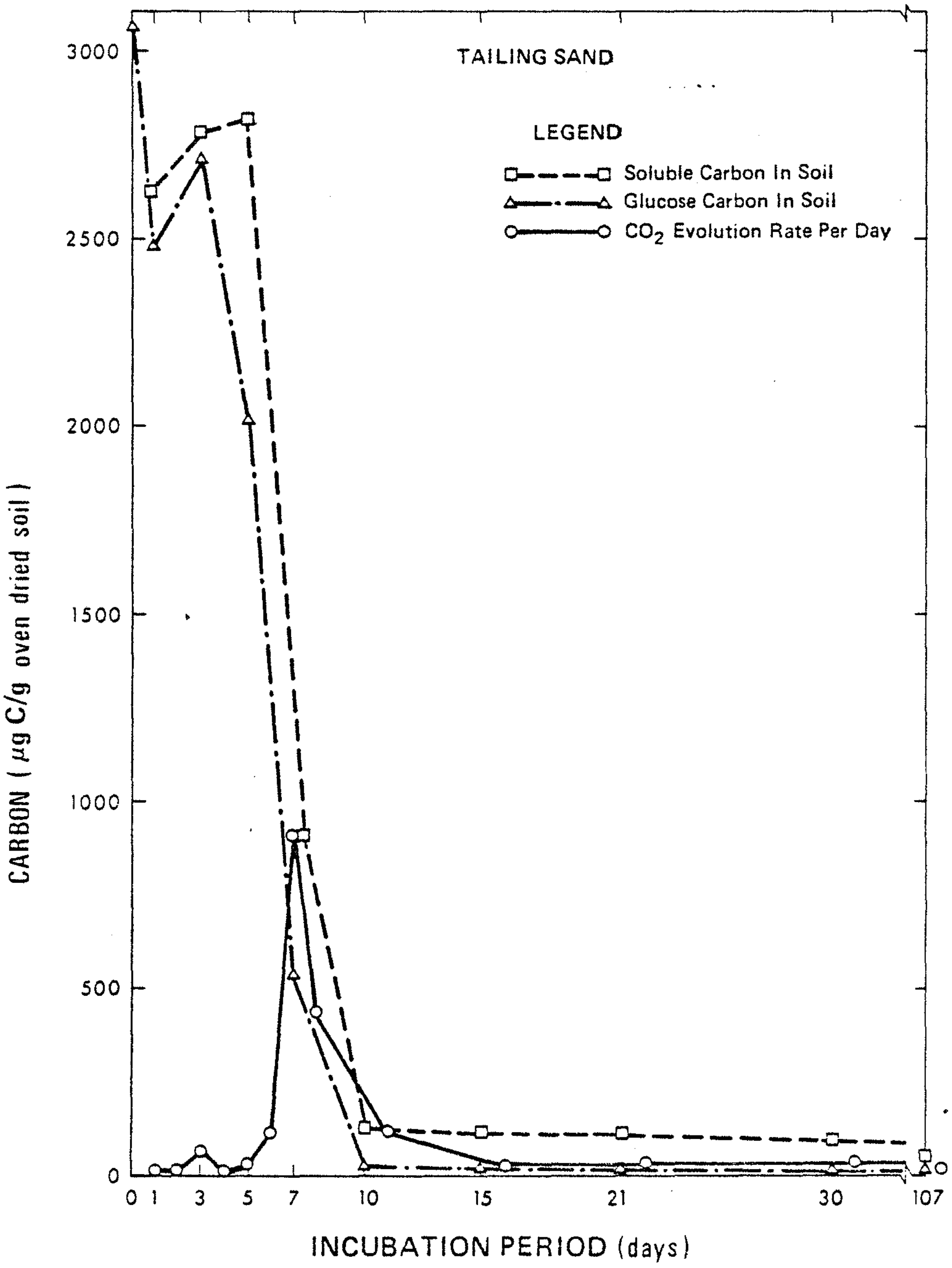


Figure 18b. Carbon dioxide production rates, soluble carbon and "glucose" carbon in Tailings sand over the incubation period.

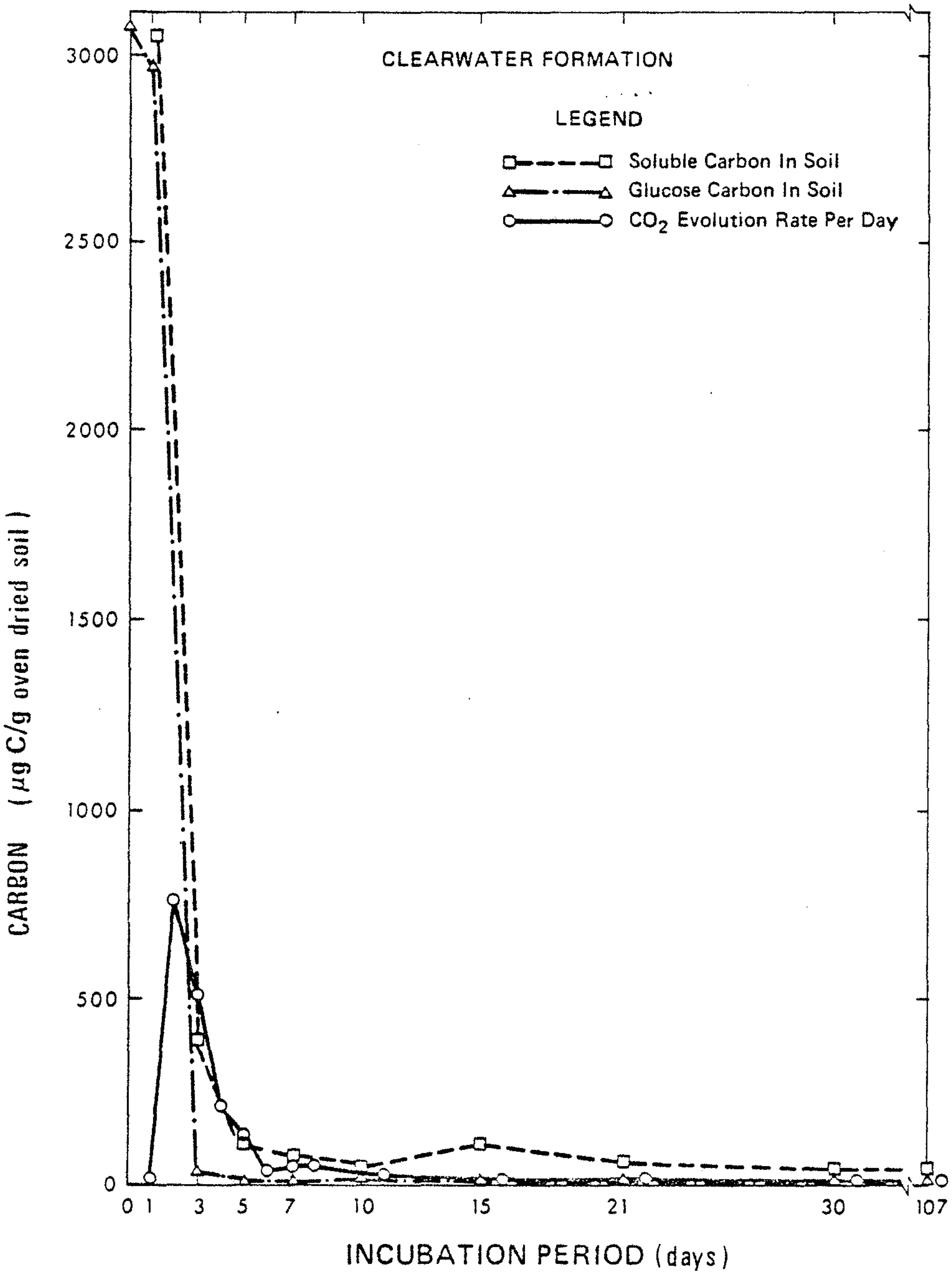


Figure 18c. Carbon dioxide production rates, soluble carbon and "glucose" carbon in Clearwater formation shale over the incubation period.

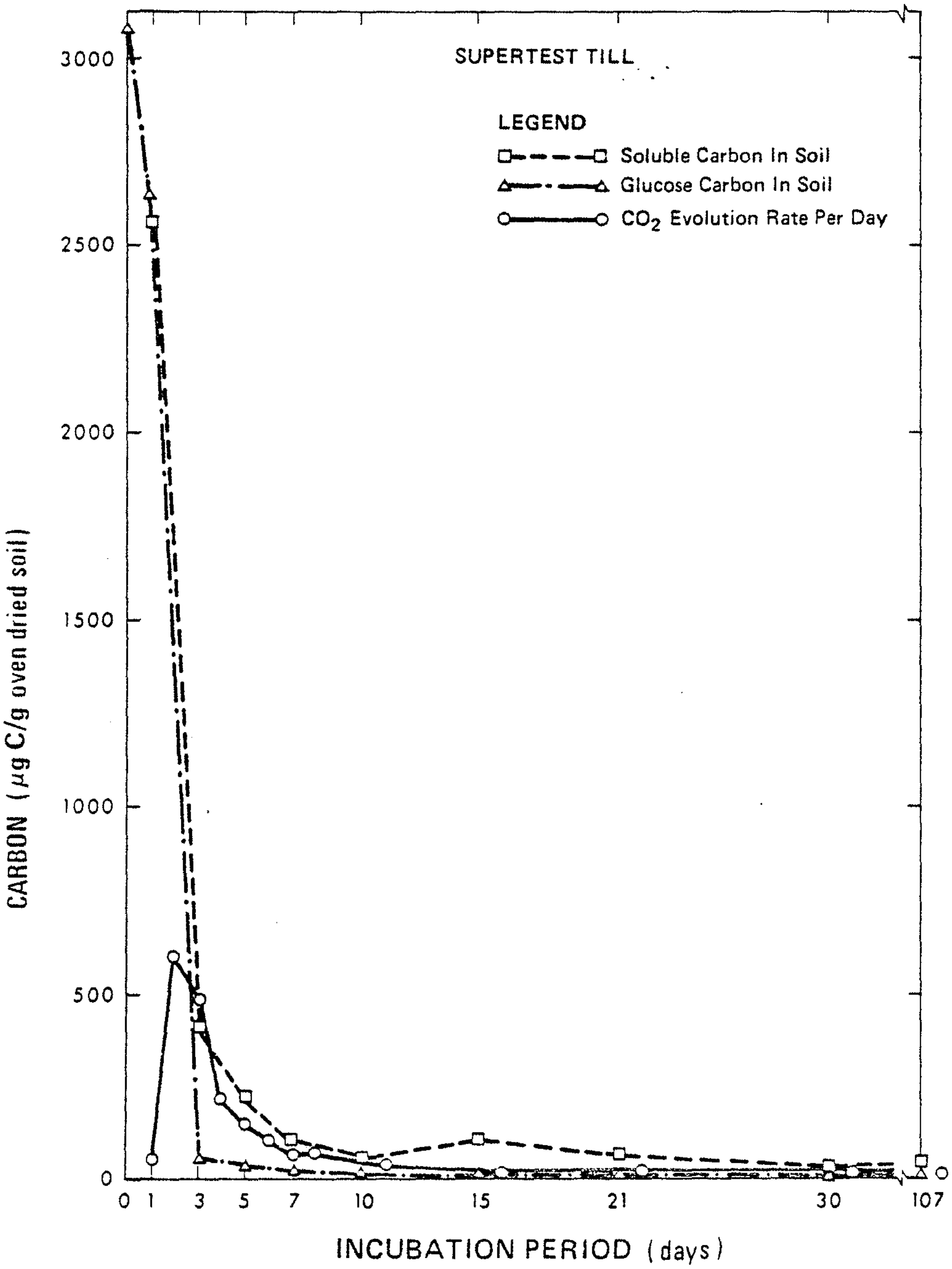


Figure 18d. Carbon dioxide production rates, soluble carbon and "glucose" carbon in Supertest till over the incubation period.

The turnover rate of the soluble carbon pool is as important as its total size. This rate can be calculated roughly from data in Tables 22 and 26. Using values for day 30 where the system is most nearly in steady state, turnover time or residence time of carbon in the soluble pool can be estimated from:

$$\begin{aligned} \mathrm{Tl/e} &= \text{C present in pool / C passed through/day} \\ &= \text{Water soluble C / } \mathrm{CO_2}\text{-C produced/day} \end{aligned}$$

Some turnover times are tabulated in Table 27. They are not constant over time, reflecting probable differences in size of active population. The highest turnover times (slowest rates) are obtained during the latter stages of incubation. This reflects stabilization of the carbon and a reduction in activity or number of organisms present. During the later stages of the incubation the slowest turnover rate of the soluble pool was generally in the Clearwater shale and the fastest in the Supertest till. It should be pointed out however that by 107 days of incubation, the soluble pool of Breton loam appeared to be the most stable. The turnover time of the soluble carbon pool in the Tailings sand was relatively constant at around three days during the period 21 to 107 days.

Table 27. Turnover time (days) of total soluble C pools at four times during the incubation period

Day	Breton loam(control)	Tailings sand	Clearwater shale	Supertest till
10	1.5	0.99	1.3	1.2
21	0.8	3.7	2.7	2.9
30	0.9	3.2	6.4	0.97
107	7.9	2.7	5.2	0.75

The size of the total water soluble pool was larger than the "glucose-carbon" pool and more variable between soils. Part of the difference in turnover times is associated with different pool sizes. This suggests an effect of substrate concentration on rate of uptake (Monod type system). Further work, involving examination of the effect of substrate concentration on its rate of uptake by soil microbes in these materials would be desirable. The very dynamic nature of the soluble carbon pool in all soils is demonstrated by the relatively short residence times.

Another concern in developing a soil system is the extent to which synthesized microbial biomass is stabilized in soil. In most mineral soils, about 20 percent of the consumed substrate-carbon remains in the soil for a considerable time. This material is microbial biomass, stabilized metabolic products and dead cells. Mechanisms to prevent complete loss of this microbial biomass are essential if a soil is to retain much organic matter. The present data can be used to see if qualitative differences in loss rate exist between the different materials. From the cumulative CO_2 plots, it can be seen that most of the added glucose-carbon can be accounted for as evolved CO_2-C in the Tailings sand but not in the Supertest till or Clearwater shale (Figure 19a,b). In the Breton loam (control not subtracted) the native soil organic matter has contributed significantly to the total CO_2-C evolved. These data together with those for changes in soluble carbon were used to calculate the biomass-C remaining in the soils (Figure 20). This calculation demonstrates that only about 12 percent of the synthesized biomass was retained in the Tailings sand. About 64 percent of the synthesized biomass was retained in the Clearwater shale and about 36 percent was retained after 30 days in the Supertest till. These data suggest that the finer materials are definitely more able than Tailings sand to stabilize organic compounds. Whether this is due to

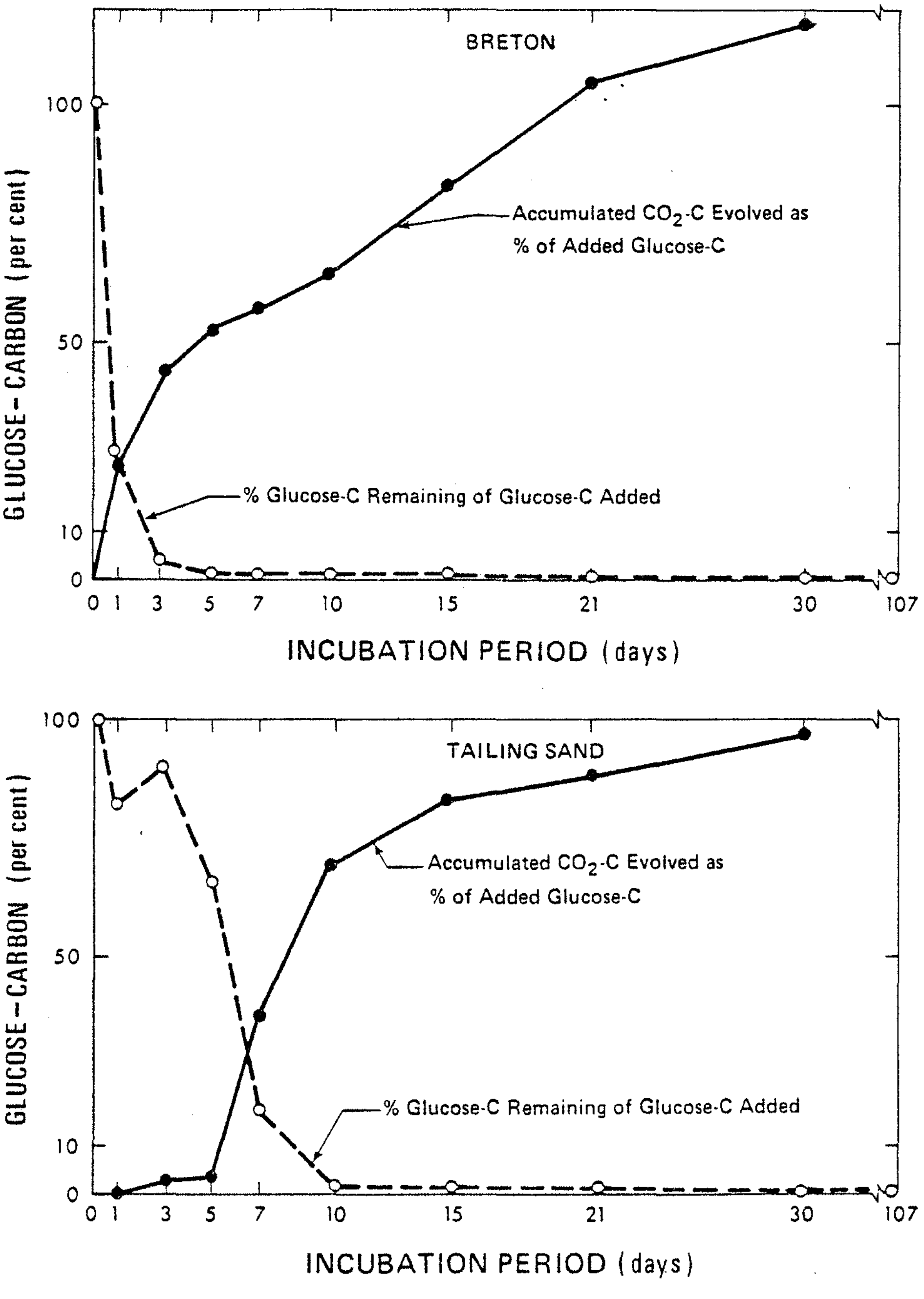


Figure 19a. Cumulative carbon dioxide production and "glucose" carbon as percent of added glucose in Breton loam and Tailings sand over the incubation period.

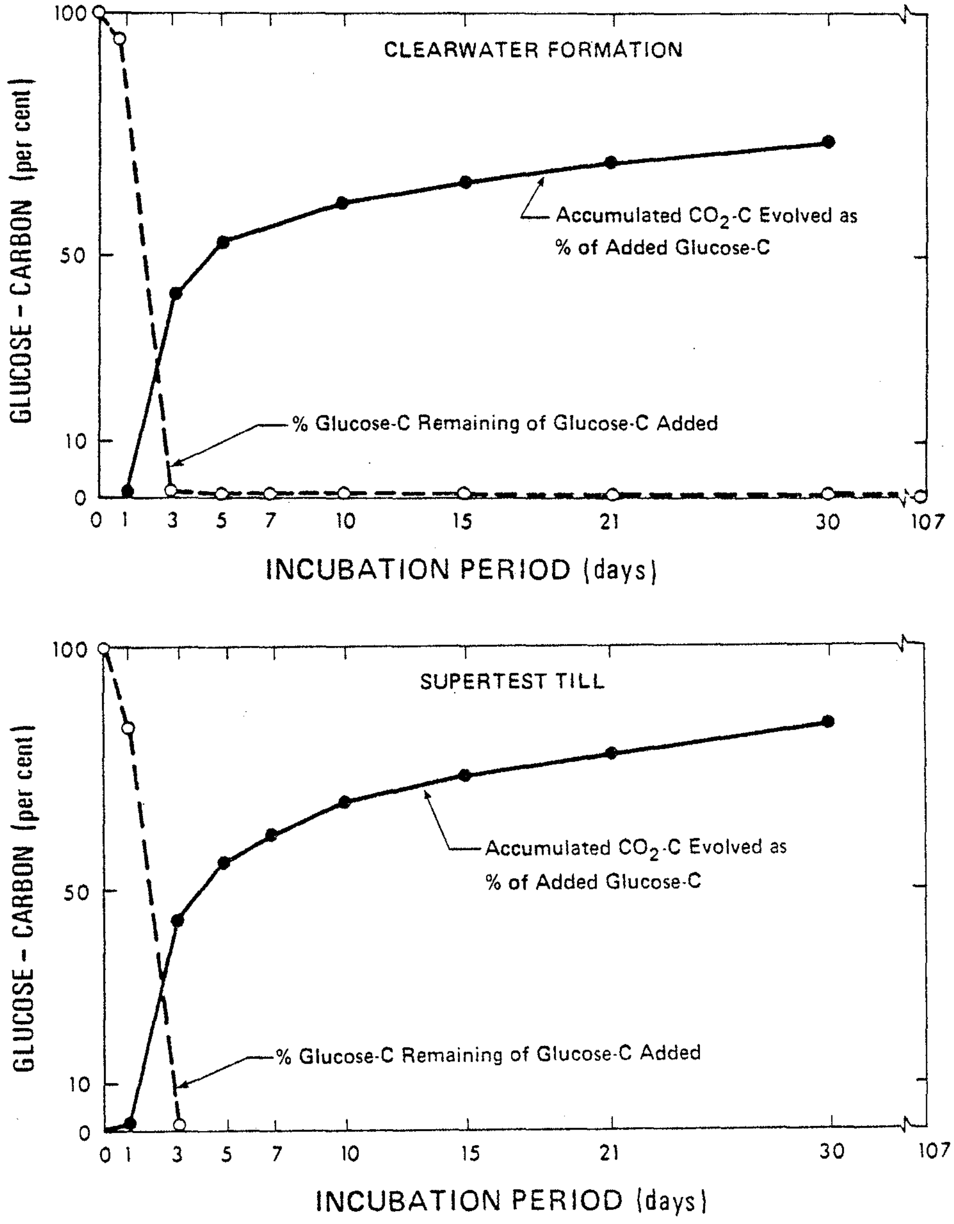


Figure 19b. Cumulative carbon dioxide production and "glucose" carbon as percent of added glucose in Clearwater formation shale and Supertest till over the incubation period.

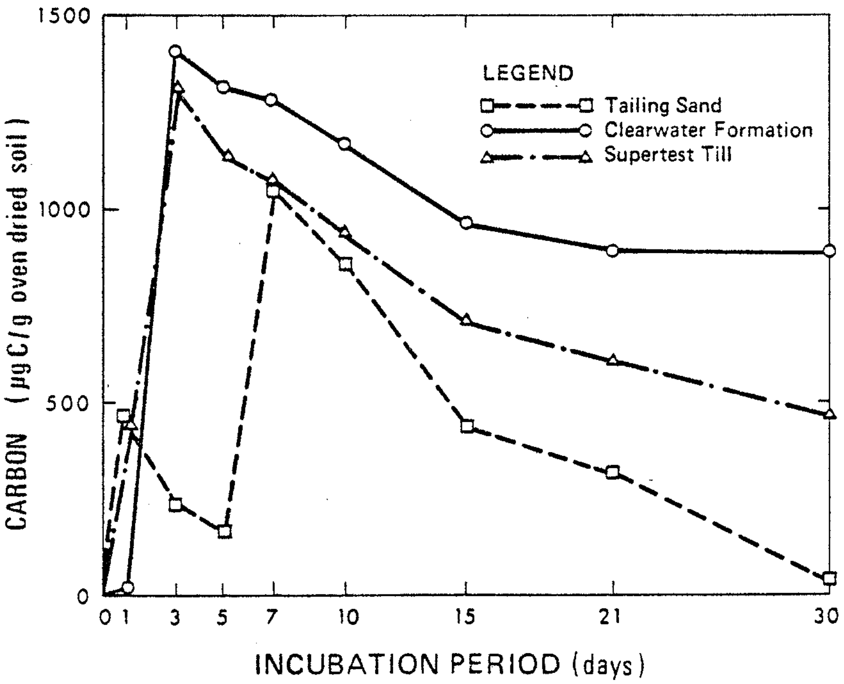


Figure 20. Biomass carbon produced in Tailings sand, Clearwater formation shale and Supertest till over the incubation period.

adsorption, metals, pH, or other factors, is not clear at present, but the retention is more or less proportional to clay content. There is definite potential, therefore for reducing the biomass loss rate with these finer materials.

6. CONCLUSIONS AND RECOMMENDATIONS

Measurements at the instrumented field sites confirm the suggestion made in the last report that ground temperatures are higher on the dike than elsewhere. A strong upward thermal gradient exists, the source of heat presumably being warm water from the tailings pond.

Detailed information on soil moisture tensions, showed that a peak of similar magnitude occurred at all the natural forest sites in late August and this peak was not exessively large. On the dike, however, large tensions occurred as early as May in the near surface, and by late August these occurred throughout most of the rooting zone. Runoff does not appear to be the reason for the high tensions, which presumably could account for the poor growth in some introduced tree species. The reason is perhaps large water use by fertilized Brome grass.

Detailed information has been obtained on moisture changes in the soil during the thaw period as well as throughout the summer, at several of the instrumented field sites at Mildred Lake and at Richardson. Information was less detailed during the Autumn and Winter. The 32 'outlying sites' confirm the general observation that Jackpine occupies sands of low moisture-holding capacity and that Spruce only occasionally grows on well-drained sand. Although Aspen generally occupies sands of intermediate moisture content and Birch is often found where drainage is impeded by Tar sand, both species occur under widely varying moisture conditions. It is important that moisture conditions at the instrumented sites seem to be fairly representative of those normally associated with each vegetative type.

Water tables were lower in 1977 than in 1976, presumably because of the very light snow accumulation during winter 1976/77.

Indoor lysimeter studies showed that growth of Brome grass during the first year, was much improved by addition of peat to Tailings sand, however the effect was not apparent in the second year. Little, if any leaching occurred in these lysimeters, and it seems possible that such could also be the case on the GCOS dike during the growing season. The high pH of soil water at a depth of 1 m in the field lysimeters and on the dike itself, is further evidence for the rate of leaching being very slow.

In field lysimeters, Tailings sand alone produced almost no growth, while treatments with peat mixed in the surface produced most growth. Evidence is inconclusive regarding the effect of a buried till layer on water storage in the layers above it, or regarding the effect of till on plant growth and more conclusive evidence will not be possible until a more mature plant cover is established.

The initial stage of a nutrient cycling study at the forest sites shows that about 80 to 90 percent of precipitation during the growing season falls through the canopy. Of this, about one-third is intercepted and recycled in the litter layer. The pH of precipitation decreases as it falls through the forest canopy and litter layers, but increases again after leaching through the soil. Winter snow sampling and continued monitoring of various parts of the nutrient cycle will eventually give a more complete picture of nutrient balance at these forest sites.

The laboratory study on carbon and nitrogen recycling demonstrates that the autotrophic process of nitrification is inhibited by Clearwater shale and Tailings sand but not by Supertest till. The data also demonstrate a very close control of substrate supply as measured by water soluble carbon content on overall microbial activity. Carbon and nitrogen cycled together through these materials. These data should be useful in constructing a model of the soil system during reclamation which involves these materials.

The nature of the field research requires that intensive gathering of information must occur during the period 1 April to 1 November. The reduction of much of this field data occurs subsequently and this is followed by interpretation. The amount of data gathered is such that interpretation should be largely complete by April, when the next field season begins. This means however that at this time of writing (December 1977) interpretation is incomplete. For example, changes in water content above the water table need to be coupled with values for hydraulic conductivity and non-intercepted precipitation, to derive deep water drainage, in the construction of a basic water model.

Field nutrient cycling studies involve several phases: a) assessment of state variables; b) growing labelled plant material; c) adding this to soil and allowing it to incubate there; d) sample removal following incubation; e) sample fractionation into various soil and plant components or sub-samples. f) subsample analysis for the desired element. g) isotopic analysis of the element; and finally, h) data reduction, interpretation, and synthesis. At present these studies are complete to "c" with parts of d,e,f, and g complete. Efforts have been directed towards streamlining analytical procedures.

It is recommended that this phase of the project continue to concentrate on field moisture and temperature monitoring at the present instrumented sites so as to cover a range of seasonal conditions. Emphasis should be placed on routine sample collection, processing, and analysis, to bring the broad field-oriented nutrient cycling studies to the stage where concentration can be on reduction, interpretation and synthesis (stage "h" above). Laboratory studies must continue on the effect of mine-waste materials on nitrogen fixation and sulphur transformations and the mechanisms by which carbon is supplied to the water soluble pool. Additional, more detailed moisture and nutrient cycling studies will be needed and should be planned after the present overall field study is more complete. In conjunction with such studies, an integrating model should be developed to summarize the concepts and data of the system, both before and after its disturbance.

7. LIST OF REFERENCES

Burford, J.R. and J.M. Bremner. 1975. Relationship between the denitrification capacities of soils and total, water-soluble and readily decomposable soil organic matter. Soil Biol. Biochem. 7: 389-394.

Cook, F.D., M. Nyborg., W.B. McGill; A.H. Maclean; S.K. Takyi; and L.W. Turchenek. Interim report on soil research related to vegetation of the Oil sands area. AOSERP sub-project VE 4. In preparation.

Elrick, D.E. and D.H. Bowman. 1964. Note on an improved apparatus for soil moisture flow measurements. Soil Sci. Soc. Amer. Proc. 28: 450-452.

Green, R.E. and J.C. Corey. 1971. Calculation of hydraulic conductivity : A further evaluation of some predictive methods. Soil Sci. Soc. Amer. Proc. 35: 3-8.

Herbert, D. 1958. Some principles of continuous culture. In Recent progress in microbiology, pp. 381-396. G. Turnevall (ed), 7th. Int. Cong. Microbiol., Stockholm.

Junk, G. and J.J. Svec. 1958. The absolute abundance of nitrogen isotopes in the atmosphere and compressed gas from various sources. Geochim. Cosmochim. Acta. 14: 234-243.

Klute, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. In Methods of Soil Analysis, Part 1, pp. 210-221. C.A. Black (ed), Agron. No. 9, Amer. Soc. Agron., Madison, Wisc.

Korven, H.C. and S.A. Taylor. 1959. Peltier effect and its use for determining relative activity of soil water. Can. J. Soil Sci. 39: 76-85.

McKeague, J.H. (ed). 1976. Manual on soil sampling and methods of analysis. Soil Res. Inst. Agric. Canada. 212p.

Mebius, L.J. 1960. A rapid method for the determination of organic carbon in soil. Analyt. Chim. Acta. 22: 120-124.

Middleboe, U., D.R. Nielson and D.A. Rennie. 1976. Tracer manual on crops and soils. Tech. Rept. Series No. 171, Intern. Atomic Energy Agency, Vienna. 277p.

Millington, R.J. and J.P. Quirk. 1961. Permeability of porous solids. Trans. Faraday Soc. 57: 1200-1207.

Morrison, J.K. and N.W. Foster. 1974. Ecological aspects of forest fertilization. In Proceedings of a Workshop on Forest Fertilization in Canada. Dept. of Env., Forestry Service, Forestry Tech. Rept. No. 5, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.

Oades, J.M. 1967. Carbohydrates in some Australian soils. Aust. J. Soil Res. 5: 103-115.

Parkinson, J.A. and S.E. Allen. 1975. A wet oxidation procedure suitable for the determination of nitrogen and mineral nutrients in biological material. Commun. Soil Sci. Pl. Anal. 6: 1-11.

Pirt, S.J. 1975. Principles of microbe and cell cultivation. Blackwell Scientific Publications, London. 274p.

Reeder, J.D. and W.A. Berg. 1977. Nitrogen mineralization and nitrification in a Cretaceous shale and coal mine spoils. Soil Sci. Soc. Amer. J. 41: 922-927.

Richards, L.A. 1949. Methods of measuring soil moisture tension. Soil Sci. 68: 95-112.

Riga, A., H.J. Van Praag and N. Brigade. 1971. Rapport isotopique naturel de l'azote dans quelques sols forestiers et agricoles de Belgique a divers traitments culturaux. Geoderma 6: 213-222.

Rose, C.W. and W.R. Stern. 1965. The drainage component of the water balance equation. Aust. J. Soil Res. 3: 95-100.

Russel, E.W. 1961. Soil Conditions and Plant Growth. Longmans, London.

Salter, P.J., G. Berry and J.B. Williams. 1967. The effect of farmyard manure on matric suctions prevailing in sandy loam soil. J. Soil Sci. 18: 318-328.

Syncrude Canada Ltd. 1977. Continued studies of soil improvement and revegetation of tailings sand slopes. Environmental Research Monograph 1977-4. Syncrude Canada Ltd.

Takyi, S.K., M.J. Rowell, W.B. McGill and M. Nyborg. 1975. Reclamation and vegetation of surface mined areas in the Alberta Oil Sands. Rept. Res. Contract between Syncrude Canada Ltd. and University of

Alberta. Environmental Research Monograph 1977-1. Syncrude Canada Ltd. 200p.

Ulrich, B. and R. Mayer. 1972. Systems analysis of mineral cycling in forest ecosystems. In Isotopes and radiation in soil-plant relationships including forestry. Intern. Atomic Energy Agency, Vienna.

Webster, R. 1966. The measurement of soil water tension in the field. New Phytol. 65: 249-258.

Webster, R. and P.H.T. Beckett. 1971. Matric suctions to which soils in South Central England drain. J. Agr. Sci. 78: 379-387.

8. APPENDICES

8.1. APPENDIX A. SOIL DESCRIPTIONS.

MILDRED LAKE SITE 1

Horizon	Depth(cm)	Description
L-H	6-0	Very dark brown (10YR 2/2) semi-decomposed organic matter; abundant fine and medium roots; clear smooth boundary.
Ae	0-16	Pale brown (10YR 6/3) sand; single grain; loose, friable; plentiful roots; diffuse wavy boundary.
Bm	16-35	Light yellowish brown (10YR 6/4) sand; single grain; loose, friable; plentiful roots; diffuse wavy boundary.
IIBC	35-55	Brown (10YR 5/3) sand; single grain; loose, friable; very few roots; diffuse wavy boundary.
IIIC	55-70	Brownish yellow (10YR 6/6) sand; single grain; loose, friable; very few roots; abrupt smooth boundary.
IVC	70-74	Black (10YR 2/1) tar sand layer; weakly cemented; abrupt smooth boundary.
VC	74+	Brownish yellow (10YR 6/6), loose non-calcareous sand.

MILDRED LAKE SITE 2

Horizon	Depth(cm)	Description
F-H	<1-0	Very dark grayish brown (10YR 3/2) semi-decomposed organic matter.
Ahe	0-5	Dark brown (10YR 4/3) sand; single grain; loose, friable; abundant roots; indistinct boundary.
AB	5-11	Dark yellowish brown (10YR 4/4) sand; single grain; loose, friable; abundant roots; indistinct boundary.
Bm	11-56	Yellowish brown (10YR 5/6) sand; single grain; loose, friable; few roots; diffuse smooth boundary.
BC	56-86	Brownish yellow (10YR 6/6) sand; single grain; loose, friable; no roots; transitional, merging to C-horizon.
C	86+	Yellow (10YR 7/6) loose sand; occasional stones; non-calcareous.

MILDRED LAKE SITE 3

Horizon	Depth(cm)	Description
L-H	9-0	Very dark grayish brown (10YR 3/2) semi-decomposed organic matter; clear smooth boundary.
Ahe	0-2	Light brownish gray (10YR 6/2) and very dark yellowish brown (10YR 3/2) sand; single grain; loose, friable; abundant roots; clear wavy boundary.
Ae	2-10	Light brownish gray (10YR 6/2) sand; single grain; abundant roots; clear smooth boundary.
Bm	10-35	Yellowish brown (10YR 5/6) sand; single grain; few roots; diffuse wavy boundary.
BC	35-57	Transitional.

Horizon	Depth(cm)	Description
C	57-100	Grayish brown (2.5Y 5/2) loose sand with some patches of tar sand; non calcareous.
IIC	100-110	Black layer of tar sand; amorphous; firm; cemented; non calcareous.

MILDRED LAKE SITE 4

Horizon	Depth(cm)	Description
L-H	7-0	Very dark brown (10YR 2/2) semi-decomposed organic matter; abundant roots; clear smooth boundary.
Ae	0-5	Grayish brown (10YR 5/2) sand; single grain; loose, friable; abundant roots; gradual wavy boundary.
AB	5-20	Brown (10YR 5/3) loamy sand; single grain; loose, friable; few roots; clear wavy boundary.
Bt	20-45	Dark yellowish brown (10YR 4/6) gravelly sandy loam to loam; few roots; clear wavy boundary.
IIB	45-63	Light olive brown (2.5Y 5/4), with black streaks, sand; single grain; no roots; no stones; gradual wavy boundary.
IIC	63+	Light olive brown (2.5Y 5/6), with black horizontal streaks, sand; stony layers; non calcareous.

MILDRED LAKE SITE 5

Horizon	Depth(cm)	Description
L-H	5-0	Very dark brown (10YR 2/2) semi-decomposed organic matter; abundant fine and medium roots; clear smooth boundary.
Ae	0-10	White (10YR 8/2) sand; single grain; loose, friable; plentiful roots; diffuse wavy boundary.

Horizon	Depth(cm)	Description
AB	10-16	Pale brown (10YR 6/3) sand; single grain; loose, friable; plentiful roots; gradual wavy boundary.
Bm	16-33	Yellowish brown (10YR 5/6) sand; single grain; loose, friable; plentiful roots; diffuse wavy boundary.
BC	33-80	Brownish yellow (10YR 6/6) sand; single grain; loose, friable; plentiful roots; gradual wavy boundary.
C	80+	Very pale brown (10YR 7/4) sand; single grain; loose, friable; no roots.

MILDRED LAKE SITE 6 (Aspen).

Horizon	Depth(cm)	Description
LFH	7-0	
Ae	0-8	Sand; single grain; loose, friable; numerous roots; diffuse wavy boundary.
AB	8-22	Sand; single grain; plentiful roots; distinct wavy boundary.
Bt	22-47	Sand (gravelly); single grain; very friable, soft; few roots; many stones; distinct wavy boundary.
C	47+	Sand; single grain.

MILDRED LAKE SITE 7 (Mixedwood).

Horizon	Depth(cm)	Description
LFH	6-0	
Ae	0-15	Sand; single grain; loose, friable; abundant roots; gradual wavy boundary.
B	15-35	Sand; single grain; loose, friable; few roots; clear, smooth boundary.
IIB	35-49	Black sand; single grain; few roots; smooth clear boundary.
C	49+	Sand; single grain; few roots.

MILDRED LAKE SITE 8 (Spruce).

Horizon	Depth(cm)	Description
LFH	8-0	Sphagnum moss.
Ae	0-3	Loamy sand to sand; single grain; very friable, soft; abundant roots; diffuse smooth boundary.
Ae(Bm)	3-25	Loamy sand; very friable, soft; massive when moist; few roots; abrupt smooth boundary.
Bt	25-31	Loam to clay loam; massive when moist; friable, slightly hard; few roots; clear smooth to wavy boundary.
BC	31-50	Loamy sand; single grain; loose.
C	50+	Gravelly layer with particles and chunks of tar sand.

SUPERTEST HILL

Horizon	Depth(cm)	Description
L-H	5-0	Very dark brown (10YR 2/2) semi-decomposed organic matter; fibrous, abundant fine and medium roots; abrupt smooth boundary.
Ae	0-8	Light brownish gray (10YR 6/2) sandy loam; weak platy; friable; abundant fine and medium roots; abrupt wavy boundary.
AB	8-20	Brown (10YR 5/3) loam; weak subangular blocky; firm; plentiful fine and medium roots; gradual wavy boundary.
Bt	20-50	Dark brown (10YR4/3) clay loam; moderate subangular blocky; firm; very few fine and medium woody roots; gradual wavy boundary.
BC	50-80	Dark yellowish brown (10YR 3/4) clay loam; very few roots; gradual wavy boundary; transitional.

Horizon	Depth(cm)	Description
C	80+	Mainly dark yellowish brown (10YR 4/4), but also gray (10YR 7/2) and other colours; stony, stones small

GCOS DIKE SITE 1

Horizon	Depth(cm)	Description
	0-15	Dark grayish brown (2.5Y 4/2) peat mixed with Tailings sand.
	15+	Olive (5Y 5/3) Tailings sand.

GCOS DIKE SITE 2

Horizon	Depth(cm)	Description
	0-25	Very dark grayish brown (2.5Y 3/2) peat mixed with Tailings sand.
	25+	Grayish brown (2.5Y 5/2) Tailings sand.

RICHARDSON SITE 4

Horizon	Depth(cm)	Description
L-H	0.5-0	Very dark gray (10YR 3/1), semi-decomposed organic matter; fibrous, abundant fine and medium woody roots; abrupt, smooth boundary.
Ahe	0-5	Pale brown (10YR 6/3) sand; single grain; loose, friable; abundant fine and medium woody roots; clear smooth boundary.
Ae	5-15	Very pale brown (10YR 7/3) sand; single grain; loose, friable; abundant fine and medium woody roots; abrupt wavy boundary.
B	15-40	Yellow (10YR 7/6 becoming 10YR 8/6 below) sand; single grain; loose, friable; few fine and medium woody roots in upper horizon.

Horizon	Depth(cm)	Description
BC	40-80	Transitional.
C	80+	Very pale brown (10YR 8/3) with patches of white (5YR 8/1) or pinkish white (5YR 8/2) surrounding dead organic material and also occasional brownish yellow (10YR 6/6) sand; single grain; loose, friable; non-calcareous.

RICHARDSON SITE 5

Horizon	Depth(cm)	Description
L-H	10-0	Very dark grayish brown (10YR 3/2) semi-decomposed organic matter; fibrous, abundant fine and medium woody roots; gradual smooth boundary.
Ahe	0-6	Light gray (10YR 7/2) and dark gray (10YR 4/1) sand; single grain; loose, friable; abundant fine and medium woody roots; gradual smooth boundary.
Ae	6-30	White (5YR 8/2) sand; single grain; loose, friable; plentiful fine and medium woody roots in upper portion; clear irregular boundary, in places tonguing to 70 cm.
Bfj	30-120	Strong brown (7.5YR 5/8) with patches of reddish brown (7.5YR 7/6 to 6/8) with a few strong brown (5YR 5/6 to 5/8) indurated iron concretions in lower portion, sand; mainly single grain; loose, friable; very few stones; smooth clear boundary .
C	120+	Pink (7.5YR 8/4) sand; single grain; loose, friable; non-calcareous.

RICHARDSON SITE 6

Horizon	Depth(cm)	Description
LF	3-1	Leaves, fungi common.
H	1-0	Black (10YR 2/1) semi-decomposed organic matter; abundant fine and medium roots; diffuse smooth boundary.
Ahe	0-4	Very dark grayish brown (10YR 3/2) and light gray (10YR 7/1) sand; single grain; loose, friable; abundant fine and medium woody roots; gradual wavy boundary.
Ae	4-12	White (10YR 8/2) sand; single grain; loose, friable; abundant fine and medium woody roots; few subrounded stones; gradual wavy boundary.
Bhj	12-27	Light yellowish brown (10YR 6/4) sand, coarser than above; single grain; loose, friable; plentiful fine and medium roots; gradual broken boundary.
BC	27-100	Yellow (10YR 8/6), with occasional dark yellowish brown (10YR 4/4) around decomposing stones, sand; single grain; loose, friable; abundant fine and medium woody roots; gradual wavy boundary.
C	100+	Pink (7.5YR 8/4) sand; single grain; loose, friable; very few medium woody roots.

8.2 APPENDIX B. TABLES OF DATA GATHERED DURING 1977 AT INSTRUMENTED SITES, FROM LYSIMETERS AND PLOTS AND FROM LABORATORY STUDIES.

Appendix Table 1. Chemical analyses of soil samples from field sites.

MILDRED LAKE SITE 2

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
LFH	4.5	42.2	0.83	50.7	
Ahe	5.5	1.08	0.026	41.5	-
AB	5.8	0.55	0.015	36.7	-
Bm	5.8	0.03	0.003	10.0	-
BC	5.8	0.04	0.004	10.0	-
C 300	6.0	0.04	0.003	13.3	-

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS(meq/100g) Na	K	Ca	Mg	BASE SAT.(%)
Ahe	3.5	0.01	0.05	1.1	0.2	38
AB	2.4	0.01	0.05	1.2	0.2	58
Bm	1.3	0.04	0.03	0.5	0.2	61
BC	1	0.01	0.02	0.3	0.1	41
C 300	0.7	0.01	0.02	0.5	0.1	90

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
Ahe	0.1	28	8	5	12	5
AB	0.09	31	4	6	13	4
Bm	0.03	20	7	1	3	1
BC	0.03	22	12	1	4	2
C 300	-	-	-	-	-	-

(continued)

Appendix Table 1. (continued)

MILDRED LAKE SITE 3

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
LFH	4.5	24.41	1.02	23.9	-
Ahe	4.5	2.9	1.136	21.3	-
Ae	4.9	0.45	0.023	19.6	-
Bm	5.7	0.31	0.013	23.8	-
BC	5.8	0.29	0.006	48.3	-
C	5.3	2.11	0.025	84.4	-
C 150	5.9	0.54	0.008	67.5	-
C 300	5.6	1.1	0.016	68.8	-
C 3-400	5.9	5.91	-	-	-
C 600	7.8	0.59	0.01	62	0.58

DEP (cm)/	CEC	NH_4 EXTRACTABLE CATIONS(meq/100g)				BASE
HORIZON	(meq/100g)	Na	K	Ca	Mg	SAT.(%)
Ahe	11.5	0.02	0.08	4.4	0.6	44
Ae	2.1	0.02	0.03	1	0.2	62
Bm	2	0.03	0.03	0.8	0.3	57
BC	1.6	0.03	0.03	0.7	0.3	66
C	2.8	0.04	0.04	1	0.4	53
C 150	2.3	0.01	0.05	1.3	0.5	81
C 300	2.9	0.02	0.05	1.5	0.6	75
C 3-400	5.9	0.05	0.08	4.8	1.2	100
C 600	2.4	0.02	0.04	3.9	0.9	100

DEP (cm)/	E.C.	SAT.	IONS IN SAT. EXT. (ppm)			
HORIZON	(mmho/cm)	(water%)	Na	K	Ca	Mg
Ahe	0.32	55	8	18	69	24
Ae	0.14	27	5	5	24	9
Bm	0.11	24	15	2	16	9
BC	0.09	25	4	3	18	6
C	0.17	28	24	5	14	8
C 150	-	-	-	-	-	-
C 300	-	-	-	-	-	-
C 3-400	-	-	-	-	-	-
C 600	-	-	-	-	-	-

(continued)

Appendix Table 1. (continued)

MILDRED LAKE SITE 4

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
LF	5.2	21.33	0.73	29.2	-
H	5.5	7.95	0.23	34.6	-
Ae	5.4	0.43	0.015	28.7	-
AB	5.5	0.42	0.026	16.2	-
Btj	5.6	0.22	0.012	18.3	-
Bm	6.3	0.12	0.009	13.0	-
C	6.7	0.06	0.004	15.0	-
C 275	8.8	-	-	-	14.33

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS(meq/100g) Na	K	Ca	Mg	BASE SAT.(%)
Ae	2.4	0.01	0.07	1.2	0.2	62
AB	3.6	0.01	0.09	1.7	0.4	61
Btj	5.8	0.08	0.08	2.0	0.7	49
Bm	4.5	0.03	0.07	2.3	1.0	76
C	1.4	0.02	0.03	0.9	0.3	89
C 275	1.5	0.04	0.02	9.0	0.6	100

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
Ae	0.3	19	5	8	67	16
AB	0.25	17	6	6	59	18
Btj	0.1	18	12	2	16	7
Bm	0.18	29	12	2	35	17
C	0.06	24	10	2	8	4
C 275	-	-	-	-	-	-

MILDRED LAKE SITE 6 (Aspen).

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
LFH	6.2	20.09	0.96	20.8	-
Ae	5.5	0.55	0.079	7.0	-
AB	5.8	0.17	0.023	7.4	-
Bt	5.8	0.24	0.023	18.5	-
C 47+	6.5	0.04	0.005	8.0	-

(continued)

Appendix Table 1. (continued)

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS(meq/100g) Na	K	Ca	Mg	BASE SAT.(%)
LFH	58.2	0.04	2.28	44.2	10.1	97
Ae	1.9	0.01	0.1	0.9	0.2	62
AB	1.3	0.05	0.05	1.3	0.3	100
Bt	3.5	0.03	0.06	2	0.6	77
C 47+	1.2	0.02	0.02	0.9	0.2	95

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
LFH	-	-	-	-	-	-
Ae	0.31	26	3	14	62	18
AB	0.16	19	18	7	29	8
Bt	0.1	20	6	2	32	9
C 47+	0.12	23	8	2	18	7

MILDRED LAKE SITE 7 (Mixedwood).

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
Ae	4.6	0.34	0.028	12.1	-
B	4.8	0.34	0.018	18.9	-
IIBC	5.1	1.02	0.020	51.0	-
IIIBC	5.5	0.22	0.010	22.0	-

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS(meq/100g) Na	K	Ca	Mg	BASE SAT.(%)
Ae	1.6	0.02	0.04	0.7	0.2	63
B	3.1	0.1	0.05	0.5	0.4	34
IIBC	2.8	0.02	0.05	0.8	0.5	48
IIIBC	3.6	0.02	0.1	1.3	0.6	56

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
Ae	-	-	-	-	-	-
B	0.17	22	9	7	12	28
IIBC	0.1	22	3	6	12	9
IIIBC	0.1	26	6	5	13	8

(continued)

Appendix Table 1. (continued)

MILDRED LAKE SITE 8 (Spruce).

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
LFH	4.8	45.62	1.19	38.3	-
Ae	4.2	0.89	0.034	26.2	-
Bm	6	0.26	0.019	13.7	-
Bt	-	0.35	-	-	-
BC	6.7	0.32	0.018	17.8	-
C 50+	8.7	0.6	0.010	60.0	-

DEP (cm)/	CEC	NH_4 EXTRACTABLE CATIONS(meq/100g)				BASE
HORIZON	(meq/100g)	Na	K	Ca	Mg	SAT.(%)
LFH	88.5	0.1	4.2	24.4	7.2	41
Ae	5	0.01	0.1	0.9	0.3	26
Bm	7	0.02	0.2	5.2	0.7	87
BC	8.7	0.04	0.2	8.5	1.5	100
C 50+	2.7	0.01	0.03	3.8	0.4	100

DEP (cm)/	E.C.	SAT.	IONS IN SAT. EXT. (ppm)			
HORIZON	(mmho/cm)	(water%)	Na	K	Ca	Mg
Ae	0.17	24	13	7	23	11
Bm	0.15	23	9	4	31	6
BC	0.15	27	5	2	25	6
C 50+	0.41	17	7	5	91	26

SUPERTEST HILL

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
Ae	5.7	0.83	0.036	23.0	-
AB	5.9	0.25	0.035	7.1	-
Bt	5.9	0.64	0.020	32.0	-
BC	6.1	0.22	0.020	11.0	-
C 300	8.1	-	-	-	8.25
C 450	8.2	-	-	-	8.08

(continued)

Appendix Table 1. (continued)

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS (meq/100g) Na	K	Ca	Mg	BASE SAT.(%)
Ae	3.9	0.04	0.07	2.7	0.5	85
AB	-	-	-	-	-	-
Bt	12.5	0.04	0.2	8.3	2.7	90
BC	11.8	0.08	0.3	8.3	1.5	86
C 300	5.2	0.06	0.2	33.5	0.2	100
C 450	7.2	0.05	0.1	21.2	2.3	100

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
Ae	0.37	21	4	5	87	31
AB	0.33	21	4	4	74	35
Bt	0.27	32	5	2	52	24
BC	-	-	-	-	-	-
C 300	-	-	-	-	-	-
C 450	0.57	36	11	7	102	45

G.C.O.S. SITE 1

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
PEATY	7.1	1.52	-	-	1.52
SUB PEAT	8.2	0.20	-	-	0.20
300	-	0.35	0.008	43.8	0.35
600	-	0.17	0.007	24.3	0.17

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS (meq/100g) Na	K	Ca	Mg	BASE SAT.(%)
PEATY	0.5	0.08	0.04	7.1	1.8	100
SUB PEAT	0.4	0.06	0.02	0.7	0.3	100
300	7.4	0.04	0.03	0.5	0.2	10
600	0.5	0.2	0.04	0.4	0.4	100

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
PEATY	1.5	41	24	11	329	152
SUB PEAT	0.52	24	14	9	35	49
300	0.44	27	43	11	35	46
600	0.95	26	180	14	21	38

(continued)

Appendix Table 1. (continued)

G.C.O.S. SITE 2

DEP (cm)/	pH	ORG.	TOTAL	C/N	CaCO$_3$
HORIZON		CARB.(%)	N (%)		Eq.(%)
PEAT	7.6	2.07	0.120	17.2	0.78
SUB PEAT	-	0.29	-	-	0.02
300	-	0.23	0.006	38.3	0.02

DEP (cm)/	CEC	NH$_4$ EXTRACTABLE CATIONS(meq/100g)				BASE
HORIZON	(meq/100g)	Na	K	Ca	Mg	SAT.(%)
PEAT	11.6	0.09	0.1	12.1	2.0	100
SUB PEAT	0.4	0.04	0.02	0.2	0.2	100
300	0.4	0.4	0.03	0.3	0.3	100

DEP (cm)/	E.C.	SAT.	IONS IN SAT. EXT. (ppm)			
HORIZON	(mmho/cm)	(water%)	Na	K	Ca	Mg
PEAT	0.96	44	8	19	221	75
SUB PEAT	0.33	23	20	8	35	38
300	1.11	24	280	5	6	4

RICHARDSON SITE 4

DEP (cm)/	pH	ORG.	TOTAL	C/N	CaCO$_3$
HORIZON		CARB.(%)	N (%)		Eq.(%)
H	4.6	4.93	0.203	24.3	-
Ahe	5.0	1.76	0.013	135.4	-
Ae	5.1	0.26	0.005	52.0	-
B UPPER	5.5	0.13	0.006	21.7	-
B LOWER	5.5	0.03	-	-	-
BC	5.7	0.02	-	-	-
C 100	5.7	0.03	-	-	-
C 150	6.0	-	-	-	-
C 300	6.3	-	-	-	-
C 450	6.2	-	-	-	-

(continued)

Appendix Table 1. (continued)

DEP (cm)/ HORIZON	CEC (meq/100g)	NH_4 EXTRACTABLE CATIONS (meq/100g) Na	K	Ca	Mg	BASE SAT. (%)
H	107.3	0.1	0.3	3.2	0.5	4
Ahe	29.9	0.03	0.04	0.7	0.1	3
Ae	18.7	0.01	0.01	0.2	0.1	1
B UPPER	0.5	0.02	0.01	0.1	0.1	44
B LOWER	0.3	0.02	0.01	0.07	0.05	44
BC	0.2	0.02	0.01	0.09	0.05	85
C 100	0.1	0.005	0.003	0.07	0.04	100
C 150	0.15	0.005	0.004	0.1	0.06	100
C 300	1.8	0.005	0.005	0.1	0.07	12
C 450	0.6	0.02	0.01	0.3	0.1	72

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
H	-	-	-	-	-	-
Ahe	0.24	25	12	14	27	8
Ae	-	-	-	-	-	-
B UPPER	-	-	-	-	-	-
B LOWER	0.02	18	0	1	2	1
BC	0.03	20	15	2	8	2
C 100	-	-	-	-	-	-
C 150	-	-	-	-	-	-
C 300	0.04	20	13	1	5	3
C 450	-	-	-	-	-	-

RICHARDSON SITE 5

DEP (cm)/ HORIZON	pH	ORG. CARB. (%)	TOTAL N (%)	C/N	$CaCO_3$ Eq. (%)
LF	6.2	39.92	1.65	24.2	-
H	6.0	22.78	0.93	24.5	-
Ahe	5.2	1.61	0.09	17.9	-
Ae UPPER	5.0	0.22	0.006	36.7	-
Ae LOWER	5.1	0.08	-	-	-
B UPPER	5.4	0.11	0.003	36.7	-
B MIDDLE	6.1	0.06	-	-	-
B LOWER	6.1	0.06	-	-	-
C 150	7.1	0.11	-	-	-
C 250	8.2	0.03	0.001	30.0	1.9
C 300	8.4	-	-	-	-

(continued)

Appendix Table 1. (continued)

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
Ahe	0.38	38	5	45	37	37
Ae UPPER	0.12	22	4	9	11	7
Ae LOWER	0.07	22	14	4	10	5
B UPPER	0.11	21	24	5	11	8
B MIDDLE	0.08	17	7	4	14	9
B LOWER	0.07	22	6	4	10	7
C 150	0.13	23	5	5	31	28
C 300	0.14	21	1	2	19	14

RICHARDSON SITE 6

DEP (cm)/ HORIZON	pH	ORG. CARB.(%)	TOTAL N (%)	C/N	$CaCO_3$ Eq.(%)
LF	6.1	40.52	1.20	33.8	-
H	6.4	14.91	0.66	22.6	-
Ahe	6.3	3.29	0.11	29.9	-
Ae	6.0	0.30	0.012	25.0	-
Bm	6.0	0.38	0.018	21.1	-
BC UPPER	6.6	0.11	0.003	36.7	-
BC LOWER	6.8	0.02	0.001	20.0	-
C 130	6.9	0.03	-	-	-
C 300	6.7	0.02	-	-	-
C 450	6.4	-	-	-	-

DEP (cm)/ HORIZON	E.C. (mmho/cm)	SAT. (water%)	IONS IN SAT. EXT. (ppm) Na	K	Ca	Mg
Ahe	-	-	-	-	-	-
Ae	0.17	18	3	4	30	15
Bm	0.16	16	4	2	27	19
BC UPPER	-	-	-	-	-	-
BC LOWER	-	-	-	-	-	-
C 130	-	-	-	-	-	-
C 450	0.04	24	11	2	6	5

Appendix Table 2. Ground Temperatures (°C) at the Mildred Lake and G.C.O.S. Dike sites during 1977.

DEPTH (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
5 JANUARY 1977								
1	-	-	-	-	-	-	-6.8	-3.5
5	-	-	-	-	-	-	-6.1	-2.8
20	-3.8	-5.2	-4.8	-4.8	-4.3	-1.9	-4.4	-.8
50	-	-3.8	-2.3	-2.9	-2.7	-.8	-2.5	1.4
100	-.1	-1.4	-.1	-.2	-.7	.5	.3	3.8
150	1.2	.7	.8	1.1	.8	1.5	1.7	5.2
200	2.0	1.3	1.8	2.1	1.5	2.5	2.9	6.9
300	3.4	2.5	2.8	3.3	3.2	3.6	4.8	9.7
450	4.8	4.2	2.9	3.8	4.4	4.3	7.0	12.3
600	5.5	5.1	4.4	4.0	-	4.6	7.9	-
10 MARCH 1977								
1	-	-	-	-	-	-	.1	7.6
5	-	-	-	-	-	-	-.1	6.7
20	-.2	.1	-.2	.0	-1.1	-.6	-.5	2.9
50	-	-.1	-.3	-.4	-1.1	-.7	-.5	3.4
100	.1	-.1	-.2	-.5	-.7	-.4	.0	4.2
150	.5	.0	.2	.0	-.2	.4	.6	4.8
200	.8	.4	.7	.8	.6	.8	1.3	5.7
300	1.9	1.5	1.7	1.4	1.8	1.9	2.9	7.4
450	3.3	2.9	2.9	2.1	3.2	2.6	4.9	10.4
600	4.3	3.9	3.5	2.7	-	3.6	6.6	-
11 APRIL 1977								
1	-	-	-	-	-	-	7.7	13.9
5	-	-	-	-	-	-	6.5	12.5
20	.1	.1	.1	.0	.1	-.1	2.3	8.3
50	.1	.1	.0	-.1	.1	-.3	-.1	6.0
100	.0	.1	.1	-.3	.1	-.2	-.2	5.5
150	.2	.1	.1	-.1	-.1	.3	.5	5.3
200	.6	.5	.5	.4	.2	.7	1.1	5.9
300	1.4	1.3	1.3	1.0	1.2	1.6	2.4	7.6
450	2.8	2.7	2.4	1.5	2.5	2.4	4.5	9.9
600	3.8	3.6	3.0	2.2	-	2.9	6.0	-
4 MAY 1977								
1	-	-	-	-	-	-	15.1	11.6
5	-	-	-	-	-	-	13.1	11.6
20	.2	5.6	5.6	3.0	5.6	4.3	8.7	12.6
50	-	2.8	2.5	.9	2.6	2.3	6.8	12.1
100	.3	.2	-.1	-.5	-.1	.7	4.4	10.3
150	.0	.0	.0	-.6	-.1	.6	3.0	9.6
200	.9	.6	.6	.0	.2	.8	2.6	9.1
300	1.3	1.1	1.1	.4	1.0	1.4	2.6	9.0
450	2.5	2.3	2.0	1.1	2.1	2.1	4.3	10.5
600	3.4	3.6	3.0	1.5	-	2.7	5.6	-

(continued)

Appendix Table 2 (continued)

DEPTH (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
10 MAY 1977								
1	-	-	-	-	-	-	11.3	13.8
5	-	-	-	-	-	-	10.3	14.0
20	-	5.6	5.1	4.1	-	-	8.2	13.3
50	-	4.6	2.8	2.4	-	-	8.2	11.3
100	-	1.5	-.1	.2	-	-	6.4	10.3
150	-	.0	.0	.0	-	-	5.4	9.7
200	-	.3	.7	.3	-	-	4.1	9.2
300	-	1.1	1.0	.8	-	-	3.3	10.5
450	-	2.1	1.8	1.3	-	-	3.3	13.3
600	-	3.6	2.6	2.0	-	-	5.1	-
19 MAY 1977								
1	-	-	-	-	-	-	20.0	13.8
5	-	-	-	-	-	-	17.5	12.6
20	-	5.4	3.8	-	5.7	5.7	10.8	11.5
50	-	4.2	2.6	-	3.8	4.1	8.3	11.4
100	-	2.9	.8	-	1.5	3.0	6.8	11.0
150	-	1.9	.2	-	.2	2.4	5.9	11.0
200	-	1.4	.5	-	.4	2.0	5.3	10.5
300	-	1.3	1.4	-	1.2	1.8	4.5	10.3
450	-	2.2	2.3	-	2.2	2.3	4.7	11.0
600	-	3.2	2.9	-	-	2.8	5.8	-
1 JUNE 1977								
1	-	-	-	-	-	-	23.8	21.6
5	-	-	-	-	-	-	21.0	20.4
20	9.7	9.9	8.3	8.1	8.6	7.9	14.6	16.0
50	-	8.6	6.5	6.0	6.9	6.7	11.5	13.6
100	6.1	6.0	3.4	3.5	4.2	4.9	9.2	12.1
150	4.4	4.4	1.9	2.3	2.6	3.8	-	11.6
200	3.5	3.4	1.2	1.3	1.7	3.0	7.6	11.3
300	2.6	2.1	1.1	1.5	1.2	2.5	6.7	10.5
450	2.6	2.5	1.8	1.6	1.9	2.6	5.4	11.1
600	3.3	3.2	2.8	2.4	-	2.9	5.3	-
8 JUNE 1977								
1	-	-	-	-	-	-	18.2	21.3
5	-	-	-	-	-	-	18.2	20.2
20	-	12.6	10.8	8.6	-	10.0	15.5	18.3
50	-	10.8	8.5	7.1	-	7.6	13.5	16.0
100	-	7.6	5.1	4.3	-	5.5	10.6	13.9
150	-	5.7	3.5	2.8	-	4.3	8.7	12.8
200	-	4.6	1.5	1.6	-	3.5	7.6	12.1
300	-	3.1	1.6	1.1	-	2.7	6.1	11.5
450	-	2.6	1.9	1.3	-	2.5	5.4	12.0
600	-	3.2	2.6	1.7	-	2.8	6.0	-

(continued)

Appendix Table 2 (continued)

DEPTH (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
14-15 JUNE 1977								
1	-	-	-	-	-	-	18.9	21.2
5	-	-	-	-	-	-	18.7	20.7
20	11.6	11.3	9.8	8.1	8.0	9.6	15.3	16.3
50	-	9.9	7.7	6.6	7.7	7.7	12.4	14.7
100	7.8	7.9	5.3	4.2	6.3	5.7	10.7	13.3
150	6.2	6.2	4.1	3.0	4.7	4.7	9.1	11.8
200	5.0	4.6	3.1	2.0	3.6	4.0	8.1	12.2
300	3.7	3.2	1.9	1.0	2.5	3.1	6.5	10.8
450	3.2	2.5	2.1	1.0	2.2	2.7	5.5	11.7
600	3.5	2.7	2.1	1.4	-	2.9	5.8	-
20 JUNE 1977								
1	-	-	-	-	-	-	30.8	34.4
5	-	-	-	-	-	-	26.9	28.6
20	-	13.2	11.4	9.3	-	-	18.2	20.8
50	-	11.7	9.3	7.6	-	-	14.4	16.9
100	-	8.8	4.6	5.0	-	-	-	14.3
150	-	7.1	3.2	3.5	-	-	11.7	13.4
200	-	5.5	1.9	2.5	-	-	9.8	12.5
300	-	3.5	3.5	1.4	-	-	8.7	11.9
450	-	2.7	1.8	1.1	-	-	5.5	11.8
600	-	2.7	2.2	1.5	-	-	6.0	-
27-28 JUNE 1977								
1	-	-	-	-	-	-	24.2	27.4
5	-	-	-	-	-	-	20.7	22.2
20	11.9	13.2	11.0	9.0	11.4	9.8	17.8	18.7
50	-	12.4	9.7	8.1	10.3	8.7	15.1	16.9
100	9.8	10.4	7.6	5.7	8.3	6.8	12.8	15.1
150	7.7	8.3	5.5	4.1	6.6	5.6	11.1	14.0
200	6.6	6.7	4.2	3.1	5.1	4.5	9.9	13.2
300	4.7	4.6	3.0	1.6	3.5	3.5	7.7	12.1
450	3.6	2.7	2.2	1.5	2.5	3.0	6.3	12.2
600	-	3.0	2.5	1.5	-	1.2	6.3	-
5 JULY 1977								
1	-	-	-	-	-	-	20.5	22.6
5	-	-	-	-	-	-	17.5	23.5
20	12.8	12.8	11.4	9.9	11.9	10.0	14.8	15.9
50	-	11.5	9.2	8.1	10.1	8.7	13.0	14.6
100	9.4	10.3	7.4	6.4	8.2	7.1	11.9	14.4
150	8.1	8.7	6.9	5.0	7.0	6.0	10.9	14.4
200	7.0	7.4	5.3	1.4	5.8	5.0	10.0	13.4
300	5.3	5.6	3.9	2.4	3.9	3.9	8.3	13.1
450	4.2	3.9	2.8	3.7	2.6	3.0	6.7	12.8
600	3.9	3.3	2.3	1.8	-	2.9	6.5	-

(continued)

Appendix Table 2 (continued)

DEPTH (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
11 JULY 1977								
1	-	-	-	-	-	-	23.1	32.0
5	-	-	-	-	-	-	21.1	27.9
20	-	14.2	12.4	10.3	-	-	16.6	21.2
50	-	13.2	10.8	9.3	-	-	15.6	18.3
100	-	10.7	8.8	6.6	-	-	13.2	16.2
150	-	9.3	7.1	5.1	-	-	10.7	15.2
200	-	7.7	5.7	3.6	-	-	10.6	14.3
300	-	5.9	4.1	2.4	-	-	8.7	13.6
450	-	3.7	3.0	1.8	-	-	6.5	13.3
600	-	3.6	2.6	1.6	-	-	5.6	-
18-19 JULY 1977								
1	-	-	-	-	-	-	20.2	22.3
5	-	-	-	-	-	-	19.5	21.7
20	12.3	13.2	11.7	10.2	11.9	9.8	15.5	17.7
50	-	12.7	11.2	9.3	10.7	8.3	13.1	16.3
100	10.3	11.2	8.9	7.1	9.1	6.7	12.2	-
150	8.9	9.7	7.6	5.5	7.7	5.5	11.8	14.8
200	7.7	8.6	6.2	4.6	6.6	4.5	11.2	14.3
300	6.1	6.5	4.6	3.0	4.6	3.1	7.2	13.5
450	4.5	4.5	3.1	2.1	3.1	2.5	5.7	13.3
600	4.1	3.6	3.0	2.0	-	2.2	7.2	-
26 JULY 1977								
1	-	-	-	-	-	-	27.9	28.6
5	-	-	-	-	-	-	24.4	25.1
20	-	15.4	14.2	11.8	-	-	19.8	19.3
50	-	13.8	12.3	10.3	-	-	15.4	14.4
100	-	11.7	9.7	7.7	-	-	13.3	11.4
150	-	10.3	8.2	5.9	-	-	11.0	11.2
200	-	8.8	6.7	4.5	-	-	10.8	10.2
300	-	6.7	4.8	3.1	-	-	9.7	13.1
450	-	4.7	3.5	2.4	-	-	5.6	13.3
600	-	3.6	3.0	2.1	-	-	5.6	-
1-2 AUGUST 1977								
1	-	-	-	-	-	-	24.2	25.4
5	-	-	-	-	-	-	21.3	22.6
20	13.8	14.5	12.8	11.2	12.3	11.3	17.6	18.7
50	-	13.8	12.2	10.3	11.4	10.3	13.7	17.2
100	11.0	12.2	10.3	8.1	9.8	6.7	13.3	16.5
150	9.5	10.8	8.7	6.2	8.6	6.7	12.3	15.9
200	8.2	9.4	7.2	4.7	7.2	5.7	11.4	15.2
300	6.6	7.2	5.1	3.4	4.7	4.5	9.7	13.8
450	4.7	5.1	3.6	2.5	3.1	3.5	8.1	13.8
600	4.1	4.0	3.1	2.1	-	3.1	7.2	-

(continued)

Appendix Table 2 (continued)

DEPTH (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
15 AUGUST 1977								
1	-	-	-	-	-	-	20.8	19.8
5	-	-	-	-	-	-	17.7	17.8
20	10.3	11.6	10.2	8.7	9.2	9.2	13.3	15.7
50	-	11.8	10.3	8.7	9.3	9.1	12.8	15.4
100	10.3	11.3	9.5	7.3	8.8	8.1	12.3	15.3
150	9.3	10.7	8.7	6.2	8.2	7.2	11.8	15.2
200	8.6	9.7	7.7	5.1	9.9	6.2	11.2	14.8
300	7.1	7.8	5.7	3.6	5.2	5.1	10.2	14.3
450	3.6	5.6	4.1	3.0	3.5	3.7	8.3	13.9
600	4.3	4.2	3.2	2.5	-	3.5	7.6	-
23 AUGUST 1977								
1	-	-	-	-	-	-	15.2	12.8
5	-	-	-	-	-	-	12.3	11.6
20	-	11.3	9.7	8.3	-	-	13.3	14.2
50	-	11.7	10.2	8.6	-	-	14.3	15.8
100	-	11.2	9.7	7.5	-	-	11.8	15.7
150	-	10.5	8.7	6.5	-	-	11.7	15.5
200	-	9.7	7.7	5.5	-	-	11.6	17.7
300	-	8.2	6.2	3.1	-	-	9.4	14.7
450	-	6.0	4.6	3.1	-	-	8.1	14.1
600	-	4.6	3.6	2.6	-	-	7.7	-
29 AUGUST 1977								
1	-	-	-	-	-	-	11.7	12.1
5	-	-	-	-	-	-	10.3	11.3
20	11.2	10.7	10.3	8.7	9.7	8.7	9.7	13.3
50	-	11.2	10.7	8.3	9.2	8.3	11.7	15.3
100	9.7	10.8	10.3	7.1	8.6	7.5	8.7	15.3
150	9.2	10.6	10.3	6.2	8.0	6.7	11.3	15.3
200	8.6	10.3	8.1	5.2	7.2	6.0	11.2	15.3
300	7.2	8.3	6.6	4.1	7.2	4.9	10.3	14.9
450	5.6	6.2	4.8	3.1	5.6	3.9	8.8	14.8
600	4.7	4.8	3.7	2.6	-	3.1	8.2	-
15 SEPTEMBER 1977								
1	-	-	-	-	-	-	13.4	9.7
5	-	-	-	-	-	-	12.6	9.5
20	10.1	9.3	9.0	7.9	9.2	8.1	10.1	11.6
50	-	9.5	9.1	7.7	8.7	8.2	10.1	13.6
100	9.4	9.2	8.5	6.7	8.2	7.4	10.4	14.4
150	8.8	8.8	7.9	5.9	7.7	7.0	10.4	14.6
200	8.5	8.6	7.5	5.3	7.3	6.4	10.3	14.8
300	7.4	7.7	6.5	4.6	5.9	5.5	9.9	14.8
450	6.3	6.1	5.0	3.7	4.4	4.6	9.0	14.5
600	5.2	4.7	4.0	3.0	-	4.1	8.2	-

(continued)

Appendix Table 2 (continued)

DEPTH (cm)	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
19 SEPTEMBER 1977								
1	-	-	-	-	-	-	14.5	20.5
5	-	-	-	-	-	-	13.3	19.0
20	-	8.8	8.6	8.3	-	8.8	10.1	13.0
50	-	9.4	8.8	7.3	-	8.2	7.9	13.0
100	-	9.2	8.5	6.7	-	7.4	10.1	14.1
150	-	9.0	8.2	6.0	-	7.0	10.3	-
200	-	8.6	7.6	5.4	-	6.5	10.3	14.6
300	-	7.7	6.5	4.6	-	5.6	9.7	14.8
450	-	6.4	5.2	3.8	-	4.7	9.0	14.9
600	-	5.2	4.2	3.1	-	4.0	8.2	-
5 OCTOBER 1977								
1	-	-	-	-	-	-	4.9	5.3
5	-	-	-	-	-	-	-	5.2
20	6.6	7.0	6.6	5.7	5.4	6.5	5.2	7.7
50	-	7.8	7.9	6.7	6.8	7.3	7.6	11.6
100	8.8	8.6	9.0	7.1	7.5	7.5	9.0	13.6
150	9.1	8.7	8.7	6.7	7.6	7.3	10.0	14.6
200	8.8	8.5	8.6	6.0	7.4	6.8	10.5	14.8
300	8.3	7.6	7.1	5.2	6.2	5.8	10.0	15.3
450	6.9	6.5	5.9	4.6	4.7	5.2	9.2	15.1
600	6.0	5.3	4.9	4.0	-	4.4	9.2	-
1 NOVEMBER 1977								
1	-	-	-	-	-	-	.6	1.5
5	-	-	-	-	-	-	2.1	2.3
20	3.1	2.7	2.4	2.6	2.3	3.6	2.5	5.2
50	-	3.1	3.6	3.4	3.1	4.4	4.1	8.3
100	5.2	4.6	4.6	4.3	4.2	6.9	5.6	10.5
150	6.0	5.3	5.2	4.6	4.8	5.6	6.9	11.6
200	6.5	5.5	5.9	4.9	5.2	5.7	7.6	12.5
300	6.8	6.4	6.1	4.6	5.4	5.5	8.5	13.8
450	6.5	5.6	5.6	4.3	4.9	5.1	8.8	14.9
600	5.7	5.3	4.8	3.9	-	4.7	9.0	-

Appendix Table 3. Ground Temperatures (°C) at the Richardson sites during 1977.

DEPTH (cm)	RICH 4	RICH 5	RICH 6
6 JANUARY 1977			
20	-6.1	-4.4	-5.7
50	-5.2	-.8	-4.3
100	-.2	.4	-1.7
150	.9	2.0	.6
200	2.6	2.8	1.3
300	4.0	3.7	2.6
450	4.7	4.3	3.6
600	-	-	4.4
9 MARCH 1977			
20	-2.0	-1.3	-2.9
50	-2.1	-.5	-2.7
100	-1.8	.0	-2.1
150	-.7	.8	-1.1
200	.1	1.4	-.1
300	1.1	2.2	1.0
450	2.4	3.1	2.3
600	3.4	-	4.0
9 APRIL 1977			
20	.3	.4	.2
50	-.5	-.1	-1.7
100	-1.9	.1	-2.4
150	-1.0	1.0	-1.9
200	-	1.5	-.3
300	1.2	2.3	1.1
450	-	3.0	2.4
600	3.3	-	3.6
16 APRIL 1977			
20	.0	.0	.0
50	.0	-.1	.0
100	-.4	-.1	.1
150	-.5	.5	-.3
200	-.1	1.1	-.1
300	.8	1.8	.7
450	1.8	2.6	1.9
600	2.9	-	3.0
12 MAY 1977			
20	9.0	13.5	8.9
50	7.4	2.7	6.8
100	4.2	1.2	3.0
150	1.5	1.4	.7
200	.7	1.7	.4
300	1.4	2.4	1.2
450	2.4	3.0	2.3
600	3.2	-	3.4
19 MAY 1977			
20	5.1	11.1	4.3
50	4.9	2.9	3.8
100	3.8	2.4	2.4
150	2.6	1.9	1.3
200	1.7	1.8	.7
300	1.3	2.2	1.1
450	2.1	2.7	2.2
600	3.0	-	3.2
26 MAY 1977			
20	10.6	12.1	9.7
50	9.2	6.2	8.1
100	6.8	4.4	5.2
150	4.4	3.1	3.1
200	3.3	2.7	2.3
300	2.4	2.6	1.7
450	2.4	3.0	2.4
600	3.1	-	3.4
2 JUNE 1977			
20	11.3	-	-
50	10.2	-	-
100	8.1	-	-
150	6.0	-	-
200	4.6	-	-
300	3.0	-	-
450	2.4	-	-
600	3.1	-	-
24 JUNE 1977			
20	14.2	-	12.3
50	13.4	9.1	11.4
100	11.5	7.5	9.5
150	9.2	5.8	7.7
200	7.7	4.6	6.5
300	5.3	3.7	4.4
450	3.6	3.3	3.4
600	3.4	-	3.6
1 JULY 1977			
20	12.2	-	10.3
50	12.2	8.3	10.1
100	11.4	7.4	9.3
150	9.6	6.1	8.1
200	8.3	5.0	7.0
300	6.0	4.0	5.2
450	3.8	3.5	3.7
600	3.5	-	3.7

(continued)

Appendix Table 3 (continued)

DEPTH (cm)	RICH 4	RICH 5	RICH 6
	18 JULY 1977		
20	12.7	-	11.7
50	12.7	9.3	11.1
100	11.6	7.9	9.6
150	10.0	6.4	8.5
200	9.0	5.4	7.7
300	6.9	4.3	6.0
450	4.4	3.8	4.3
600	3.9	-	3.8
	25 JULY 1977		
20	14.8	-	14.1
50	14.2	10.5	12.8
100	12.5	8.9	10.9
150	10.6	7.1	9.4
200	9.4	5.9	8.4
300	7.3	4.8	6.7
450	5.1	4.1	5.0
600	4.2	-	4.1

DEPTH (cm)	RICH 4	RICH 5	RICH 6
	31 JULY 1977		
20	14.4	16.1	13.2
50	14.0	10.4	12.7
100	12.7	9.1	11.4
150	11.0	7.5	10.0
200	9.8	6.2	9.0
300	7.6	4.9	7.0
450	5.1	4.2	5.2
600	4.2	-	4.3
	21 SEPTEMBER 1977		
20	9.5	14.4	18.2
50	9.2	7.8	10.3
100	8.8	7.0	8.6
150	8.5	6.4	8.1
200	8.1	5.8	7.7
300	7.5	5.1	7.2
450	6.3	4.5	5.7
600	5.1	-	4.6

Appendix Table 4. Soil Moisture Tensions (geometric means) in bars at the Mildred Lake and G.C.O.S. sites during 1977.

DEPTH (cm)	MAY 10	MAY 13	MAY 16	MAY 20	MAY 25	MAY 30	JUN 2	JUN 3
MILDRED LAKE SITE 2								
5	-	-	<1	3	1	<1	<1	<1
10	-	-	2	4	3	3	3	3
20	0.19	0.14	0.22	0.22	0.051	0.053	0.17	5
50	0.07	0.08	0.08	0.08	0.09	0.057	0.052	2
100	0.038	0.047	0.046	0.046	0.051	0.056	0.057	-
200	0.012	0.017	0.018	0.018	0.029	0.024	0.026	-
300	0.016	0.01	0.027	0.027	0.029	0.036	0.033	-
MILDRED LAKE SITE 3								
5	-	-	<1	8	5	4	3	5
10	-	-	<1	4	7	3	3	4
20	0.063	0.062	0.07	0.07	0.056	0.062	0.06	-
50	0.031	0.031	0.057	0.057	0.08	0.08	0.08	-
100	0.006	0.005	0.014	0.014	0.035	0.042	0.046	-
200	0.023	0.013	0.08	0.08	0.08	0.08	0.08	-
300	0.034	0.031	-	0.041	0.039	0.041	0.042	-
MILDRED LAKE SITE 4								
5	-	-	<1	<1	2	2	2	3
10	-	-	<1	<1	<1	1	<1	2
20	0.12	0.19	0.25	0.25	0.11	0.08	0.11	-
50	0.053	0.056	0.055	0.055	0.044	0.061	0.06	-
100	0.016	0.035	0.051	0.051	0.038	0.045	0.047	-
200	0	-0.002	-0.01	-0.01	-0.008	-0.009	-0.011	-
SUPERTEST HILL								
10	-	-	-	5	-	-	-	5
20	-	-	-	-	-	0.18	-	4
50	-	-	-	-	-	0.13	-	3
100	-	-	-	-	-	0.11	-	-
200	-	-	-	-	-	0.058	-	-
GCOS DIKE SITE 1								
5	-	-	-	-	25	15	-	10
10	-	-	-	-	-	4	-	4
20	-	0.069	-	-	0.23	2	-	3
50	-	0.047	-	-	0.056	0.06	-	-
100	-	0.018	-	-	0.028	0.031	-	-
200	-	0.02	-	-	0.019	0.021	-	-
300	-	0.08	-	-	0.038	0.046	-	-
GCOS DIKE SITE 2								
5	-	-	-	-	16	10	-	7
10	-	-	-	-	-	19	-	12
20	-	0.66	-	-	0.63	0.7	-	8
50	-	0.048	-	-	0.064	0.028	-	-
100	-	0.008	-	-	0.003	0.017	-	-
200	-	-0.024	-	-	-0.012	-0.014	-	-

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	JUN 4	JUN 5	JUN 7	JUN 8	JUN 9	JUN 10	JUN 11	JUN 12
MILDRED LAKE SITE 2								
5	<1	2	2	<1	<1	2	4	4
10	3	3	3	3	2	4	4	5
20	-	0.048	0.042	0.1	0.037	0.035	0.046	0.051
50	-	0.052	0.029	0.052	0.055	0.048	0.043	0.043
100	-	0.044	0.055	0.051	0.053	0.052	0.048	0.046
200	-	0.025	0.052	0.026	0.03	0.027	0.024	0.025
300	-	0.037	0.039	0.05	0.032	0.009	0.028	0.035
MILDRED LAKE SITE 3								
5	4	4	5	4	3	4	5	6
10	6	4	4	4	3	4	4	5
20	-	0.09	0.12	0.13	0.046	0.08	0.09	0.1
50	-	0.07	0.08	0.08	0.05	0.051	0.08	0.08
100	-	0.049	0.049	0.05	0.01	0.05	0.049	0.05
200	-	0.07	0.07	0.07	0.07	0.068	0.066	0.066
300	-	0.041	0.041	0.043	0.036	0.04	0.04	0.038
MILDRED LAKE SITE 4								
5	2	3	2	<1	2	3	5	7
10	<1	2	3	<1	<1	2	3	4
20	-	0.15	0.2	0.23	0.058	0.08	6	6
50	-	0.06	0.065	0.09	0.058	0.064	6	5
100	-	0.048	0.049	0.049	0.049	0.007	0.051	0.054
200	-	-0.011	-0.011	-0.009	-0.011	-0.009	-0.01	-0.007
SUPERTEST HILL								
10	-	-	-	6	-	-	-	-
20	-	-	-	5	-	-	-	-
50	-	-	-	4	-	-	-	-
100	-	-	-	0.16	-	-	-	-
200	-	-	-	0.055	-	-	-	-
GCOS DIKE SITE 1								
5	-	-	40	27	-	5	-	-
10	-	-	7	10	-	8	-	-
20	-	-	5	5	-	3	-	-
50	-	-	6	8	-	0.069	-	-
100	-	-	0.035	0.038	-	0.011	-	-
200	-	-	0.024	0.024	-	0.012	-	-
300	-	-	0.059	0.066	-	0.05	-	-
GCOS DIKE SITE 2								
5	-	-	12	14	-	8	-	-
10	-	-	23	18	-	9	-	-
20	-	-	11	14	-	5	-	-
50	-	-	0.3	0.11	-	4	-	-
100	-	-	0.021	0.02	-	0.015	-	-
200	-	-	0.009	-0.017	-	-0.015	-	-

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	JUN 14	JUN 15	JUN 18	JUN 19	JUN 20	JUN 23	JUN 24	JUN 26
			MILDRED LAKE SITE 2					
5	8	<1	5	5	-	4	5	5
10	8	3	6	7	-	8	5	4
20	0.035	0.038	0.055	0.068	-	0.12	0.15	0.23
50	0.045	0.034	0.036	0.038	-	0.059	0.056	0.059
100	0.049	0.048	0.046	0.049	-	0.043	0.043	0.041
200	0.03	0.029	0.033	0.033	-	0.037	0.04	0.037
300	0.032	0.03	0.031	0.028	-	0.029	0.019	0.01
			MILDRED LAKE SITE 3					
5	5	4	4	4	-	6	7	8
10	6	7	8	7	-	6	6	6
20	5	5	7	7	-	6	2	5
50	0.08	0.055	0.08	0.08	-	0.09	0.09	0.09
100	0.052	0.007	0.049	0.055	-	0.061	0.062	0.063
200	0.067	0.061	0.059	0.059	-	0.058	0.057	0.055
300	0.038	0.041	0.041	0.041	-	0.041	0.041	0.041
			MILDRED LAKE SITE 4					
5	6	6	3	6	-	4	4	4
10	3	5	3	4	-	5	4	5
20	0.021	0.033	0.08	7	-	19	16	18
50	0.07	0.069	0.07	-	-	0.08	0.08	0.059
100	0.051	0.052	0.055	0.056	-	0.063	0.064	-
200	-0.009	-0.009	-0.007	-0.006	-	-0.003	-0.002	-0.001
			SUPERTEST HILL					
10	-	8	-	-	-	-	-	-
20	-	7	-	-	-	-	-	-
50	-	0.26	-	-	-	-	-	0.53
100	-	0.21	-	-	-	-	-	0.45
200	-	0.062	-	-	-	-	-	0.13
			GCOS DIKE SITE 1					
5	17	-	-	-	74	-	85	-
10	5	-	-	-	18	-	25	-
20	0.045	-	-	-	16	-	17	0.66
50	0.035	-	-	-	0.1	-	0.13	0.16
100	0.011	-	-	-	0.035	-	0.038	0.039
200	0.022	-	-	-	0.022	-	0.024	0.022
300	0.054	-	-	-	0.059	-	0.028	0.046
			GCOS DIKE SITE 2					
5	5	-	-	-	34	-	50	-
10	10	-	-	-	19	-	29	-
20	12	-	-	-	13	-	12	-
50	0.19	-	-	-	0.29	-	0.28	0.3
100	0.017	-	-	-	0.014	-	0.013	0.017
200	-0.025	-	-	-	-0.017	-	-0.016	-0.015

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	JUN 29	JUL 4	JUL 6	JUL 7	JUL 11	JUL 12	JUL 13	JUL 14
MILDRED LAKE SITE 2								
5	2	1	-	1	-	3	5	10
10	3	2	-	3	-	5	5	5
20	0.19	0.034	-	0.055	-	0.09	0.11	0.1
50	0.07	0.035	-	0.034	-	0.045	0.047	0.049
100	0.044	0.047	-	0.032	-	0.033	0.032	0.033
200	0.036	0.041	-	0.037	-	0.036	0.033	0.034
300	0.023	0.026	-	0.025	-	0.022	0.025	0.018
MILDRED LAKE SITE 3								
5	4	3	-	3	-	6	5	5
10	4	3	-	3	-	6	6	5
20	0.03	0.048	-	0.07	-	0.15	0.17	5
50	0.1	0.067	-	0.059	-	0.08	0.08	0.18
100	0.064	0.07	-	0.08	-	0.07	0.08	0.08
200	0.057	0.058	-	0.051	-	0.062	0.056	0.056
300	0.042	0.047	-	0.048	-	0.039	0.039	0.038
MILDRED LAKE SITE 4								
5	3	3	-	2	-	-	7	7
10	4	<1	-	2	-	-	3	2
20	0.09	0.01	-	0.04	-	0.1	0.12	0.12
50	0.06	0.053	-	0.044	-	0.053	0.058	0.058
100	0.06	0.067	-	0.068	-	0.067	0.067	0.067
200	0.004	-0.003	-	-0.003	-	-0.006	-0.005	-0.005
SUPERTEST HILL								
10	6	-	5	-	-	-	-	-
20	8	-	6	-	-	-	-	-
50	4	-	5	-	-	-	-	-
100	0.47	-	0.53	-	-	-	-	-
200	0.14	-	0.15	-	-	-	-	-
GCOS DIKE SITE 1								
5	6	11	-	<1	8	-	-	3
10	12	2	-	3	6	-	-	7
20	0.015	0.03	-	0.041	0.16	-	-	0.17
50	0.1	0.023	-	0.034	0.037	-	-	0.08
100	0.04	0.042	-	0.038	0.028	-	-	0.07
200	0.024	0.025	-	0.021	0.022	-	-	0.051
300	0.053	0.037	-	0.038	0.039	-	-	0.032
GCOS DIKE SITE 2								
5	14	6	-	3	10	-	-	8
10	16	8	-	4	15	-	-	5
20	18	3	-	0.3	7	-	-	5
50	-	0.22	-	0.13	0.13	-	-	0.14
100	-	0.022	-	0.021	0.014	-	-	0.018
200	-	-0.011	-	-0.011	0.008	-	-	-0.014

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	JUL 18	JUL 19	JUL 20	JUL 22	JUL 23	JUL 24	JUL 25	JUL 26
MILDRED LAKE SITE 2								
5	4	-	<1	6	6	9	6	-
10	4	-	3	5	5	7	4	-
20	0.067	-	0.032	5	5	6	4	-
50	0.058	-	0.061	0.064	0.11	6	5	-
100	0.036	-	0.038	0.038	0.09	0.039	-	-
200	0.038	-	0.042	0.041	0.061	0.047	-	-
300	0.025	-	0.021	0.025	0.04	0.018	-	-
MILDRED LAKE SITE 3								
5	5	-	5	6	9	11	10	-
10	4	-	7	5	7	9	8	-
20	0.2	-	6	3	5	5	4	-
50	0.1	-	0.1	0.11	0.11	5	3	-
100	0.08	-	0.08	0.08	0.09	0.09	-	-
200	0.059	-	0.058	0.063	0.061	0.06	-	-
300	0.04	-	0.037	0.042	0.04	0.04	-	-
MILDRED LAKE SITE 4								
5	5	-	4	5	6	8	6	-
10	2	-	4	5	6	7	5	-
20	5	-	5	5	5	9	4	-
50	0.055	-	0.06	7	8	10	5	-
100	0.066	-	0.067	0.067	0.068	0.069	-	-
200	-0.003	-	-0.004	-0.003	-0.002	-0.001	-	-
SUPERTEST HILL								
10	-	6	-	-	-	-	-	-
20	-	4	-	-	-	-	-	-
50	-	4	-	-	-	-	-	-
100	-	0.63	-	-	-	-	-	-
200	-	0.11	-	-	-	-	-	-
GCOS DIKE SITE 1								
5	16	-	-	29	-	-	-	76
10	7	-	-	16	-	-	-	36
20	3	-	-	11	-	-	-	29
50	0.049	-	-	10	-	-	-	5
100	0.03	-	-	0.028	-	-	-	0.028
200	0.026	-	-	0.024	-	-	-	0.026
300	0.038	-	-	0.041	-	-	-	0.01
GCOS DIKE SITE 2								
5	15	-	-	26	-	-	-	54
10	14	-	-	18	-	-	-	36
20	10	-	-	18	-	-	-	21
50	0.19	-	-	6	-	-	-	9
100	0.014	-	-	0.016	-	-	-	0.018
200	-0.019	-	-	-0.017	-	-	-	-0.014

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	JUL 28	JUL 29	JUL 31	AUG 1	AUG 2	AUG 5	AUG 6	AUG 15
MILDRED LAKE SITE 2								
5	4	9	8	-	8	-	7	-
10	3	8	6	-	5	-	4	-
20	0.28	8	0.27	-	5	-	2	-
50	0.063	0.65	0.08	-	0.09	-	0.09	-
100	0.04	0.039	0.041	-	0.041	-	0.041	-
200	0.035	0.035	0.035	-	0.036	-	0.033	-
300	0.023	0.015	0.021	-	0.023	-	0.046	-
MILDRED LAKE SITE 3								
5	2	11	8	-	11	-	5	-
10	5	7	7	-	8	-	6	-
20	3	6	4	-	5	-	0.2	-
50	0.12	0.09	0.12	-	0.13	-	0.14	-
100	0.09	0.09	0.09	-	0.09	-	0.1	-
200	0.065	0.063	0.067	-	0.068	-	0.068	-
300	0.044	0.035	0.038	-	0.039	-	0.039	-
MILDRED LAKE SITE 4								
5	-	4	4	-	4	-	4	-
10	-	4	5	-	4	-	2	-
20	0.33	4	4	-	5	-	4	-
50	0.069	6	5	-	4	-	7	-
100	0.069	0.07	0.07	-	0.07	-	0.07	-
200	0	-0.001	0.001	-	0.002	-	0.002	-
SUPERTEST HILL								
10	-	-	-	-	9	-	-	-
20	-	-	-	-	9	-	-	-
50	-	-	-	-	6	-	-	-
100	-	-	-	-	0.69	-	-	-
200	-	-	-	-	0.29	-	-	-
GCOS DIKE SITE 1								
5	-	11	-	49	-	35	-	72
10	-	22	-	27	-	11	-	35
20	-	21	-	6	-	4	-	32
50	-	9	-	0.12	-	0.08	-	5
100	-	0.032	-	0.034	-	0.037	-	0.039
200	-	0.027	-	0.026	-	0.026	-	0.028
300	-	0.036	-	0.04	-	0.04	-	0.035
GCOS DIKE SITE 2								
5	-	49	-	50	-	44	-	53
10	-	34	-	40	-	34	-	44
20	-	27	-	29	-	32	-	31
50	-	8	-	7	-	6	-	11
100	-	0.016	-	0.022	-	0.016	-	0.016
200	-	-0.013	-	0.013	-	0.006	-	0.007

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	AUG 16	AUG 17	AUG 18	AUG 21	AUG 23	AUG 25	AUG 26	AUG 27
MILDRED LAKE SITE 2								
5	11	20	24	28	22	3	5	12
10	8	11	15	14	16	4	6	7
20	7	9	10	9	14	0.032	0.048	6
50	5	4	5	8	4	0.17	0.16	0.15
100	0.047	0.048	0.049	0.05	0.045	0.052	0.052	0.051
200	0.042	0.046	0.042	0.031	0.036	0.038	0.038	0.039
300	0.022	0.026	0.016	0.016	0.017	0.029	0.027	0.026
MILDRED LAKE SITE 3								
5	5	11	12	9	3	7	12	13
10	10	12	18	15	13	5	7	9
20	6	11	7	7	8	0.067	5	7
50	4	6	4	4	6	0.1	0.1	8
100	0.12	0.12	0.13	0.12	0.13	0.13	0.07	0.054
200	0.08	0.08	0.08	0.08	0.03	0.08	0.08	0.08
300	0.038	0.038	0.041	0.041	0.035	0.04	0.04	0.04
MILDRED LAKE SITE 4								
5	6	11	-	11	6	5	6	17
10	7	11	-	11	8	2	5	7
20	3	6	-	4	3	0.11	4	8
50	5	10	-	5	9	8	9	8
100	0.08	0.08	-	0.09	0.09	0.09	0.09	0.09
200	0.005	0.006	-	0.007	0.006	0.007	0.003	0.006
SUPERTEST HILL								
10	13	-	-	-	-	-	-	-
20	15	-	-	-	-	-	-	-
50	14	-	-	-	-	-	-	-
100	0.7	-	-	-	-	-	-	-
200	0.37	-	-	-	-	-	-	-
GCOS DIKE SITE 1								
5	-	-	79	-	75	-	-	-
10	-	-	48	-	33	-	-	-
20	-	-	40	-	51	-	-	-
50	-	-	17	-	0.27	-	-	-
100	-	-	0.042	-	0.042	-	-	-
200	-	-	0.029	-	0.026	-	-	-
300	-	-	0.054	-	0.034	-	-	-
GCOS DIKE SITE 2								
5	-	-	60	-	76	-	-	-
10	-	-	45	-	47	-	-	-
20	-	-	41	-	44	-	-	-
50	-	-	12	-	8	-	-	-
100	-	-	0.018	-	0.016	-	-	-
200	-	-	0.005	-	0.006	-	-	-

(continued)

Appendix Table 4 (continued)

DEPTH (cm)	AUG 28	AUG 29	AUG 31	SEP 15	SEP 19	SEP 22	OCT 5
MILDRED LAKE SITE 2							
5	15	11	10	2	<1	<1	<1
10	7	5	5	2	<1	<1	1
20	7	5	0.12	0.22	0.11	0.16	0.047
50	0.15	0.14	0.13	0.13	0.12	0.13	0.14
100	0.051	0.05	0.044	0.048	0.052	0.052	0.055
200	0.039	0.04	0.037	0.04	0.034	0.036	0.037
300	0.028	0.028	0.022	0.036	0.03	0.034	0.039
MILDRED LAKE SITE 3							
5	13	<1	16	1	<1	<1	3
10	10	7	5	3	<1	2	1
20	7	6	0.17	0.09	0.17	0.19	0.056
50	7	4	0.12	0.16	0.16	0.17	0.16
100	0.038	0.046	0.015	0.14	0.13	0.14	0.13
200	0.08	0.08	0.08	0.08	0.04	0.07	0.07
300	0.04	0.041	0.04	0.038	0.036	0.036	0.04
MILDRED LAKE SITE 4							
5	15	10	6	1	2	1	2
10	8	4	2	1	2	2	1
20	8	4	5	3	2	1	0.064
50	10	8	6	0.11	0.1	0.11	0.12
100	0.09	0.09	0.1	0.1	0.1	0.1	0.11
200	0.007	0.008	0.009	0.007	0	0.004	0.011
SUPERTEST HILL							
10	-	9	-	6	3	5	3
20	-	6	-	8	5	4	0.047
50	-	14	-	13	9	10	9
100	-	0.7	-	-	0.7	0.8	0.8
200	-	0.44	-	-	0.51	0.51	0.51
GCOS DIKE SITE 1							
5	-	7	-	12	17	14	3
10	-	18	-	6	6	3	2
20	-	0.11	-	0.27	0.2	0.31	0.029
50	-	9	-	0.08	0.1	0.1	0.1
100	-	0.044	-	0.044	0.043	0.049	0.058
200	-	0.028	-	0.032	0.029	0.034	0.036
300	-	0.033	-	0.021	0.023	0.038	0.044
GCOS DIKE SITE 2							
5	-	13	-	6	7	5	2
10	-	11	-	15	5	<1	1
20	-	14	-	8	3	0.7	0.24
50	-	0.09	-	0.14	0.13	0.24	0.11
100	-	0.016	-	0.016	0.016	0.017	0.017
200	-	0.002	-	-0.005	-0.013	-0.012	-0.011

Appendix Table 5. Soil Moisture (neutron probe) as percent by volume at Mildred Lake and G.C.O.S. sites during 1976.

DEPTH (cm)	JUL 16	AUG 10	AUG 27	AUG 28	SEP 14	SEP 17	NOV 23	NOV 24
MILDRED LAKE SITE 1								
10	10.6	-	12.3	-	-	-	-	10.9
20	9.0	-	10.7	-	-	-	-	9.2
30	9.3	-	12.1	-	-	-	-	9.6
50	8.0	-	10.6	-	-	-	-	7.1
100	7.7	-	12.7	-	-	-	-	8.9
150	5.0	-	4.9	-	-	-	-	7.6
200	5.8	-	4.2	-	-	-	-	7.6
300	12.3	-	9.3	-	-	-	-	7.2
400	8.5	-	9.4	-	-	-	-	10.3
500	11.8	-	11.7	-	-	-	-	12.3
600	18.5	-	18.4	-	-	-	-	-
MILDRED LAKE SITE 2								
10	10.8	3.2	15.4	12.9	9.6	7.6	11.6	-
20	8.5	3.7	11.6	10.5	8.1	7.0	9.4	-
30	8.6	4.3	10.9	10.1	8.0	7.4	7.9	-
50	7.4	5.2	9.6	8.3	7.0	6.5	5.7	-
100	6.2	5.2	9.9	8.9	7.2	6.6	5.2	-
150	4.6	4.6	8.1	8.2	8.0	7.9	5.8	-
200	6.2	5.6	5.5	5.5	9.1	8.9	7.5	-
300	9.4	8.8	8.1	8.0	7.6	7.6	7.5	-
400	7.3	7.6	7.4	7.4	7.3	7.0	7.2	-
500	5.9	6.0	6.0	5.6	6.0	5.7	5.2	-
600	41.6	41.0	41.0	41.0	41.2	40.7	-	-
MILDRED LAKE SITE 3								
10	13.8	3.9	17.2	14.8	9.9	7.9	16.0	-
20	9.4	4.2	12.8	11.0	8.5	7.4	10.5	-
30	10.0	6.0	12.9	12.0	9.7	9.1	10.9	-
50	8.8	6.8	11.3	10.6	9.9	9.4	9.9	-
100	9.8	8.8	11.9	12.8	13.9	14.1	13.9	-
150	12.6	11.2	9.8	9.7	8.9	9.0	9.9	-
200	10.9	10.8	10.1	9.8	9.5	9.2	10.2	-
300	10.8	11.2	11.0	11.2	11.1	11.6	10.7	-
400	6.8	7.0	6.8	6.9	6.8	6.9	6.2	-
500	3.3	3.7	3.5	3.3	3.8	3.9	3.6	-
600	4.8	5.2	4.8	4.7	4.7	5.2	-	-
MILDRED LAKE SITE 4								
10	18.2	5.8	21.6	18.7	16.8	14.4	18.1	-
20	14.1	7.1	16.0	15.6	14.5	13.5	15.7	-
30	13.9	9.5	15.7	14.8	14.2	14.2	13.1	-
50	9.7	8.8	12.4	12.0	11.3	10.9	9.7	-
100	8.6	7.8	10.2	10.2	12.1	12.0	10.0	-
150	10.5	9.7	9.1	9.5	9.9	10.5	9.5	-
200	29.4	30.9	30.9	30.2	31.6	31.1	29.8	-
300	36.4	36.9	36.1	36.7	36.9	37.3	35.3	-

(continued)

Appendix Table 5 (continued)

DEPTH (cm)	JUL 16	AUG 10	AUG 27	AUG 28	SEP 14	SEP 17	NOV 23	NOV 24
			MILDRED LAKE SITE 5					
10	15.8	-	20.1	-	11.4	-	-	18.6
20	10.8	-	13.7	-	9.7	-	-	10.7
30	10.4	-	13.2	-	9.6	-	-	8.4
50	10.2	-	13.5	-	10.6	-	-	11.6
100	5.6	-	14.4	-	9.2	-	-	8.4
150	6.3	-	5.2	-	6.7	-	-	6.9
200	9.4	-	6.5	-	6.3	-	-	6.6
300	27.0	-	23.7	-	23.8	-	-	25.5
400	32.1	-	32.0	-	33.5	-	-	32.8
500	22.6	-	22.3	-	23.6	-	-	23.4
600	29.1	-	29.2	-	30.5	-	-	-
			SUPERTEST HILL					
10	14.7	-	-	12.8	-	8.7	-	19.7
20	20.4	-	-	19.9	-	17.6	-	23.2
30	22.0	-	-	23.1	-	23.1	-	23.1
50	20.2	-	-	18.5	-	19.1	-	18.9
100	22.6	-	-	18.7	-	19.6	-	19.8
150	21.8	-	-	20.9	-	20.5	-	19.5
200	23.7	-	-	23.3	-	22.6	-	22.0
300	24.0	-	-	26.8	-	27.1	-	26.7
			GCOS DIKE SITE 1					
10	-	3.4	10.1	9.3	12.8	10.0	11.0	-
20	-	3.8	7.4	6.5	9.0	8.2	7.7	-
30	-	4.3	7.9	7.0	8.6	7.7	7.2	-
50	-	6.9	11.9	10.8	11.1	10.2	8.6	-
100	-	10.2	9.9	10.3	12.3	12.1	10.4	-
150	-	11.4	11.2	10.8	12.8	13.1	11.5	-
200	-	12.6	12.1	11.8	12.1	12.7	12.3	-
300	-	16.7	15.5	15.2	15.3	16.5	15.9	-
400	-	17.0	16.1	15.9	15.7	7.7	15.9	-
500	-	23.4	22.0	22.1	21.4	22.7	21.9	-
600	-	22.2	22.1	21.3	21.3	21.6	-	-
			GCOS DIKE SITE 2					
10	-	7.1	12.6	11.1	11.5	11.5	-	11.6
20	-	7.8	9.9	9.3	10.7	10.3	-	10.7
30	-	9.7	12.0	11.7	13.8	13.2	-	13.3
50	-	7.5	9.7	9.1	10.0	10.0	-	11.3
100	-	22.9	22.6	22.6	23.2	24.4	-	28.7
150	-	26.0	27.1	26.7	30.3	30.6	-	42.8
200	-	36.8	35.3	36.1	37.0	37.5	-	37.7
300	-	33.7	33.8	34.2	35.1	34.3	-	37.3

Appendix Table 6. Soil Moisture (neutron probe) as percent by volume at Mildred Lake and G.C.O.S. sites during 1977.

DEPTH (cm)	JAN 5	MAR 9	APR 11	MAY 4	MAY 5	MAY 10	MAY 14	MAY 18
MILDRED LAKE SITE 1								
10	17.5	27.8	19.0	12.3	-	-	-	-
20	10.0	14.8	14.9	9.4	-	-	-	-
30	9.8	13.0	17.1	9.9	-	-	-	-
50	6.7	7.2	17.5	8.0	-	-	-	-
100	8.4	8.8	18.4	12.1	-	-	-	-
150	6.3	7.3	9.9	11.2	-	-	-	-
200	7.3	7.6	7.5	12.8	-	-	-	-
300	6.3	6.3	6.3	6.2	-	-	-	-
400	9.0	8.5	8.7	8.6	-	-	-	-
500	11.6	11.6	12.1	11.7	-	-	-	-
600	-	18.5	18.5	18.3	-	-	-	-
MILDRED LAKE SITE 2								
10	16.9	30.0	20.4	9.1	-	2.8	-	10.8
20	9.8	21.8	17.6	6.8	-	4.3	-	9.0
30	7.9	21.5	23.7	6.7	-	5.3	-	8.9
50	5.8	17.8	28.2	6.1	-	5.4	-	7.2
100	4.9	7.4	11.8	7.0	-	5.4	-	5.2
150	4.8	5.3	5.4	11.5	-	9.1	-	6.5
200	6.7	6.0	5.3	7.8	-	10.6	-	10.8
300	7.5	7.4	7.1	7.0	-	7.0	-	7.0
400	6.4	6.4	6.9	6.8	-	7.0	-	6.6
500	5.2	5.3	5.3	5.6	-	5.7	-	5.5
600	-	37.5	40.0	40.1	-	39.3	-	38.3
MILDRED LAKE SITE 3								
10	20.1	44.5	30.0	15.0	-	9.1	-	15.0
20	10.6	23.3	21.3	10.6	-	8.6	-	11.1
30	10.6	15.3	21.8	11.5	-	10.4	-	11.2
50	10.1	10.6	21.7	13.9	-	12.2	-	10.6
100	18.2	18.6	29.6	32.3	-	31.6	-	27.8
150	8.8	14.4	15.0	13.2	-	14.1	-	14.0
200	8.9	8.9	8.9	8.7	-	9.0	-	8.9
300	10.2	10.6	10.7	10.5	-	11.1	-	10.8
400	6.4	6.7	6.6	6.5	-	6.5	-	6.2
500	3.5	3.7	3.6	3.5	-	3.4	-	3.3
600	-	4.7	4.8	4.8	-	4.8	-	4.6
MILDRED LAKE SITE 4								
10	25.8	42.2	39.2	15.0	-	8.4	-	10.7
20	16.2	20.1	25.8	13.7	-	10.2	-	10.7
30	13.7	15.8	22.9	13.6	-	12.0	-	11.6
50	10.5	12.5	24.9	13.3	-	11.4	-	10.4
100	11.9	12.0	15.5	21.0	-	18.4	-	13.2
150	9.6	13.9	15.7	11.1	-	10.7	-	10.7
200	27.5	25.5	24.7	27.0	-	24.6	-	25.4
300	36.3	35.6	37.0	38.3	-	36.4	-	36.3

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	JAN 5	MAR 9	APR 11	MAY 4	MAY 5	MAY 10	MAY 14	MAY 18
MILDRED LAKE SITE 5								
10	26.2	21.9	29.3	17.5	-	-	-	16.8
20	11.9	11.9	18.3	11.3	-	-	-	12.0
30	9.9	9.8	16.4	10.0	-	-	-	10.5
50	11.3	11.5	26.4	12.5	-	-	-	10.6
100	9.7	10.0	18.5	19.8	-	-	-	9.2
150	6.7	9.0	8.9	14.2	-	-	-	13.4
200	6.7	6.3	6.0	7.6	-	-	-	12.3
300	26.2	25.9	26.5	26.6	-	-	-	26.1
400	32.7	31.0	30.4	31.2	-	-	-	29.2
500	23.5	22.9	22.9	22.2	-	-	-	23.5
600	-	-	29.4	30.0	-	-	-	29.2
SUPERTEST HILL								
10	22.7	26.9	39.0	-	23.9	-	-	-
20	23.0	26.9	45.8	-	32.8	-	-	-
30	23.0	24.4	42.2	-	33.9	-	-	-
50	19.8	21.0	25.9	-	30.3	-	-	-
100	16.6	23.7	24.7	-	27.6	-	-	-
150	17.8	18.9	19.7	-	23.9	-	-	-
200	19.5	20.1	21.2	-	22.1	-	-	-
300	24.1	23.8	26.1	-	26.3	-	-	-
GCOS DIKE SITE 1								
10	16.4	30.1	26.9	-	13.0	-	4.6	-
20	9.0	17.9	17.1	-	9.5	-	5.7	-
30	7.3	18.3	22.1	-	8.4	-	6.6	-
50	8.6	23.9	33.6	-	9.8	-	8.6	-
100	9.3	11.9	11.6	-	12.3	-	11.4	-
150	10.7	9.8	9.7	-	16.0	-	15.3	-
200	11.6	11.7	11.2	-	12.8	-	14.0	-
300	15.0	15.2	14.5	-	14.7	-	15.6	-
400	14.9	15.5	15.1	-	15.2	-	15.7	-
500	21.7	21.7	21.6	-	21.1	-	21.8	-
600	-	22.3	20.3	-	20.3	-	21.4	-
GCOS DIKE SITE 2								
10	16.1	17.0	16.6	-	11.3	-	8.4	-
20	11.4	13.1	13.8	-	12.5	-	9.8	-
30	11.4	16.2	17.4	-	16.9	-	14.3	-
50	12.3	16.6	16.9	-	15.0	-	14.2	-
100	32.7	34.9	35.1	-	33.5	-	32.7	-
150	42.0	45.6	45.7	-	44.9	-	42.7	-
200	36.5	37.9	38.2	-	37.9	-	37.3	-
300	35.8	37.7	37.7	-	37.4	-	37.0	-

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	MAY 19	MAY 20	MAY 21	MAY 31	JUN 1	JUN 8	JUN 14	JUN 15
			MILDRED LAKE SITE 1					
10	-	-	9.8	-	10.0	-	-	14.1
20	-	-	9.6	-	9.4	-	-	11.2
30	-	-	10.3	-	9.9	-	-	11.5
50	-	-	8.0	-	7.7	-	-	8.4
100	-	-	8.7	-	8.2	-	-	7.3
150	-	-	7.5	-	6.4	-	-	5.7
200	-	-	11.7	-	10.1	-	-	8.5
300	-	-	6.1	-	6.3	-	-	7.2
400	-	-	8.5	-	9.0	-	-	8.9
500	-	-	12.2	-	11.8	-	-	11.7
600	-	-	20.6	-	19.0	-	-	18.5
			MILDRED LAKE SITE 2					
10	9.7	-	-	9.1	-	6.5	16.2	-
20	8.4	-	-	8.3	-	6.3	11.6	-
30	8.3	-	-	8.3	-	6.8	10.3	-
50	7.0	-	-	6.9	-	6.2	6.9	-
100	5.1	-	-	5.0	-	5.4	5.4	-
150	6.5	-	-	5.4	-	5.4	5.1	-
200	10.9	-	-	9.4	-	8.9	8.4	-
300	7.1	-	-	6.8	-	7.3	7.7	-
400	6.9	-	-	6.5	-	6.9	6.8	-
500	5.6	-	-	5.4	-	5.5	5.3	-
600	39.0	-	-	39.6	-	39.4	39.4	-
			MILDRED LAKE SITE 3					
10	14.6	-	-	14.2	-	8.8	17.2	-
20	10.8	-	-	10.4	-	8.1	10.5	-
30	11.2	-	-	10.6	-	9.4	9.7	-
50	10.2	-	-	9.7	-	9.0	8.6	-
100	26.7	-	-	20.1	-	17.4	16.0	-
150	14.1	-	-	15.8	-	15.9	15.3	-
200	8.8	-	-	9.1	-	9.6	9.7	-
300	10.8	-	-	10.9	-	10.9	10.8	-
400	6.6	-	-	6.4	-	6.3	6.3	-
500	3.4	-	-	3.4	-	3.3	3.1	-
600	4.7	-	-	4.8	-	4.8	4.7	-
			MILDRED LAKE SITE 4					
10	-	-	-	11.1	-	8.7	19.0	-
20	-	-	-	10.6	-	9.7	12.5	-
30	-	-	-	11.0	-	10.7	11.4	-
50	-	-	-	9.7	-	9.3	9.3	-
100	-	-	-	11.4	-	10.5	9.8	-
150	-	-	-	10.4	-	10.1	9.8	-
200	-	-	-	28.4	-	27.8	27.6	-
300	-	-	-	36.5	-	36.5	36.3	-

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	MAY 19	MAY 20	MAY 21	MAY 31	JUN 1	JUN 8	JUN 14	JUN 15
MILDRED LAKE SITE 5								
10	-	-	14.1	-	16.3	-	-	20.7
20	-	-	11.0	-	11.4	-	-	13.8
30	-	-	10.2	-	10.6	-	-	12.2
50	-	-	10.4	-	10.5	-	-	11.5
100	-	-	8.6	-	7.5	-	-	7.0
150	-	-	12.0	-	9.1	-	-	8.1
200	-	-	12.3	-	11.7	-	-	10.7
300	-	-	24.8	-	24.6	-	-	24.7
400	-	-	29.8	-	31.0	-	-	31.3
500	-	-	23.7	-	23.5	-	-	23.6
600	-	-	29.6	-	29.5	-	-	23.5
SUPERTEST HILL								
10	-	21.2	-	-	17.5	11.3	-	10.9
20	-	29.3	-	-	25.8	20.9	-	19.0
30	-	30.8	-	-	28.1	26.1	-	23.5
50	-	26.7	-	-	25.5	24.4	-	23.3
100	-	25.4	-	-	23.8	23.7	-	23.4
150	-	22.0	-	-	21.4	21.3	-	21.4
200	-	21.2	-	-	21.0	21.5	-	22.0
300	-	25.1	-	-	24.7	25.3	-	25.6
GCOS DIKE SITE 1								
10	-	7.6	-	5.5	-	3.2	5.5	-
20	-	6.4	-	5.6	-	4.1	5.2	-
30	-	7.5	-	6.0	-	5.0	5.6	-
50	-	9.3	-	7.9	-	7.4	7.1	-
100	-	13.7	-	10.6	-	10.6	10.2	-
150	-	15.0	-	14.3	-	13.7	13.5	-
200	-	14.4	-	14.2	-	14.0	13.7	-
300	-	15.8	-	16.2	-	16.1	15.8	-
400	-	15.8	-	16.4	-	16.1	15.8	-
500	-	21.9	-	21.9	-	21.7	21.4	-
600	-	21.5	-	20.9	-	20.8	20.6	-
GCOS DIKE SITE 2								
10	-	8.9	-	7.6	-	7.2	9.6	-
20	-	9.5	-	9.2	-	8.5	9.1	-
30	-	13.6	-	12.8	-	11.7	11.5	-
50	-	13.9	-	12.9	-	11.6	12.1	-
100	-	32.3	-	31.8	-	31.6	31.2	-
150	-	42.5	-	42.5	-	42.3	42.6	-
200	-	37.6	-	37.3	-	37.0	37.7	-
300	-	36.7	-	37.4	-	37.1	37.2	-

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	JUN 20	JUL 5	JUL 6	JUL 11	JUL 18	JUL 19	JUL 26	AUG 1
MILDRED LAKE SITE 1								
10	-	-	11.6	-	-	10.7	-	-
20	-	-	10.3	-	-	9.4	-	-
30	-	-	11.4	-	-	9.5	-	-
50	-	-	9.5	-	-	6.8	-	-
100	-	-	10.3	-	-	8.3	-	-
150	-	-	5.0	-	-	4.8	-	-
200	-	-	6.5	-	-	5.8	-	-
300	-	-	9.4	-	-	9.7	-	-
400	-	-	8.9	-	-	8.2	-	-
500	-	-	11.6	-	-	11.6	-	-
600	-	-	20.2	-	-	18.6	-	-
MILDRED LAKE SITE 2								
10	6.8	13.6	-	7.5	9.0	-	4.9	4.6
20	6.8	10.9	-	7.2	8.0	-	5.9	4.2
30	7.2	11.1	-	7.6	7.8	-	6.3	4.9
50	6.4	9.9	-	6.9	6.6	-	6.3	5.7
100	5.5	7.4	-	6.9	6.4	-	6.0	6.3
150	5.1	5.3	-	5.8	5.9	-	6.0	6.3
200	8.1	7.2	-	7.2	6.9	-	7.0	7.2
300	8.3	9.0	-	8.8	8.8	-	8.7	8.9
400	6.7	6.8	-	6.5	6.8	-	6.7	7.0
500	5.5	5.4	-	5.5	5.5	-	5.4	5.9
600	39.2	39.8	-	39.6	39.2	-	39.6	39.1
MILDRED LAKE SITE 3								
10	7.9	18.2	-	8.1	7.7	-	3.9	5.6
20	7.7	12.6	-	8.0	6.8	-	5.3	4.9
30	9.2	11.9	-	9.5	8.1	-	6.8	6.1
50	8.6	9.6	-	9.4	8.4	-	7.5	7.4
100	14.4	11.6	-	12.0	11.1	-	10.0	9.1
150	15.1	13.8	-	13.3	12.7	-	11.7	11.7
200	10.0	9.9	-	9.7	9.5	-	9.2	9.6
300	11.0	10.8	-	10.8	10.6	-	10.7	11.1
400	6.3	6.3	-	6.5	6.2	-	6.3	7.1
500	3.4	3.3	-	3.2	3.4	-	3.4	4.0
600	4.7	4.6	-	4.6	4.6	-	4.7	6.4
MILDRED LAKE SITE 4								
10	10.9	23.2	-	14.7	15.5	-	10.1	7.5
20	10.9	16.9	-	13.4	12.4	-	10.7	6.9
30	11.2	15.1	-	13.2	12.4	-	11.3	9.2
50	9.0	11.1	-	10.6	10.2	-	9.6	9.3
100	9.6	9.3	-	10.5	9.9	-	9.2	8.7
150	9.9	9.4	-	9.3	9.2	-	8.9	10.9
200	27.4	27.0	-	26.8	26.7	-	26.5	17.5
300	36.5	36.2	-	36.7	36.4	-	36.3	36.4

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	JUN 20	JUL 5	JUL 6	JUL 11	JUL 18	JUL 19	JUL 26	AUG 1
MILDRED LAKE SITE 5								
10	-	-	17.3	-	-	11.0	-	-
20	-	-	12.6	-	-	7.9	-	-
30	-	-	11.7	-	-	7.4	-	-
50	-	-	12.9	-	-	9.4	-	-
100	-	-	7.1	-	-	6.9	-	-
150	-	-	7.2	-	-	6.6	-	-
200	-	-	8.8	-	-	7.9	-	-
300	-	-	23.7	-	-	22.7	-	-
400	-	-	31.0	-	-	30.4	-	-
500	-	-	23.5	-	-	23.6	-	-
600	-	-	29.9	-	-	29.7	-	-
SUPERTEST HILL								
10	-	-	17.5	-	-	6.6	-	-
20	-	-	21.4	-	-	13.2	-	-
30	-	-	21.7	-	-	18.4	-	-
50	-	-	19.6	-	-	17.0	-	-
100	-	-	20.3	-	-	14.0	-	-
150	-	-	20.3	-	-	18.3	-	-
200	-	-	21.3	-	-	20.6	-	-
300	-	-	25.9	-	-	25.1	-	-
GCOS DIKE SITE 1								
10	1.6	12.4	-	4.5	3.5	-	4.0	4.3
20	3.4	9.1	-	5.6	4.4	-	3.3	3.6
30	4.3	9.1	-	6.8	5.3	-	4.1	4.1
50	6.8	11.7	-	10.2	8.6	-	7.0	6.4
100	10.1	10.2	-	11.3	10.8	-	11.0	10.6
150	13.4	12.8	-	12.8	12.7	-	13.7	13.3
200	13.8	13.3	-	13.1	12.9	-	13.6	13.6
300	16.3	16.1	-	16.1	16.0	-	17.1	16.9
400	16.1	15.9	-	16.1	15.8	-	16.7	16.5
500	22.0	21.5	-	21.6	21.3	-	23.1	22.6
600	21.0	20.7	-	20.5	20.4	-	22.1	21.8
GCOS DIKE SITE 2								
10	5.9	12.2	-	7.2	7.7	-	7.4	7.9
20	7.8	10.2	-	8.5	8.1	-	6.5	6.6
30	10.8	11.6	-	11.3	10.7	-	9.4	9.3
50	11.0	11.4	-	10.9	10.7	-	10.1	9.5
100	31.4	31.0	-	31.1	31.4	-	31.0	30.7
150	42.1	41.6	-	42.2	41.9	-	41.9	41.9
200	37.3	37.0	-	37.3	37.1	-	38.5	38.1
300	37.2	36.7	-	37.3	36.7	-	37.4	37.2

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	AUG 2	AUG 15	AUG 16	AUG 29	SEP 15	SEP 19	OCT 5	NOV 1
MILDRED LAKE SITE 1								
10	9.9	-	6.6	10.3	8.5	-	12.1	9.1
20	6.4	-	4.6	8.6	8.8	-	11.2	8.9
30	7.5	-	5.6	9.5	9.2	-	11.8	9.7
50	7.5	-	5.1	6.5	6.4	-	9.4	8.2
100	6.6	-	5.9	5.3	4.9	-	5.4	7.4
150	4.8	-	4.7	4.2	4.0	-	4.0	4.0
200	5.6	-	5.0	4.5	4.2	-	4.3	4.1
300	10.2	-	9.6	8.5	8.6	-	8.2	7.9
400	8.7	-	8.1	8.6	8.3	-	8.5	8.6
500	12.5	-	12.3	11.4	11.7	-	11.5	11.5
600	19.8	-	19.1	18.8	18.2	-	18.7	18.3
MILDRED LAKE SITE 2								
10	-	4.5	-	12.8	10.7	8.3	12.8	7.9
20	-	3.9	-	8.6	8.8	7.9	10.7	7.8
30	-	4.5	-	7.9	8.2	7.6	10.5	7.9
50	-	5.6	-	6.9	5.9	5.8	9.2	6.5
100	-	5.7	-	5.6	5.5	5.3	5.1	5.7
150	-	6.0	-	5.2	5.2	5.0	4.9	4.6
200	-	7.0	-	6.4	6.6	6.6	6.5	6.0
300	-	8.6	-	7.9	7.6	7.5	7.4	6.9
400	-	6.9	-	6.6	7.1	6.8	7.0	6.9
500	-	5.9	-	5.1	5.4	5.4	5.3	5.5
600	-	38.5	-	39.0	40.5	39.5	40.3	39.4
MILDRED LAKE SITE 3								
10	-	4.5	-	7.3	6.0	6.0	13.2	9.8
20	-	4.2	-	5.0	5.0	5.0	8.4	8.4
30	-	5.4	-	5.5	5.2	5.3	7.3	8.6
50	-	6.5	-	6.3	5.6	5.7	6.0	7.8
100	-	8.1	-	7.9	7.3	7.3	7.6	7.6
150	-	10.4	-	9.4	8.6	8.6	8.6	8.4
200	-	9.1	-	8.9	8.1	8.2	8.4	8.2
300	-	11.4	-	10.8	10.5	10.6	10.5	10.4
400	-	6.9	-	6.0	6.1	6.3	6.3	6.1
500	-	4.0	-	3.3	3.2	3.3	3.4	3.1
600	-	5.3	-	5.0	4.6	4.6	4.7	4.5
MILDRED LAKE SITE 4								
10	-	8.5	-	14.6	9.4	7.7	11.3	7.9
20	-	6.8	-	10.7	8.6	8.2	9.2	9.1
30	-	8.9	-	10.0	9.1	8.8	9.0	9.5
50	-	8.8	-	7.7	7.8	7.6	7.3	7.2
100	-	8.0	-	6.9	7.1	6.6	6.2	6.2
150	-	9.0	-	8.1	9.1	8.2	8.3	8.1
200	-	21.7	-	25.5	23.1	22.2	21.3	15.2
300	-	36.1	-	38.0	37.3	36.2	36.0	36.3

(continued)

Appendix Table 6 (continued)

DEPTH (cm)	AUG 2	AUG 15	AUG 16	AUG 29	SEP 15	SEP 19	OCT 5	NOV 1
			MILDRED LAKE SITE 5					
10	9.4	-	7.3	14.6	12.2	-	18.6	14.5
20	6.2	-	4.6	9.2	8.8	-	12.9	10.8
30	6.3	-	5.4	8.5	7.7	-	11.8	10.0
50	7.4	-	6.8	7.9	7.1	-	11.3	10.6
100	6.9	-	6.5	6.0	5.4	-	5.2	5.6
150	6.6	-	6.4	5.7	5.3	-	5.2	5.1
200	7.3	-	7.1	5.7	5.7	-	5.6	5.5
300	22.6	-	21.5	19.4	18.7	-	18.7	19.0
400	27.5	-	28.8	32.6	27.5	-	26.5	24.6
500	23.5	-	23.8	24.2	23.7	-	24.0	23.8
600	29.3	-	29.4	29.7	30.3	-	29.6	29.6
			SUPERTEST HILL					
10	5.3	-	4.6	7.6	5.5	5.2	14.5	14.1
20	8.0	-	7.4	11.1	12.1	12.7	19.0	20.6
30	14.1	-	13.9	14.0	15.7	16.1	17.6	18.6
50	13.3	-	13.1	15.3	13.5	14.0	14.3	14.2
100	15.2	-	14.4	13.7	14.9	14.9	14.9	14.8
150	16.5	-	16.0	17.3	16.5	16.6	16.3	16.4
200	18.8	-	18.5	20.8	19.5	20.1	19.8	19.1
300	23.5	-	23.2	26.9	25.2	25.4	25.0	24.3
			GCOS DIKE SITE 1					
10	-	4.2	-	7.0	5.3	4.2	8.2	5.4
20	-	3.3	-	5.0	4.9	4.6	6.5	5.6
30	-	3.8	-	4.6	4.5	4.5	5.9	5.6
50	-	5.8	-	7.6	6.4	6.6	7.3	7.5
100	-	10.4	-	9.9	9.7	9.8	9.5	9.5
150	-	13.1	-	12.1	12.1	12.1	11.7	11.4
200	-	13.4	-	12.1	12.4	12.7	12.4	12.2
300	-	16.7	-	15.4	15.8	15.8	15.5	15.5
400	-	16.8	-	16.6	16.1	16.3	15.9	15.9
500	-	22.4	-	20.7	21.3	21.6	21.1	20.9
600	-	21.6	-	20.0	20.4	20.4	20.2	19.9
			GCOS DIKE SITE 2					
10	-	8.2	-	9.7	8.7	7.6	10.0	6.5
20	-	6.8	-	8.0	8.3	8.3	9.0	8.2
30	-	9.5	-	9.7	9.9	9.9	10.2	10.2
50	-	9.5	-	9.5	9.6	9.7	10.1	10.5
100	-	30.9	-	31.7	31.2	31.2	30.8	31.5
150	-	41.7	-	42.2	41.7	41.7	41.5	41.5
200	-	37.9	-	36.6	37.2	37.1	37.0	36.7
300	-	36.9	-	37.7	36.7	36.9	36.6	36.2

Appendix Table 7. Soil Moisture (neutron probe) as percent by volume at the Richardson sites during 1976.

DEPTH (cm)	JUN 25	JUL 5	JUL 10	JUL 12	JUL 20	SEP 1	SEP 24	NOV 26
			RICHARDSON SITE 4					
10	-	2.7	-	2.0	2.8	2.3	1.6	-
20	-	3.7	-	2.9	3.7	3.1	2.7	-
30	-	4.9	-	4.1	4.4	3.9	3.2	-
50	-	7.2	-	5.7	5.4	4.8	4.1	-
100	-	3.7	-	3.6	3.5	3.0	2.9	-
150	-	3.9	-	3.5	3.6	3.2	3.2	-
200	-	4.3	-	4.3	4.1	3.4	3.2	-
300	-	6.9	-	7.2	7.2	6.6	6.4	-
400	-	13.4	-	13.0	13.2	13.4	13.4	-
500	-	19.1	-	19.1	19.3	17.4	19.2	-
600	-	10.4	-	10.6	11.0	10.8	10.9	-
			RICHARDSON SITE 5					
10	12.3	6.7	4.9	-	8.1	6.0	4.3	24.8
20	8.4	6.0	4.8	-	6.1	5.6	4.7	11.4
30	6.8	5.8	5.3	-	6.1	5.8	5.2	8.2
50	7.2	7.0	6.5	-	6.6	6.7	6.1	8.3
100	11.2	10.5	9.5	-	8.8	7.3	7.0	9.5
150	14.3	13.5	12.8	-	12.3	11.3	12.1	12.5
200	33.3	33.7	33.0	-	32.9	31.9	32.4	31.8
300	41.3	-	40.8	-	40.4	40.2	40.2	39.8
			RICHARDSON SITE 6					
10	9.2	3.0	2.3	-	3.1	1.8	1.5	22.1
20	5.8	3.1	2.7	-	3.0	2.3	2.3	8.8
30	4.4	2.9	2.5	-	3.0	2.2	2.4	6.3
50	3.5	2.9	2.8	-	3.4	2.4	2.4	4.9
100	4.0	3.3	3.1	-	3.3	2.8	2.4	3.1
150	3.8	3.7	3.4	-	3.4	2.7	2.6	2.3
200	4.2	3.7	3.7	-	3.3	3.2	3.0	2.7
300	5.5	5.2	5.3	-	5.0	4.7	4.7	4.5
400	4.0	3.6	4.3	-	4.0	3.7	3.6	3.7
500	3.4	3.1	3.5	-	3.3	3.1	3.2	3.1
600	3.5	3.6	3.6	-	3.6	3.1	3.6	-

Appendix Table 8. Soil Moisture (neutron probe) as percent by volume at the Richardson sites during 1977.

DEPTH (cm)	JAN 6	MAR 8	APR 16	APR 24	MAY 14	MAY 27	JUN 1	JUN 29
			RICHARDSON SITE 4					
10	20.9	21.2	16.8	8.9	4.3	10.6	9.3	2.7
20	8.8	9.4	15.9	8.4	4.9	8.5	8.1	3.8
30	10.5	9.0	20.6	10.6	6.6	8.6	7.8	4.9
50	7.6	12.1	27.3	20.3	11.9	11.9	11.4	8.6
100	3.1	3.0	8.0	10.9	6.7	5.3	4.3	4.7
150	2.0	2.7	2.6	3.2	5.6	4.7	3.8	4.3
200	3.0	2.7	2.8	3.0	4.4	5.1	4.1	4.7
300	6.8	4.6	4.7	4.8	5.0	5.0	4.0	6.0
400	14.6	12.9	13.0	12.6	11.9	12.3	9.1	11.3
500	19.0	19.3	18.5	17.7	15.5	16.4	12.3	16.8
600	-	6.4	10.0	10.6	6.7	6.7	4.5	6.6
			RICHARDSON SITE 5					
10	28.9	29.2	23.1	16.4	-	15.5	-	-
20	11.6	11.5	16.8	12.1	-	10.1	-	-
30	8.4	8.7	18.8	12.5	-	8.9	-	-
50	8.9	9.6	24.5	17.5	-	9.2	-	-
100	10.0	12.1	21.6	22.6	-	16.2	-	-
150	12.3	11.9	12.5	13.9	-	16.5	-	-
200	31.9	31.4	32.8	32.9	-	33.5	-	-
300	39.1	38.9	40.7	36.6	-	40.5	-	-
			RICHARDSON SITE 6					
10	27.9	24.4	18.8	14.0	-	12.6	-	-
20	9.3	9.4	13.0	9.0	-	8.7	-	-
30	6.5	6.5	13.5	8.3	-	7.9	-	-
50	4.8	4.9	22.3	11.7	-	6.0	-	-
100	3.1	3.2	22.2	17.9	-	5.4	-	-
150	2.3	2.4	11.7	14.4	-	5.3	-	-
200	2.2	2.7	6.8	6.2	-	7.3	-	-
300	4.1	4.2	4.6	4.9	-	6.6	-	-
400	3.3	3.3	3.6	3.6	-	4.0	-	-
500	2.6	2.9	2.9	3.1	-	3.1	-	-
600	-	3.5	3.2	3.2	-	3.5	-	-

(continued)

Appendix Table 8 (continued)

DEPTH (cm)	JUL 29	AUG 2	SEP 21
RICHARDSON SITE 4			
10	5.2	-	7.2
20	5.0	-	5.2
30	6.1	-	5.3
50	9.9	-	6.3
100	4.3	-	3.4
150	4.0	-	3.3
200	4.4	-	3.3
300	6.7	-	6.1
400	10.4	-	10.2
500	16.1	-	15.8
600	6.3	-	9.8
RICHARDSON SITE 5			
10	-	7.5	12.9
20	-	5.7	7.2
30	-	6.0	6.3
50	-	7.8	6.8
100	-	10.4	8.3
150	-	11.8	13.5
200	-	31.7	31.8
300	-	41.7	39.5
RICHARDSON SITE 6			
10	-	2.0	7.2
20	-	2.6	4.2
30	-	2.6	3.4
50	-	2.6	2.4
100	-	3.2	2.7
150	-	3.0	2.7
200	-	3.4	2.9
300	-	5.5	5.3
400	-	4.0	4.1
500	-	3.2	3.2
600	-	3.4	3.3

Appendix Table 9. Soil Moisture (gravimetric) as percent by volume at the Mildred Lake and G.C.O.S. Dike sites during the thaw period.

DEPTH	M.L.2		M.L.3		M.L.4	SUPER-TEST	GCOS1	GCOS2
(cm)	1	2	1	2				
			11 APRIL 1977					
H	17.0	8.6	15.3	34.1	36.5	41.2	-	-
0-5	7.9	14.3	34.5	25.2	18.7	45.9	24.5	16.2
10	9.6	10.4	31.2	23.5	18.8	46.1	12.5	19.4
20	10.2	11.2	26.7	26.0	14.3	43.6	9.8	31.9
30	12.3	11.8	10.6	20.8	13.7	31.5	10.4	30.9
50	6.1	12.7	10.8	16.1	7.8	-	6.8	9.8
75	4.8	6.6	13.5	24.5	-	-	9.8	15.7
100	4.7	4.9	10.0	14.4	-	-	10.7	20.4
125	-	-	-	-	-	-	-	-
150	4.9	5.1	11.4	-	-	-	-	-
			4-5 MAY 1977					
H	-	-	30.5	35.7	13.0	27.1	-	-
0-5	7.7	8.6	16.5	21.2	13.5	25.5	11.7	6.1
10	7.1	6.5	15.0	8.2	13.1	22.5	9.3	7.5
20	8.0	6.0	9.6	7.7	14.2	26.0	5.1	11.1
30	5.0	6.5	7.6	8.0	15.1	28.7	6.6	-
50	4.4	8.1	8.5	10.2	13.6	27.4	8.7	-
75	4.5	4.7	16.2	11.8	12.8	-	-	-
100	5.0	6.6	21.1	29.5	-	-	-	-
125	7.2	10.7	9.1	-	-	-	-	-
150	11.4	11.0	9.5	8.1	-	-	-	-
200	10.4	4.9	10.3	-	-	-	-	-
			19-20 MAY 1977					
H	-	-	26.3	30.1	-	-	-	-
0-5	11.3	10.6	12.9	21.6	16.7	-	-	-
10	7.6	9.1	12.6	14.5	-	22.1	-	-
20	5.5	9.6	10.0	10.3	-	22.4	-	-
30	3.8	8.5	10.2	7.2	-	35.3	-	-
50	4.1	4.4	8.6	10.6	-	25.9	-	-
75	4.1	4.4	17.4	15.3	-	21.4	-	-
100	4.9	4.6	26.4	19.7	-	23.7	-	-
125	5.4	4.9	14.8	16.9	-	-	-	-
150	6.3	6.5	11.2	18.9	-	-	-	-

Appendix Table 10. Soil Moisture (gravimetric) as percent by volume at the Richardson sites during the thaw period.

15-16 APRIL 1977

DEPTH (cm)	RICH 4	RICH 5	RICH 6
H	-	29.8	21.9
0-5	15.1	52.0	55.7
10	12.4	34.2	36.6
20	9.9	30.6	27.0
30	5.9	19.1	17.3
50	11.8	20.3	11.3
75	5.9	15.8	9.4
100	1.7	15.1	8.1
150	2.6	-	1.9

10 MAY 1977

DEPTH (cm)	RICH 4	RICH 5	RICH 6
H	-	-	-
0-5	6.1	-	-
10	6.6	-	-
20	7.1	-	-
30	5.3	-	-
50	10.9	-	-
75	-	-	-
100	2.9	-	-
150	3.6	-	-

Appendix Table 11. Surface soil (0-5 cm) moisture content (gravimetric) at Mildred Lake and G.C.O.S. Dike sites during 1977.

DATE	M.L. 1	M.L. 2	M.L. 3	M.L. 4	M.L. 5	SUPER-TEST	GCOS 1	GCOS 2
MAY 10	-	4.6	-	24.1	-	-	-	-
MAY 14	-	-	-	-	-	-	6.6	6.8
MAY 18	-	9.9	20.3	31.7	22.3	-	-	-
MAY 20	-	-	-	-	-	22.3	17.1	-
MAY 31	-	11.1	21.9	25.1	-	-	-	10.2
JUNE 1	14.7	-	-	-	14.8	22.3	6.4	-
JUNE 8	-	6.4	15.0	16.0	-	21.2	7.2	5.1
JUNE 14	-	16.3	32.3	32.5	-	-	-	26.8
JUNE 15	30.2	-	-	-	46.7	43.4	1.3	-
JUNE 20	-	8.6	19.5	47.6	-	-	15.6	2.5
JULY 5	-	10.8	19.1	14.1	-	25.8	-	27.1
JULY 6	12.1	-	-	-	15.2	-	-	-
JULY 8	-	10.1	14.0	-	-	-	4.3	-
JULY 11	-	9.1	20.1	29.9	-	-	14.6	2.7
JULY 18	-	12.2	20.1	35.7	-	-	-	10.2
JULY 19	20.7	-	-	-	19.6	15.4	3.4	-
JULY 26	-	5.6	9.9	31.6	-	-	7.6	3.0
AUG 1	-	4.6	8.3	13.5	-	-	-	4.5
AUG 2	15.5	-	-	-	16.6	48.4	4.7	-
AUG 15	-	5.8	13.4	15.0	-	-	-	3.7
AUG 16	7.8	-	-	-	7.1	42.3	-	-
AUG 29	19.1	9.2	20.8	17.7	16.7	-	19.6	-
AUG 30	-	-	-	-	-	44.8	19.6	9.8
SEP 15	17.5	12.0	18.4	18.2	-	-	-	22.2
SEP 19	-	14.1	17.2	15.3	20.7	16.0	16.4	14.0
OCT 5	20.7	15.4	19.9	19.2	20.3	34.0	20.3	22.2

Appendix Table 12. Water Table levels (m below ground level) during 1977.

DATE	M.L. 2	M.L. 4	M.L. 5	SUPER TEST	GCOS 2	RICH 5	RICH SLOUGH
JAN 5	5.97	2.16	4.09	3.31	1.57	-	-
JAN 7	-	-	-	-	-	.84	1.72
MAR 9	6.00	2.20	3.92	3.38	1.65	.61	1.84
APR 11	5.97	2.20	3.91	3.34	1.63	-	-
APR 16	-	-	-	-	-	.02	1.83
APR 24	-	-	-	-	-	.33	1.79
MAY 4	6.00	2.14	3.99	3.40	1.65	-	-
MAY 9	-	-	-	-	-	.40	1.79
MAY 10	5.98	1.83	-	-	-	-	-
MAY 12	-	-	-	-	1.65	-	-
MAY 16	-	-	-	-	-	.41	1.79
MAY 18	6.02	2.09	3.95	-	-	-	-
MAY 20	-	-	-	3.44	1.58	-	-
MAY 24	-	-	-	-	-	.39	1.77
MAY 30	-	2.02	-	-	1.76	.35	1.77
JUN 1	5.99	-	-	3.44	1.76	-	-
JUN 8	5.98	2.02	-	3.44	1.73	-	-
JUN 14	6.02	2.01	-	-	1.76	-	-
JUN 15	-	-	-	3.43	-	-	-
JUN 20	6.01	2.04	-	-	1.73	-	-
JUN 24	-	-	-	-	-	.49	1.79
JUN 27	6.02	2.10	-	-	1.75	-	-
JUN 28	-	-	-	3.37	-	-	-
JUL 1	-	-	-	-	-	.49	1.79
JUL 5	6.02	2.05	-	-	1.75	-	-
JUL 6	-	-	3.74	3.35	-	-	-
JUL 11	6.02	2.08	-	-	1.74	-	-
JUL 18	6.01	2.09	3.84	3.34	1.67	.39	1.80
JUL 25	6.01	2.10	-	-	1.73	-	-
JUL 27	-	-	-	-	-	.47	1.81
AUG 1	-	2.18	-	-	1.76	-	-
AUG 2	-	-	-	3.25	-	-	-
AUG 15	-	2.22	-	3.30	1.78	-	-
AUG 23	6.06	2.23	-	-	1.77	-	-
AUG 29	-	2.22	-	3.24	1.74	-	-
SEP 16	6.05	2.25	-	3.30	1.75	-	-
SEP 19	6.05	2.26	-	3.31	1.71	-	-
SEP 21	-	-	-	-	-	1.02	1.85
OCT 5	6.09	2.26	3.98	3.34	1.78	-	-
NOV 1	6.08	2.30	-	3.41	1.63	-	-

Appendix Table 13. Properties of Throughfall at Mildred Lake site 1. (I=inner position, M=middle position, O=outer position)

REPLICATE TREE	POS.	MAY 16 -31	MAY 31- JUN 10	JUN 21- JUL 10	JUL 10- JUL 24	JUL 24- AUG 15	AUG 15- AUG 27	AUG 27- SEP 20
				AMOUNT (mm)				
1	I	13.5	10.1	25.7	11.8	6.4	8.1	10.2
	M	12.2	23.4	32.0	16.2	9.8	13.6	14.7
	O	18.5	30.9	33.2	17.3	11.5	17.3	16.7
2	I	16.6	11.4	24.8	13.3	5.2	7.8	9.0
	M	14.3	24.6	26.2	17.3	4.6	13.9	8.4
	O	22.9	33.2	52.2	18.2	18.5	22.2	21.7
3	M	32.6	12.8	55.7	17.9	9.8	19.9	12.7
	O	28.2	17.0	43.3	17.0	13.0	19.1	18.5
	I	48.7	46.2	98.2	-	5.5	46.2	43.6
				pH				
1	M	5.4	5.8	6.0	6.1	6.5	6.0	6.4
	O	5.8	5.6	6.1	6.4	6.4	6.2	6.7
	I	5.4	6.0	6.2	6.3	6.5	6.3	6.5
2	M	5.4	5.5	5.8	6.0	6.4	5.7	6.3
	O	5.5	5.8	5.9	6.0	6.4	5.8	6.3
	I	5.8	5.9	6.0	6.3	6.3	6.1	6.5
3	I	5.7	5.8	5.8	5.7	6.2	5.8	6.4
	M	5.7	5.8	6.0	5.9	6.2	6.0	6.4
	O	5.5	6.1	6.1	-	6.2	5.8	6.1
				ELECTRICAL CONDUCTIVITY (umho/cm)				
1	I	19.1	27.6	14.5	9.2	22.9	33.7	21.4
	M	21.6	16.9	5.6	12.8	31.3	19.0	14.5
	O	22.9	11.6	4.3	9.5	15.1	12.6	11.3
2	I	27.2	35.3	21.0	16.8	29.3	39.4	17.3
	M	28.4	24.1	21.5	18.0	34.8	30.2	21.4
	O	10.4	6.5	1.4	6.0	10.4	136.9	8.5
3	I	16.0	20.3	10.4	15.0	24.3	20.9	17.4
	M	5.5	17.4	8.1	10.4	22.6	13.6	11.6
	O	8.5	9.3	4.4	-	12.2	7.3	7.3

(continued)

Appendix Table 13 (continued)

REPLICATE	TREE POS.	SEP 20- OCT 6	OCT 6- NOV 1
AMOUNT (mm)			
1	I	10.0	4.3
	M	9.8	3.6
	O	14.1	4.3
2	I	10.4	6.1
	M	11.3	3.5
	O	16.2	4.3
3	I	19.3	7.7
	M	21.1	6.6
	O	41.3	11.0
pH			
1	I	6.0	6.7
	M	6.3	6.9
	O	6.2	6.7
2	I	5.8	6.4
	M	5.9	6.5
	O	6.3	6.6
3	I	6.7	6.3
	M	6.0	6.5
	O	5.8	6.0
ELECTRICAL COND. (umho/cm)			
1	I	37.1	21.9
	M	26.0	22.0
	O	14.8	16.7
2	I	37.3	18.7
	M	37.0	34.2
	O	8.8	12.9
3	I	23.2	14.5
	M	12.5	11.9
	O	9.6	8.7

Appendix Table 14. Properties of throughfall, litter leachate and openland precipitation at Mildred L. sites 2 and 3. (M=May; J=June; Jy=July; A=August; S=September; O=October; N=November)

		MILDRED LAKE SITE @2									
		M20-M26	M26-M31	M31-J21	J21-Jy10	Jy10-Jy22	Jy22-A15	A15-A28	A28-S20	S20-O5	O5-N1
		THROUGHFALL									
AMOUNT (cm)	mean	0.95	1.26	3.79	4.79	2.20	2.29	2.33	2.14	2.17	0.62
	s.d.	0.13	0.18	0.62	0.84	0.37	0.46	0.35	0.43	0.22	0.10
pH	mean	nd	5.7	5.9	6.2	6.2	6.9	5.9	6.5	6.4	6.8
	s.d.	-	0.3	0.4	0.3	0.2	0.3	0.3	0.1	0.1	0.2
E.C. (umho /cm)	mean	nd	6.0	5.2	3.2	4.0	11.1	4.6	4.4	4.9	8.6
	s.d.	-	2.3	1.3	1.0	1.0	1.3	0.9	1.5	1.6	1.2
		LITTER LEACHATE									
AMOUNT (cm)	mean	nd	0.82	2.26	3.22	1.59	1.02	1.92	1.51	1.74	0.56
	s.d.	-	0.22	0.34	0.36	0.25	0.18	0.38	0.28	0.29	0.13
pH	mean	5.7	5.6	5.6	5.6	5.6	5.8	5.6	5.9	5.7	5.9
	s.d.	0.2	0.2	0.2	0.4	0.5	0.5	0.3	0.3	0.4	0.3
E.C. (umho /cm)	mean	11.0	12.8	10.5	10.7	10.6	18.6	11.3	10.3	11.5	11.5
	s.d.	2.7	4.2	3.2	2.5	4.6	4.0	2.9	2.6	3.6	2.3

(continued)

Appendix Table 14. (continued)

MILDRED LAKE SITE 3

		M16- M26	M26- J1	J1- J21	J21- Jy10	Jy10- A15	A15- A28	A28- S19	S19- 06	06- N1
THROUGHFALL										
AMOUNT (cm)	mean	1.67	1.24	3.88	4.35	3.63	2.22	1.93	1.96	0.81
	s.d.	0.43	0.49	0.58	0.92	1.24	0.48	0.23	0.31	0.12
pH	mean	nd	5.7	5.8	6.1	6.7	6.1	6.7	8.5	7.1
	s.d.	-	0.4	0.2	0.4	0.4	0.2	0.1	1.0	0.2
E.C. (umho /cm)	mean	nd	9.2	5.4	5.6	13.9	8.2	13.8	24.8	20.6
	s.d.	-	2.6	2.3	2.7	3.4	3.1	3.9	6.1	8.7
LITTER LEACHATE										
AMOUNT (cm)	mean	0.64	0.84	2.24	3.06	2.93	1.69	1.10	1.50	0.62
	s.d.	0.28	0.41	0.25	0.52	0.94	0.36	0.31	0.25	0.14
pH	mean	5.1	4.9	4.8	4.9	5.0	4.7	4.9	4.9	5.0
	s.d.	0.2	0.2	0.3	0.4	0.4	0.3	0.3	0.4	0.4
E.C. (umho /cm)	mean	16.1	16.3	16.0	22.8	27.5	48.9	49.3	64.6	61.4
	s.d.	3.2	4.3	5.1	4.0	7.2	19.5	35.4	34.1	30.6

OPENLAND PRECIPITATION

	M20- J1	J1- J21	J21- Jy10	Jy10- Jy24	Jy24- A15	A15- A28	A28- S20	S20- 05	05- N1
AMOUNT (cm)	2.40	3.98	5.57	2.40	nd	2.54	2.47	2.45	0.71
pH	5.6	5.3	6.2	6.3	6.1	6.1	6.3	5.9	6.3
E.C. (umho\cm)	3.8	4.8	2.2	2.4	3.6	1.5	3.2	2.9	6.7
AMOUNT *	-	4.18	5.72	2.70	3.04	2.62	2.69	2.38	0.34

* data from Atmospheric Environment weather station at AOSERP field facility

Appendix Table 15. Moisture conditions (neutron probe) at 'Outlying Sites' during June 1977.

SITE NO	SOIL P.M.	VEGETATION	WATER (mm) 0-50	50-100	WATER AT 10cm (%vol)
11	SAND	PINE	35	46	9.2
12	SAND	PINE	34	25	9.3
13	SAND	ASPEN	77	31	21.7
14	SAND	SPRUCE	111	44	29.4
15	SAND	ASPEN	73	41	20.1
16	SAND	ASPEN	76	122	21.0
17	SAND	BIRCH/ASPEN	66	27	21.1
18	SAND	ASPEN	58	31	16.8
19	SAND	PINE	52	44	12.0
20	TILL	ASPEN	116	272	26.9
21	TILL	SPRUCE	134	34	29.4
22	TILL	SPRUCE	154	84	39.3
23	TILL	SPRUCE	105	57	30.4
24	SAND	ASPEN	70	90	15.3
25	SAND	SPRUCE	56	40	15.7
26	SAND	ASPEN	68	76	15.1
27	SAND	BIRCH/ASPEN	125	87	28.7
28	SAND	BIRCH/ASPEN	159	100	37.8
29	SAND	MIXED	81	140	14.3
30	TILL	SPRUCE	81	22	16.6
31	SAND	MIXED	159	33	41.4
32	SAND	PINE	34	29	6.9
33	SAND	BIRCH/ASPEN	49	43	10.5
34	SAND	PINE	44	44	9.2
35	TILL	BIRCH	124	112	26.8
36	TILL	PINE	162	147	39.4
37	SAND	PINE	27	28	3.7
38	SAND	PINE	54	43	13.6
39	SAND	PINE	47	37	10.8
40	SAND	ASPEN	39	30	8.8
41	SAND	PINE	53	43	12.8
42	SAND	PINE	49	41	11.2

Appendix Table 16. Water applied and leachate collected from indoor lysimeters between August 1976 and November 1977.

MONTH	WATER APPL (mm)	LEACHATE COLLECTED (mm)									
		TAILINGS ONLY		TILL SURF MIX		1 TILL LAYER		2 TILL LAYERS		PEAT SURF MIX	
		LYS 1	LYS 9	LYS 2	LYS 8	LYS 3	LYS 6	LYS 4	LYS 10	LYS 5	LYS 7
AUG	77.1	11.3	45.8	18.4	30.7	21.2	50.1	21.0	62.9	16.3	67.8
SEP	44.0	3.0	29.6	6.8	3.0	4.2	28.8	3.6	32.9	0.3	33.8
OCT	12.6	-	20.4	4.3	8.8	1.6	8.7	0.2	21.9	-	10.6
NOV	-	-	-	-	-	-	-	-	-	-	-
DEC	-	-	17.4	4.9	19.8	0.5	13.4	-	17.2	-	18.8
JAN	-	-	-	-	-	-	-	-	-	-	-
FEB	26.4	-	5.2	1.2	5.2	-	3.5	-	4.6	-	2.7
MAR	59.4	-	10.1	1.9	8.1	-	21.1	-	7.9	-	18.9
APR	57.2	-	10.7	2.1	8.7	0.9	8.1	-	12.4	-	0.4
MAY	52.8	2.5	9.7	1.8	8.0	0.8	9.0	-	30.5	0.6	0.7
JUN	39.6	1.4	5.7	1.3	3.7	0.5	5.2	-	0.1	0.2	1.4
JUL	48.4	0.6	6.4	-	3.3	0.4	3.6	-	-	-	6.7
AUG	57.2	-	-	-	-	0.2	1.9	-	-	-	-
SEP	61.6	-	-	-	-	-	-	-	-	-	-
OCT	70.4	-	-	-	-	-	-	-	-	-	-
NOV	8.8	-	-	-	-	-	-	-	-	-	-

Appendix Table 17. Record of water applied to indoor lysimeters in 1977.

DATE	WATER APPLIED (mm)	DATE	WATER APPLIED (mm)
FEB 23	8.8	JUN 3	4.4
25	8.8	8	4.4
28	8.8	10	4.4
MAR 3	8.8	13	4.4
5	8.8	16	4.4
8	2.2	22	8.8
10	2.2	27	8.8
11	2.2	JUL 5	4.4
15	4.4	8	8.8
17	4.4	12	4.4
19	4.4	15	8.8
21	4.4	19	8.8
24	4.4	26	4.4
27	4.4	29	8.8
29	4.4	AUG 2	4.4
31	4.4	5	8.8
APR 2	4.4	9	4.4
4	8.8	13	8.8
7	8.8	16	4.4
12	4.4	19	8.8
14	4.4	23	4.4
18	4.4	26	8.8
20	4.4	29	4.4
22	8.8	SEP 1	8.8
26	4.4	8	8.8
28	4.4	13	8.8
29	4.4	17	8.8
MAY 2	4.4	22	8.8
4	4.4	24	8.8
6	4.4	27	8.8
9	4.4	OCT 1	8.8
11	4.4	4	8.8
14	8.8	7	8.8
18	4.4	11	8.8
22	8.8	19	8.8
25	4.4	24	8.8
27	4.4	27	8.8
		31	8.8
		NOV 8	8.8
		DEC 2	4.4

Appendix Table 18. Leachate analysis from indoor lysimeters between August, 1976 and November, 1977.

MONTH	pH	E.C. (mmho/cm)	C (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	SO_2 (ppm)
AUG	8.4	1.6	107	69	36	270	21	-
SEP	8.5	1.7	105	57	39	350	20	215
MAY	-	-	-	-	-	-	-	-
JUN	-	-	-	-	-	-	-	-
JUL	9.1	0.6	-	-	-	-	-	-
TAILINGS ONLY - LYS 9								
AUG	8.1	0.8	41	51	26	100	11	90
SEP	8.0	0.7	36	40	22	110	9	90
OCT	-	-	-	-	-	-	-	-
DEC	8.2	0.5	10	46	47	37	12	-
FEB	8.2	0.6	38	63	54	30	10	-
MAR	8.1	0.5	32	57	55	22	9	-
APR	-	-	-	-	-	-	-	-
MAY	-	-	-	-	-	-	-	-
JUN	-	-	-	-	-	-	-	-
JUL	-	-	-	-	-	-	-	-
TILL SURFACE MIX - LYS 2								
AUG	8.4	1.2	74	56	29	220	16	177
SEP	8.4	1.2	64	60	33	190	16	153
OCT	-	-	-	-	-	-	-	-
DEC	9.0	0.5	37	17	350	79	18	-
FEB	8.3	0.7	46	37	35	113	20	-
MAR	8.2	1.1	53	98	650	139	27	-
APR	8.2	1.3	65	122	88	151	30	-
MAY	8.2	1.5	78	126	108	167	30	-
JUN	-	-	-	-	-	-	-	-
TILL SURFACE MIX - LYS 8								
AUG	8.2	1.0	58	59	31	140	13	-
SEP	7.9	0.8	53	56	30	100	12	-
OCT	7.8	0.7	41	45	23	80	10	-
DEC	8.4	0.6	32	46	44	50	13	-
FEB	8.4	0.8	49	68	62	67	15	-
MAR	8.4	0.8	56	80	82	61	16	-
APR	8.2	1.0	66	103	122	64	16	-
MAY	8.1	1.1	72	127	126	71	17	-
JUN	-	-	-	-	-	-	-	-
JUL	8.5	0.6	-	-	-	-	-	-

(continued)

Appendix Table 18. (continued)

MONTH	pH	E.C. (mmho/ cm)	C (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	SO$_2$ (ppm)
			ONE TILL LAYER - LYS 3					
AUG	8.5	1.3	74	63	35	220	12	182
SEP	8.4	1.3	64	47	35	210	9	156
OCT	-	-	-	-	-	-	-	-
DEC	-	-	-	27	105	110	11	-
APR	8.2	1.6	117	118	97	350	24	-
MAY	8.4	1.8	126	94	39	300	26	-
JUN	-	-	-	-	-	-	-	-
JUL	9.1	1.0	-	-	-	-	-	
AUG	8.6	1.1	-	-	-	-	-	-
			ONE TILL LAYER - LYS 6					
AUG	8.2	1.2	74	69	41	200	9	212
SEP	8.0	1.0	64	57	34	180	7	215
OCT	7.9	1.0	55	42	23	150	8	111
DEC	9.0	0.7	44	28	41	100	4	-
FEB	8.8	0.9	61	37	40	150	5	-
MAR	8.9	0.9	64	40	45	170	4	-
APR	8.4	0.9	56	55	50	130	5	-
MAY	8.2	1.2	64	44	37	40	3	-
JUN	-	-	-	-	-	-	-	-
JUL	8.8	0.3	-	-	-	-	-	-
AUG	8.5	0.5	-	-	-	-	-	-
			TWO TILL LAYERS - LYS 4					
AUG	8.2	1.4	80	69	39	240	12	262
SEP	8.4	1.5	80	63	44	240	10	206
OCT	-	-	-	-	-	-	-	-
			TWO TILL LAYERS - LYS 10					
AUG	8.4	0.9	55	41	24	160	6	210
SEP	8.0	0.7	36	40	22	110	9	58
OCT	8.0	0.7	41	37	21	110	6	52
DEC	9.1	0.5	37	18	25	83	5	-
FEB	8.6	0.6	47	31	35	106	6	-
MAR	9.0	0.6	46	26	45	88	5	-
APR	8.2	0.7	78	47	53	88	6	-
MAY	8.3	0.8	49	77	70	85	7	-
JUN	-	-	-	-	-	-	-	-
			PEAT SURFACE MIX - LYS 5					
AUG	8.4	1.2	56	74	35	180	17	196
SEP	8.4	1.0	-	49	34	140	18	168
MAY	-	-	-	267	123	230	78	-
JUN	-	-	-	-	-	-	-	-

(continued)

Appendix Table 18. (continued)

MON- TH	pH	E.C. (mmho/ cm)	C (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	SO_2 (ppm)
			PEAT SURFACE MIX - LYS 7					
AUG	8.0	0.9	53	58	29	120	9	111
SEP	8.1	0.9	58	68	31	140	10	89
OCT	-	-	-	-	-	-	-	-
DEC	8.1	0.5	32	55	51	34	10	-
FEB	8.4	0.7	46	66	70	52	13	-
MAR	7.9	0.7	50	81	84	45	12	-
APR	-	-	-	98	79	53	13	-
MAY	8.5	0.8	59	93	98	50	13	-
JUN	-	-	-	-	-	-	-	-
JUL	8.8	0.4	-	-	-	-	-	-

Appendix Table 19. Soil moisture tensions (mbar) in indoor lysimeters in 1977.

DATE	TAILINGS ONLY							
	LYS 1				LYS 9			
	10cm	20cm	50cm	75cm	10cm	20cm	50cm	75cm
MAR 15	72	52	54	28	59	57	35	8
MAR 21	40	70	57	27	36	50	36	9
MAR 29	54	138	63	29	32	43	38	11
APR 4	40	348	68	27	26	30	30	7
APR 12	51	358	46	23	44	37	30	6
APR 18	54	303	55	25	41	40	31	5
APR 26	48	352	58	21	38	25	30	5
MAY 2	51	353	60	34	35	30	33	6
MAY 9	53	52	62	29	33	26	32	3
MAY 22	174	190	66	33	61	55	36	7
JUN 1	62	276	67	38	50	44	37	10
JUN 8	318	>400	64	38	120	138	40	13
JUN 13	65	>400	67	35	89	163	44	17
JUN 27	>400	>400	80	42	76	96	50	21
JUL 1	68	178	52	47	50	74	54	23
JUL 5	103	381	61	47	63	107	54	23
JUL 12	42	31	37	47	44	49	56	25
JUL 19	58	41	36	42	52	57	54	26
JUL 26	>400	172	47	45	195	160	56	27
AUG 2	>400	>400	70	57	105	295	77	36
AUG 9	>400	>400	106	77	154	344	79	45
AUG 16	>400	>400	156	99	277	291	102	62
AUG 23	>400	>400	239	155	390	398	141	80
SEP 8	>400	>400	156	265	>400	-	278	133
SEP 13	>400	>400	144	289	>400	>400	382	171
OCT 27	>400	-	65	271	44	212	208	385
NOV 8	>400	52	108	80	106	144	194	341

(continued)

Appendix Table 19. (continued)

DATE	TILL SURFACE MIX				ONE TILL LAYER				
	LYS 2		LYS 8		LYS 3		LYS 6		
	10cm	20cm	10cm	20cm	10cm	20cm	10cm	20cm	50cm
MAR 15	79	67	80	51	95	69	93	57	44
MAR 21	28	77	20	57	36	73	33	36	44
Mar 29	59	72	47	45	64	85	51	40	42
APR 4	51	65	40	27	40	62	40	38	35
APR 12	82	50	59	37	78	48	78	50	35
APR 18	98	63	53	43	76	53	81	49	45
APR 26	82	66	56	38	69	44	74	47	35
MAY 2	97	178	51	36	61	46	60	46	38
MAY 9	147	277	47	34	58	44	57	44	31
MAY 22	>400	>400	124	80	224	52	88	61	40
JUN 1	>400	344	73	56	58	38	64	48	38
JUN 8	258	>400	260	138	>400	64	114	70	45
JUN 13	358	>400	212	102	89	74	60	48	54
JUN 27	-	>400	194	116	88	76	82	60	62
JUL 1	>400	262	108	80	50	44	60	40	52
JUL 5	199	>400	163	114	66	54	80	58	60
JUL 12	>400	277	74	61	37	41	67	58	46
JUL 19	238	264	67	60	57	42	72	55	43
JUL 26	20	>400	271	174	118	56	156	106	68
AUG 2	>400	>400	183	135	56	74	78	64	74
Aug 9	>400	>400	325	160	56	48	82	58	77
AUG 16	>400	>400	>400	221	49	43	77	61	79
AUG 23	-	>400	>400	304	48	48	79	62	86
SEP 8	-	>400	-	>400	90	50	120	86	82
SEP 13	48	>400	-	>400	70	50	90	72	90
OCT 27	>400	>400	356	286	60	150	64	-	-
NOV 8	>400	>400	>400	>400	110	88	362	158	302

(continued)

Appendix Table 19. (continued)

	TWO TILL LAYERS				PEAT SURFACE MIX				
	LYS 4		LYS 10		LYS 5		LYS 7		
	10cm	20cm	10cm	20cm	10cm	20cm	10cm	20cm	50cm
Mar 15	48	56	70	41	23	61	46	84	53
MAR 21	34	80	30	32	28	62	43	20	39
MAR 29	46	131	40	31	25	71	50	53	41
APR 4	34	180	31	26	23	46	42	43	33
APR 12	59	41	60	34	23	57	46	71	50
APR 18	62	50	56	38	26	60	50	69	53
APR 26	60	42	53	32	20	50	41	65	46
MAY 2	56	45	47	32	24	43	43	56	51
MAY 9	63	42	47	31	20	42	37	48	40
MAY 22	>400	64	77	61	35	66	50	93	82
JUN 1	254	193	51	40	37	43	42	58	54
JUN 8	>400	262	72	78	43	81	70	244	122
JUN 13	>400	>400	51	91	50	71	74	92	143
JUN 27	>400	160	60	62	68	80	130	96	194
JUL 1	352	106	54	46	76	48	126	70	114
JUL 5	>400	>400	66	66	77	20	191	103	160
JUL 12	66	61	58	48	82	30	145	63	108
JUL 19	154	100	62	48	83	48	43	81	81
JUL 26	>400	>400	174	126	90	91	74	>400	244
AUG 2	>400	>400	86	118	145	78	193	278	>400
AUG 9	>400	>400	166	310	230	76	300	>400	>400
AUG 16	>400	>400	>400	398	344	64	192	>400	>400
AUG 23	>400	>400	>400	>400	>400	58	292	>400	>400
SEP 8	>400	-	>400	-	>400	120	274	230	-
SEP 13	>400	>400	>400	>400	>400	106	332	>400	-
Oct 27	250	>400	36	100	60	178	>400	175	>400
NOV 8	182	>400	>400	28	284	144	>400	>400	>400

Appendix Table 20. Soil temperatures in field lysimeters during 1977, °C.

DEPTH (cm)	TAIL-INGS ONLY (1)	PEAT SURF. MIX (2)	TILL SURF MIX (4)	(7)	PEAT + TILL (5)	(8)
10 MAY 1977						
10	12.5	12.0	11.0	11.3	11.8	11.5
40	10.3	10.3	9.2	9.5	10.5	10.0
100	4.4	4.9	4.4	3.6	4.6	3.8
16 JUNE 1977						
10	16.3	15.7	15.4	15.7	15.1	16.2
40	14.8	14.8	14.8	-	14.7	15.3
100	11.8	11.9	11.9	11.1	11.7	11.9
23 JUNE 1977						
10	18.3	17.9	20.2	16.9	17.7	18.1
40	17.6	18.2	17.6	16.9	17.8	18.2
100	13.8	14.2	13.7	12.9	13.7	13.3
28 JUNE 1977						
10	23.2	20.2	16.7	21.2	19.2	19.2
40	17.2	16.9	16.7	16.5	16.9	17.2
100	14.2	14.6	14.2	13.7	14.2	13.7
12 JULY 1977						
10	16.2	17.8	17.8	16.3	17.7	17.7
40	17.7	18.2	17.7	16.9	17.7	17.8
100	14.3	14.7	14.4	13.8	14.4	13.9
20 JULY 1977						
10	17.4	15.4	15.5	16.9	15.3	15.8
40	14.7	15.6	15.8	15.2	15.7	16.2
100	13.7	14.2	14.6	14.3	14.4	14.7
27 JULY 1977						
10	22.7	21.3	21.0	21.6	20.8	21.6
40	19.8	20.3	19.7	19.6	19.8	20.4
100	15.7	16.2	15.9	15.2	16.1	15.9
4 AUGUST 1977						
10	12.8	15.9	15.8	13.4	15.7	15.7
40	16.8	17.7	17.6	16.3	17.2	16.8
100	16.3	16.7	15.9	15.5	16.0	15.5
17 AUGUST1977						
10	13.0	13.8	13.8	12.8	13.8	13.8
40	14.3	14.7	14.2	13.7	14.3	14.3
100	13.7	13.7	13.7	13.2	13.7	13.3

(continued)

Appendix Table 20. (continued)

DEPTH (cm)	TAIL-INGS ONLY (1)	PEAT SURF. MIX (2)	TILL SURF MIX (4)	(7)	PEAT + TILL (5)	(8)
			24 AUGUST 1977			
10	12.3	13.7	13.7	13.7	13.7	13.3
40	13.8	14.1	14.3	14.3	13.8	13.7
100	13.8	13.7	13.6	13.6	13.7	13.3
			31 AUGUST 1977			
10	8.7	11.2	11.2	11.2	11.1	9.9
40	11.9	11.8	13.3	13.3	11.8	12.1
100	12.3	13.2	12.3	12.3	12.1	12.6
			15 SEPTEMBER 1977			
10	8.3	9.6	9.5	9.5	9.5	9.5
40	10.5	10.0	10.6	10.6	10.3	10.0
100	11.0	11.1	11.0	11.0	11.0	10.8
			5 OCTOBER 1977			
10	3.4	4.2	4.2	4.2	4.4	4.0
40	5.8	5.6	6.8	6.8	6.2	6.0
100	8.6	8.7	8.8	8.8	8.7	8.7

Appendix Table 21. Soil Moisture tensions (mbar) at a depth of 40 cm in the field lysimeters.

DATE	TAILINGS ONLY		TILL SURF. MIX		PEAT SURF. MIX		PEAT + TILL S/MIX		PEAT SURF MIX +TILL LAYER	
	(1)	(9)	(2)	(10)	(3)	(6)	(4)	(7)	(5)	(8)
MAY 9	56	9	23	30	40	26	49	22	37	46
13	34	15	17	31	26	15	36	19	35	48
16	55	20	31	39	41	30	49	22	46	49
20	30	3	35	43	31	30	33	33	37	31
30	11	-7	36	38	37	35	29	23	27	8
JUN 15	15	-3	16	34	24	30	7	2	27	35
22	26	0	21	31	27	32	9	11	19	28
23	32	3	26	35	34	37	14	16	23	33
28	32	10	26	40	34	35	22	16	27	38
JUL 6	10	13	8	15	12	18	5	21	17	19
12	32	21	13	2	24	21	22	17	23	17
20	30	11	16	5	32	24	21	21	21	33
23	26	9	19	9	33	25	18	20	26	13
27	28	8	21	9	34	26	17	22	29	23
31	28	26	23	22	35	27	28	24	39	32
AUG 2	36	18	26	23	41	29	29	25	45	32
17	38	11	28	22	48	30	31	27	50	33
20	33	13	29	24	42	29	31	28	46	27
SEP 15	20	11	36	36	32	40	41	26	52	37
17	16	15	35	40	29	39	44	27	55	41
OCT 5	3	4	37	37	4	19	43	10	52	44

Appendix Table 22. Soil Moisture (neutron probe) as percent by volume in lysimeters during 1977.

DEPTH (cm)	TAILINGS ONLY		TILL SURFACE MIX		PEAT SURFACE MIX		PEAT + TILL SURFACE MIX		PEAT SURF MIX + TILL LAYER	
	1	2	1	2	1	2	1	2	1	2
					9 MAY 1977					
10	2.6	7.3	5.0	6.2	25.7	30.2	39.4	43.9	33.6	36.1
20	4.7	8.9	5.6	7.1	9.1	10.7	14.7	14.1	11.3	12.2
30	6.0	10.5	6.4	7.9	6.8	6.9	8.0	8.9	9.2	8.9
50	6.2	8.4	6.9	7.2	5.8	5.8	5.7	8.4	11.7	10.3
75	6.3	7.4	6.7	7.4	6.4	5.9	6.5	8.8	7.6	7.6
100	6.7	7.9	6.7	7.7	7.4	6.7	7.9	10.9	7.4	8.4
					1 JUNE 1977					
10	5.3	15.4	8.4	13.4	34.6	38.0	46.3	52.8	41.2	43.6
20	6.7	13.6	8.4	11.7	11.1	12.4	15.8	16.4	12.7	13.9
30	8.9	15.8	9.3	11.6	8.2	7.8	8.3	10.4	9.8	9.9
50	9.1	10.3	9.0	9.3	6.9	7.0	5.6	8.5	11.1	10.3
75	8.2	7.6	8.3	7.5	6.6	6.9	5.9	8.2	6.8	7.2
100	7.9	7.5	8.0	7.1	7.2	7.3	7.2	10.5	6.6	7.4
					16 JUNE 1977					
10	6.8	18.3	10.5	17.1	38.4	41.5	50.5	54.3	45.0	47.4
20	8.0	14.9	9.2	14.0	12.3	13.4	16.1	16.9	13.8	14.4
30	9.9	17.4	10.1	12.6	9.0	8.8	8.7	10.5	10.4	9.9
50	9.9	12.4	10.0	8.5	7.3	7.5	5.6	8.5	11.1	10.1
75	9.1	9.2	8.5	7.7	6.6	7.1	6.0	8.1	6.8	6.8
100	8.7	7.6	8.3	7.3	6.9	6.9	6.7	10.2	6.4	7.2

(continued)

Appendix Table 22 (continued)

DEPTH (cm)	TAILINGS ONLY 1	2	TILL SURFACE MIX 1	2	PEAT SURFACE MIX 1	2	PEAT + TILL SURFACE MIX 1	2	PEAT SURF MIX + TILL LAYER 1	2
					23 JUNE 1977					
10	4.2	13.1	6.8	12.6	27.4	32.8	34.5	42.2	35.6	-
20	6.4	12.6	7.2	11.5	10.0	11.5	13.3	14.5	11.9	-
30	8.2	15.5	8.3	11.3	7.8	7.6	22.2	9.7	9.7	-
50	8.7	11.9	8.6	9.5	6.9	6.4	5.6	8.4	10.9	-
75	8.2	9.9	8.4	8.7	6.6	6.4	5.9	8.0	6.5	-
100	8.4	8.7	7.9	7.8	6.9	6.9	6.7	10.1	6.2	-
					6 JULY 1977					
10	6.8	16.9	10.1	16.1	37.2	41.7	45.6	41.3	49.8	50.7
20	7.7	15.1	9.1	14.5	12.9	13.8	15.9	18.2	17.0	17.4
30	9.6	17.7	10.1	14.1	10.2	9.8	9.2	13.0	15.0	13.7
50	10.2	14.2	10.2	11.3	8.6	8.5	7.2	11.8	16.7	14.3
75	10.1	12.6	9.7	11.3	9.1	8.8	7.1	10.2	8.8	9.6
100	10.4	12.4	9.6	11.1	9.3	9.2	7.1	10.9	6.4	7.5
					12 JULY 1977					
10	4.7	13.3	6.7	10.8	25.6	33.5	30.3	40.7	40.1	40.9
20	6.6	12.6	7.1	11.5	10.4	12.2	12.2	15.0	15.2	15.1
30	8.2	15.5	8.6	11.6	8.5	8.5	8.2	11.4	13.4	11.8
50	9.0	13.0	9.0	10.3	7.8	7.4	6.8	11.0	15.9	13.0
75	8.5	11.2	8.7	9.8	8.1	7.5	7.6	10.3	9.5	9.8
100	9.3	11.0	8.7	9.8	8.9	8.3	7.9	11.8	8.0	9.3

(continued)

Appendix Table 22 (continued)

DEPTH (cm)	TAILINGS ONLY		TILL SURFACE MIX		PEAT SURFACE MIX		PEAT + TILL SURFACE MIX		PEAT SURF MIX + TILL LAYER	
	1	2	1	2	1	2	1	2	1	2
				20 JULY 1977						
10	10.4	20.8	30.4	18.4	29.7	41.7	30.4	43.4	45.7	45.6
20	9.0	14.7	11.0	13.3	9.7	12.6	11.0	13.9	14.6	14.7
30	9.7	15.9	7.5	11.8	7.8	8.1	7.5	10.5	12.3	11.2
50	8.7	11.6	6.2	9.3	7.1	6.9	6.2	10.1	14.9	12.0
75	7.8	10.0	7.0	9.0	7.4	7.0	7.0	9.9	9.2	9.4
100	8.2	9.9	7.9	8.8	8.2	7.5	7.9	11.5	7.9	9.2
				27 JULY 1977						
10	9.5	17.7	9.7	16.4	15.4	22.6	18.5	23.6	28.6	27.6
20	7.1	13.2	6.7	11.4	7.7	10.6	7.9	11.0	12.5	12.4
30	8.9	15.6	8.0	11.3	7.1	7.9	6.6	9.7	12.1	10.8
50	9.2	12.1	8.6	9.8	7.0	7.1	6.5	10.3	13.8	11.6
75	8.5	10.4	8.1	9.3	7.6	7.3	7.5	10.2	9.3	9.6
100	8.5	10.1	8.0	9.3	8.4	8.2	8.7	12.4	8.6	9.7
				4 AUGUST 1977						
10	9.7	17.4	10.5	15.9	14.3	20.5	17.0	22.2	26.9	24.5
20	6.8	12.5	6.4	10.3	6.6	9.3	7.0	9.6	11.5	11.0
30	8.4	15.0	7.4	10.4	6.3	7.6	5.8	8.9	11.2	9.9
50	8.7	11.6	8.0	9.4	6.6	7.0	6.0	9.8	13.2	11.0
75	8.4	10.3	7.9	8.8	7.5	7.4	7.1	9.8	9.0	9.2
100	8.6	9.8	8.0	8.9	8.2	7.6	8.4	12.4	8.4	9.3

(continued)

Appendix Table 22 (continued)

DEPTH (cm)	TAILINGS ONLY 1	2	TILL SURFACE MIX 1	2	PEAT SURFACE MIX 1	2	PEAT + TILL SURFACE MIX 1	2	PEAT SURF MIX + TILL LAYER 1	2
17 AUGUST 1977										
10	9.8	17.2	8.6	15.5	11.7	16.5	15.0	17.7	22.1	20.3
20	6.8	12.4	5.3	9.8	5.6	7.8	6.4	8.3	10.2	9.6
30	8.2	14.9	6.6	10.0	5.4	6.4	5.2	8.2	10.1	9.1
50	8.7	11.7	7.4	9.1	6.1	6.6	5.4	9.4	12.3	10.6
75	8.3	10.2	7.5	8.6	7.1	7.1	6.8	9.7	8.8	9.1
100	8.5	9.7	7.8	9.0	8.0	7.7	8.2	12.1	8.1	9.4
31 AUGUST 1977										
10	13.2	30.5	12.7	28.8	11.7	14.9	17.6	22.0	20.0	23.8
20	23.5	16.4	7.4	13.2	5.7	5.7	6.7	9.0	8.2	8.3
30	8.9	16.7	6.9	9.8	5.3	4.4	5.6	7.9	7.7	8.0
50	8.2	10.2	5.6	7.2	6.0	3.4	5.1	7.9	8.6	9.1
75	7.7	7.9	3.1	6.3	5.6	1.9	5.3	7.7	5.7	6.9
100	6.5	6.8	1.9	5.4	5.4	1.0	5.9	9.5	4.6	6.8
16 SEPTEMBER 1977										
10	11.1	25.8	14.4	25.1	11.1	22.7	17.9	22.2	28.0	24.8
20	9.1	16.9	10.1	14.1	5.2	8.4	7.0	8.8	10.0	9.0
30	10.4	18.4	10.1	11.8	5.2	6.4	5.8	8.5	9.8	8.4
50	9.6	12.1	9.3	9.2	6.1	6.1	5.3	9.2	11.5	9.9
75	8.8	10.4	7.6	8.7	6.6	6.5	6.2	9.2	7.7	8.4
100	8.7	9.3	7.1	8.5	7.4	7.2	7.4	12.1	7.4	8.3

(continued)

Appendix Table 22 (continued)

DEPTH	TAILINGS		TILL SURFACE		PEAT SURFACE		PEAT + TILL		PEAT SURF MIX	
(cm)	ONLY	MIX	MIX				SURFACE MIX		+ TILL LAYER	
	1	2	1	2	1	2	1	2	1	2
			6 OCTOBER 1977							
10	12.7	32.6	17.4	29.2	14.2	30.8	22.1	31.8	36.1	31.6
20	10.1	18.6	11.2	16.5	6.3	10.6	8.3	11.6	10.9	10.0
30	11.2	19.9	11.7	13.7	5.6	8.2	7.5	10.7	9.4	8.6
50	11.0	12.9	11.5	10.4	6.2	6.9	6.4	9.3	11.0	9.7
75	9.6	10.6	9.0	9.2	6.5	6.8	6.5	8.8	7.5	7.8
100	8.8	9.7	7.5	8.5	7.1	7.0	7.2	11.6	7.1	8.2

Appendix Table 23. Carbon dioxide production rates (ug CO_2-C/g oven-dried soil/day) in laboratory incubations.

SOIL	REP	INCUBATION DAY												
		1	2	3	4	5	6	7	8	11	16	22	31	108
Breton Ap	1	>742	303	183	132	129	59	24	76	356	52	60	12	2
	2	>766	346	267	183	124	68	24	88	154	65	70	23	0
	3	>739	443	242	177	104	55	63	74	103	83	61	16	0
	4	>744	436	236	183	114	68	84	92	61	70	57	12	7
Tailings Sand	1	9	6	-	9	9	25	960	462	60	16	43	25	26
	2	3	9	81	9	42	254	735	401	63	27	27	34	10
	3	9	9	29	6	31	54	957	411	234	22	18	38	3
	4	9	6	81	0	18	136	980	470	137	33	25	22	21
Clearwater Shale	1	13	678	503	242	149	64	61	41	35	9	32	4	6
	2	15	715	459	212	118	54	52	49	28	24	13	12	3
	3	10	848	415	197	124	14	63	54	28	18	27	8	3
	4	11	797	653	235	116	-	44	63	28	28	22	8	10
Supertest Till	1	60	761	493	212	165	81	74	70	53	15	30	17	25
	2	52	762	507	226	140	129	73	75	46	19	22	25	16
	3	59	805	497	229	155	90	74	85	45	26	22	23	23
	4	52	878	444	198	143	125	65	69	30	23	26	24	0
Analytical Controls														
Breton Ap		-								28				7
Tailings Sand		9								15				3
Clearwater Shale		15								15				24
Supertest Till		26								36				14

(> means all NaOH utilized)

Appendix Table 24. Ammonium nitrogen contents (ug NH_4-N/g oven-dried soil) in laboratory soil incubations.

SOIL	REP	INCUBATION DAY								
		1	3	5	7	10	15	21	30	107
Breton Ap	1	33.2	21.1	30.6	59.2	61.7	77.9	65.2	27.8	1.0
	2	26.9	9.8	33.1	45.8	62.7	70.0	60.9	29.5	1.0
	3	23.0	13.7	43.2	51.3	50.2	77.4	63.1	29.3	1.7
	4	17.0	18.5	32.1	53.1	65.9	85.8	86.3	28.4	2.2
Tailings Sand	1	178.2	155.0	174.6	6.5	5.1	14.2	16.8	15.0	69.9
	2	193.5	164.1	185.4	25.4	3.8	13.1	13.9	18.7	29.3
	3	153.0	160.0	176.4	18.8	5.4	7.3	8.5	10.1	20.9
	4	178.8	165.9	171.5	25.5	3.5	6.5	54.3	26.7	107.9
Clearwater Shale	1	156.6	11.6	11.3	17.7	32.2	36.8	47.5	47.9	53.7
	2	144.3	0.9	13.1	17.4	20.0	34.2	44.7	62.0	49.7
	3	170.5	0.0	17.3	14.2	27.2	33.2	42.9	47.9	64.4
	4	167.8	2.3	11.2	12.1	25.9	27.5	38.3	33.6	50.3
Supertest Till	1	102.2	0.0	4.3	12.2	14.8	22.1	23.5	13.3	0.0
	2	98.0	0.0	5.4	10.7	15.9	20.3	21.9	11.3	0.0
	3	84.0	0.4	1.9	3.0	11.1	17.4	18.5	12.2	0.2
	4	98.8	0.0	4.3	10.2	15.7	23.6	27.8	22.6	0.4
Analytical Controls										
Breton Ap		5.3			5.3					0.2
Tailings Sand		3.7			25.1					1.3
Clearwater Shale		5.4			2.0					0.4
Supertest Till		1.0			2.0					0.4

Appendix Table 25 Nitrate nitrogen contents (ug NO_3-N/g oven-dried soil) in laboratory soil incubations.

SOIL	REP	INCUBATION DAY								
		1	3	5	7	10	15	21	30	107
Breton Ap	1	0.0	1.8	0.6	0.0	0.8	2.2	8.3	28.0	110.9
	2	0.0	1.3	0.0	1.2	0.6	1.6	6.5	37.3	132.5
	3	0.4	0.0	0.6	1.7	0.8	3.2	6.4	26.1	125.3
	4	0.0	0.5	0.0	0.6	0.6	2.1	2.2	36.9	121.1
Tailings Sand	1	0.0	1.1	0.7	0.0	0.0	0.7	0.2	0.5	0.3
	2	0.7	1.1	0.6	2.5	0.2	0.4	0.4	0.7	0.2
	3	0.7	0.7	0.8	0.4	1.1	0.0	0.7	0.9	0.0
	4	1.1	0.4	0.2	1.1	0.7	0.4	0.5	0.7	0.4
Clearwater Shale	1	0.0	0.0	1.1	0.6	0.3	0.5	0.3	1.9	1.0
	2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	1.0	0.0
	3	0.5	0.0	0.0	0.3	1.7	0.3	0.0	2.5	0.0
	4	0.0	0.0	0.5	0.0	1.8	0.0	0.0	2.0	0.0
Supertest Till	1	0.2	0.0	0.5	1.2	2.1	0.2	2.7	16.9	42.0
	2	0.0	0.0	0.5	0.9	1.4	0.4	4.6	26.6	41.5
	3	0.4	0.8	0.5	0.7	1.0	0.4	5.6	12.4	40.4
	4	0.0	0.0	0.2	0.5	1.9	0.0	5.4	21.5	44.5
Analytical Controls										
Breton Ap		2.3			2.7					50.8
Tailings Sand		o.o			0.4					1.0
Clearwater Shale		0.0			0.9					2.8
Supertest Till		0.8			1.2					1.4

Appendix Table 26. Water soluble carbon contents (ug C/g oven-dried soil) in laboratory soil incubations.

SOIL	REP	INCUBATION DAY 1	3	5	7	10	15	21	30	107
Breton Ap	1	2345.4	252.0	243.1	118.5	104.3	130.5	56.5	34.9	22.5
	2	2970.1	302.1	127.3	150.2	102.4	113.1	34.5	5.1	11.9
	3	2410.6	191.9	98.4	162.5	56.7	141.4	52.4	4.9	12.4
	4	2954.1	190.6	165.9	115.4	123.2	157.9	74.6	10.0	26.2
Tailings Sand	1	2786.6	2820.3	2953.8	701.5	125.6	108.4	103.3	94.0	55.9
	2	2741.3	2754.8	2883.1	1148.5	158.7	135.0	102.7	99.7	37.4
	3	2441.6	2790.9	2723.0	932.9	96.5	115.1	105.3	98.8	29.1
	4	2530.7	2767.7	2712.8	869.8	107.1	102.1	110.1	84.4	41.9
Clearwater Shale	1	2775.4	475.6	164.5	73.2	60.1	83.8	55.3	20.3	18.9
	2	3098.0	395.1	136.6	72.9	13.2	148.4	65.1	21.1	33.7
	3	3171.3	301.7	75.9	50.5	38.8	112.6	88.8	22.2	27.1
	4	3081.2	348.6	109.6	52.4	39.0	113.0	49.2	38.8	35.0
Supertest Till	1	2490.9	319.5	194.6	131.5	70.1	99.3	74.2	30.1	14.5
	2	2629.0	340.9	206.8	115.3	62.0	115.5	72.8	12.1	7.4
	3	2568.4	529.5	300.2	105.2	51.0	124.8	64.7	20.3	7.7
	4	2520.7	443.0	192.1	92.8	25.3	94.5	80.8	24.4	18.9
Analytical Controls										
Breton Ap		0.0			8.4					11.5
Tailings Sand		25.9			79.2					15.0
Clearwater Shale		104.3			0.0					12.8
Supertest Till		117.4			29.3					3.8

Appendix Table 27. "Glucose" carbon contents (ug C/g oven-dried soil) in laboratory soil incubations.

SOIL	REP	INCUBATION DAY								
		1	3	5	7	10	15	21	30	107
Breton Ap	1	855.0	130.5	52.5	32.8	29.7	27.0	5.2	5.6	7.1
	2	850.1	115.2	46.9	37.9	30.9	17.2	2.0	2.2	3.8
	3	914.7	121.4	31.9	29.1	16.6	24.4	6.1	1.8	3.4
	4	737.4	115.5	41.4	-	32.5	24.4	11.6	1.3	6.1
Tailings Sand	1	2647.4	2744.6	2116.7	-	21.5	14.4	19.4	14.1	9.9
	2	2611.3	2746.1	2066.6	557.5	28.8	22.0	17.0	17.0	3.3
	3	2264.4	2659.4	1951.9	483.4	19.7	18.5	21.2	16.5	3.5
	4	2394.5	2710.2	1944.6	569.2	26.8	15.9	20.8	16.6	1.9
Clearwater Shale	1	2850.9	38.5	17.4	-	13.1	15.5	11.6	19.5	3.6
	2	2908.3	42.8	13.0	6.4	15.7	14.0	14.9	10.4	7.1
	3	3037.8	26.5	10.6	6.4	18.5	22.8	18.0	8.1	4.6
	4	3017.2	26.0	10.4	7.0	13.4	10.9	13.1	14.5	6.1
Supertest Till	1	2193.4	48.9	34.1	16.5	16.7	9.5	5.8	8.5	2.2
	2	2674.8	50.8	30.6	16.3	16.2	7.8	3.9	2.4	1.5
	3	3022.7	52.0	34.4	18.0	14.0	18.2	2.8	1.3	1.1
	4	2642.1	49.1	30.0	16.3	9.0	12.1	7.3	3.5	1.2
Analytical Controls										
Breton Ap		5.8			0.5					1.5
Tailings Sand		4.7			2.2					0.7
Clearwater Shale		40.8			0.0					0.0
Supertest Till		33.4			0.0					0.6

Appendix Table 28. Soil moisture contents (% wt) in laboratory soil incubations

SOIL	REP	INCUBATION DAY								
		1	3	5	7	10	15	21	30	107
Breton Ap	1	21.8	20.2	39.0	37.3	32.4	29.5	25.5	20.8	8.5
	2	22.5	20.4	38.3	36.3	34.1	30.2	25.9	22.0	13.1
	3	20.8	20.3	39.0	36.2	33.0	31.0	25.8	20.7	14.9
	4	22.0	20.9	37.4	37.6	33.7	29.6	24.5	21.5	17.9
Tailings Sand	1	1.0	0.8	4.2	3.1	1.6	0.4	0.2	0.5	0.2
	2	1.1	0.8	5.7	2.8	2.0	0.2	0.2	1.1	0.2
	3	1.1	0.9	6.3	2.8	-	0.2	0.2	0.5	0.2
	4	1.0	0.7	4.4	3.6	2.1	0.5	0.2	0.6	1.7
Clearwater Shale	1	19.0	17.9	34.3	33.8	31.1	29.8	27.8	22.9	9.5
	2	22.0	20.6	36.9	37.9	36.2	33.2	28.3	24.0	9.5
	3	23.0	21.9	33.6	38.2	36.1	32.8	30.0	26.6	11.7
	4	22.4	21.3	36.3	39.1	35.9	34.5	30.9	26.2	12.6
Supertest Till	1	14.1	12.3	24.5	22.4	21.1	19.5	16.9	11.8	8.3
	2	13.2	12.4	20.6	21.9	20.1	18.0	17.1	11.8	9.1
	3	12.8	12.4	23.9	22.2	21.3	18.6	16.1	10.8	10.5
	4	13.1	12.6	22.2	23.0	21.8	19.3	17.3	11.5	10.9
Analytical Controls										
Breton Ap		21.5			19.6					13.5
Tailings Sand		0.9			0.2					0.2
Clearwater Shale		22.5			20.3					18.8
Supertest Till		9.0			11.4					10.5

Appendix Table 29. Hydrolysable amine contents (ug N/g oven-dried soil) in laboratory soil incubations.

SOIL	REP	INCUBATION DAY							
		1		3		5		7	
		N HCl		N HCl		N HCl		N HCl	
		0.5	6	0.5	6	0.5	6	0.5	6
Breton Ap	1	284.2	-	234.6	222.3	281.1	227.7	325.7	-
	2	245.2	-	212.5	86.1	-	-	252.7	187.8
	3	301.1	-	316.3	129.8	229.8	169.5	262.2	175.1
	4	339.6	-	459.6	251.4	295.5	124.8	281.0	214.7
Tailings Sand	1	-	-	122.6	7.1	-	-	-	-
	2	-	-	156.9	28.5	-	-	-	-
	3	99.8	-	145.4	28.4	191.8	0.0	-	-
	4	-	-	199.8	36.9	191.8	0.0	81.9	9.3
Clearwater Shale	1	92.5	-	-	288.4	279.4	192.4	122.9	323.8
	2	-	-	170.5	131.4	-	-	95.5	233.8
	3	85.5	-	92.7	128.4	63.4	200.3	114.3	178.6
	4	106.7	-	143.3	99.7	-	-	64.0	179.2
Supertest Till	1	147.3	-	135.7	105.7	-	-	113.5	69.3
	2	205.6	-	145.9	7.2	181.9	49.9	128.6	89.3
	3	-	-	122.3	21.6	52.9	225.7	-	-
	4	128.3	-	300.6	7.2	105.6	99.9	71.3	83.4

(continued)

Appendix Table 29. (continued)

SOIL	REP	INCUBATION DAY							
		10		15		21		30	
		N HCl		N HCl		N HCl			
		0.5	6	0.5	6	0.5	6	0.5	6
Breton Ap	1	259.3	128.2	271.4	190.4	246.0	195.8	102.7	107.7
	2	259.5	124.7	270.4	286.9	442.3	181.1	95.9	232.2
	3	281.3	209.1	163.0	191.8	312.9	182.8	-	97.4
	4	299.7	121.3	268.3	264.6	369.7	231.9	265.7	183.1
Tailings Sand	1	259.9	34.3	-	-	85.1	51.7	103.5	40.7
	2	130.9	9.2	92.7	0.0	57.0	3.6	124.8	12.1
	3	64.2	-	35.5	38.3	85.1	55.3	93.9	14.9
	4	-	-	85.7	42.7	190.9	66.2	85.6	26.4
Clearwater Formation	1	135.2	209.2	42.8	236.6	83.2	189.3	96.4	-
	2	121.3	-	-	-	118.6	230.9	140.0	186.9
	3	123.8	250.5	85.6	224.8	128.6	219.3	50.0	221.4
	4	92.8	169.1	105.5	68.4	111.8	239.1	-	-
Supertest Till	1	225.5	76.6	95.4	24.9	-	-	127.1	-
	2	349.6	114.1	67.9	82.2	105.9	115.1	153.8	211.0
	3	74.0	103.2	74.8	85.9	116.7	98.0	87.5	53.4
	4	114.3	87.1	85.7	-	-	52.1	94.6	84.0

(continued)

Appendix Table 29. (continued)

SOIL	1 N HCL 0.5	 6	7 N HCL 0.5	 6
Analytical Controls				
Breton Ap	288.4	-	-	-
Tailings Sand	-	-	32.7	0.0
Clearwater Shale	21.4	-	22.9	33.6
Supertest Till	92.7	135.6	74.3	188.0

8.3. APPENDIX C. ^{15}NITROGEN CALCULATIONS.

1) Relation of Atom % Abundance of ^{15}N to ratio of masses ^{14}N and ^{15}N, ratio of masses 28/29 and Delta ^{15}N.

%Ab = ^{15}Nx100/(^{14}N + ^{15}N) Divide top and bottom by ^{15}N:
%Ab = 100/(1+(^{14}N/^{15}N)); ^{14}N/^{15}N=T
With respect to ratios of mass 28/29:
(28=^{14}N+^{14}N; 29=^{14}N+^{15}N)
%Ab = 100/(2R+1) R = 28/29 ratio obtained from mass spec.
Relation of ratio R to ratio T:
From above it can be seen that T = 2R.
Thus ratio of masses 14/15 = 2(28/29)

a) Delta ^{15}N values (d^{15}N)

d^{15}N=((Sample ^{15}N/^{14}N)-(Ref.^{15}N/^{14}N))x1000/Ref.^{15}N/^{14}N
Output from mass spec. provides 29/28 ratios for the diatomic gas N≡N
d^{15}N=[(1/2)xSa(29/28)-(1/2)xR(29/28)x1000]/[(1/2)xR(29/28)]
thus:
d^{15}N=((Sa29/28) - (R29/28))x1000/(R29/28)

b) Relation of Delta ^{15}N to atom % abundance ^{15}N

d^{15}N=((Sa^{15}N/^{14}N) - (R^{15}N/^{14}N)x1000/(R^{15}N/^{14}N)
The reference (atmospheric nitrogen) has an ^{14}N/^{15}N ratio of 272 (Junk and Svec 1958)
Therefore reference ^{15}N/^{14}N = 0.00367647

0.00367647xd^{15}N=(Sa^{15}N/^{14}N - 0.00367647)x1000
(0.00367647xd^{15}N/1000) + 0.00367647 = Sa^{15}N/^{14}N
Therefore:
Sa^{15}N/^{14}N = 0.00367647((d^{15}N/1000)+1)

Since atom % abundance ^{15}N = A =100/(($^{14}N/^{15}N$)+1)
Substituting from above for $^{14}N/^{15}N$ yields:

$$A=100(1+[1/0.00367647x([d^{15}N/1000]+1)])$$

Therefore % Abundance ^{15}N can be calculated using either ratios of mass 28/29 or using d^{15}N values. Mass 30 values can be omitted. Similarly d^{15}N values can be calculated using ratios of mass 29/28 without using mass 30 values and without calculating $^{15}N/^{14}N$ ratios.

For samples having low abundance ^{15}N, it is best to calculate both d^{15}N and atom % abundance ^{15}N. For samples which are highly enriched (tracer studies) calculations of atom % abundance are the only meaningful numbers.

If atom % abundance ^{15}N is calculated from the d^{15}N values using the equation reported earlier, automatic correction occurs for the difference between the absolute reference 29/28 ratio and the measured ratios. Delta ^{15}N provides the per mill (parts per 1000) difference between the sample and the reference. The equation uses the absolute ratio for the reference. Thus the data are automatically normalized to the absolute reference.

2) Treatment of Mass Spectrometer Output to Obtain d^{15}N and Atom % Abundance ^{15}N (A)

a) Where sample and reference have similar ^{15}N contents.

i) To obtain ratio of masses 28/29 or 29/28.

Actual example
Data format

Mass spec No. 1741 Sample MC-3 0-6 <2mm 95
Reference: High purity nitrogen gas

Amplifier: Major (Ma) 2E-9 amps
Minor (Mi) 1E-10 amps

Major peak height: 0.8X10E-9

Ratio (Ra): 0.144 (Ratio control settings to balance recorder)

Offset: 0.0

Integrator readings:

Reading	Ref	Sample	Sa - R = A	$\frac{An + An+1}{2}$
1	5254		-428	
		4826	-442	-435
2	5268		-434	-438
		4834	-446	-440
3	5280		-436	-441
		4844	-445	-449.5
4	5289		-431	-438
		4858	-448	-482.5
5	5306		-435	-441.5
		4871	-450	-442.5
6	5321		-438	-444
		4883		
	R=5286	S=4853		X=-441.2

ii) To calculate ratio 29/28:

- Amplifier ranges provide the order of magnitude of the differences in ion currents for mass 28 and mass 29 for the Major and minor amplifiers respectively. Mass 28 = major; mass 29 = minor.

- The ratio control unit provides the ratio of currents after necessary current amplification above representing minor/major currents.

- The integrator provides the final four decimal places in a six place number representing the ratio of 29/28.

Therefore the 29/28 ratio for the reference gas in the above data is:

29/28 = Mix[Ra+R/1E6)]/Ma

= [(1E-10x(0.144+0.005286)]/2E-9

= 0.149286/20

= 0.0074643

Compare to the absolute ratio: 1/136 = 0.0073529

Note: $^{14}N/^{15}N$ = 272; 28/89 = 0.5x$^{14}N/^{15}N$ = 136

Correction factor = actual ratio/measured ratio

= 0.0073529/0.0074643

= 0.98608

Ratio of 29/28 in the sample:

29/28 = Mi x [(Ra+(S/1E6))+offset]/Ma

Note: Offset is applied to the sample to balance it with the reference gas and represents a pos. or neg. difference in ratio (29/28) in the sample relative to the reference.

Sa29/28 = [1E-10x(0.144+0.004853+0.0)]/2E-9

= 0.148853/20

= 0.00744265

Corrected ratio = Sax(Abs Ref)/Meas.Ref

= 0.00744265x0.98508

= 0.00733157

iii) To calculate delta ^{15}N:

d^{15}N = [S(29/28)-Ref(29/28)]/Ref(29/28)

Using uncorrected values:

d^{15}N = (0.00744265-0.0074643)x1000/0.0074643

= -2.90

Using corrected values:

d^{15}N = (0.00733157-0.0073529)x1000/0.0073529

= -2.90

Thus, since in the $d^{15}N$ calculation both top and bottom are multiplied by the correction factor, it is quickly seen that the same value is obtained regardless of whether or not corrected values are used.

Delta ^{15}N values may also be calculated using a more rigorous statistical approach. Rather than using the difference between the average sample and reference integrator values as was done above, the average difference of consecutive sample and reference integrator values (Y) can be used.

The ratios then become:

Reference:

$[Ra+(R/1E6)]xMi/Ma$

Sample:

(Ref. + Diff. betwen samples and Ref. + Offset)xMi/Ma

$= ([Ra+(R/1E6)]+offset+[Y/1E6])XMi/Ma$

$d^{15}N=([Ra+(R/1E6)]+offset+(Y/1E6))$

$-[Ra+(R/1E6)]x1000/[Ra+(R/1E6)]$

which expands to:

$=[Ra+(R/1E6)+cffset+(Y/1E6)-Ra-(R/1E6)x1000]/[Ra+(R/1E6)]$

$=[offset+(Y/1E6)]x1000/[Ra+(R/1E6)]$

This allows the $d^{15}N$ to be calculated directly.

Example:

$d^{15}N=[0.0+(-441.2/1E6)]x1000/(0.144+0.005286)$

$=(-0.0004412x1000)/0.148286$

$=-2.96$

Note that this is a slightly larger number than was calculated previously.

iv) To calculate atom % abundance ^{15}N.

1) $A = 100/(2R+1)$; R here = sample 28/29 ratio.

Or:

2) $A = 100/[1+(1/[0.00367647x([d^{15}N/1000]+1)])]$

Using the first approach, the sample 28/29 ratio must be known and must be the corrected value.

Corrected sample 29/28 ratio = 0.00733157 (from above).

Therefore:

Corrected sample 28/29 ratio = 136.3964

Therefore:

$A = 100/([2X136.3964]+1)$

$= 0.36524$ % Ab. ^{15}N

Using the second approach, the $d^{15}N$ value must be known.

In this case:

$A = 100/[1+(1/[0.00367647X([-2.96/1000]+1)])]$

$= 0.36522$ % Ab. ^{15}N

The $d^{15}N$ value obtained using the difference in the average integrator values may also be used.

In this case:

$A = 100/[1+(1/[0.00367647X([-2.90/1000]+1)])]$

$= 0.36524$ % Ab. ^{15}N

This is the same as was obtained using approach (1). By using the average of consecutive differences in integrator values (to correct for drift) a small change in the sixth decimal place occurs. This method of calculating $d^{15}N$ and from that Atom % Ab. ^{15}N is recommended where the sample and the reference have the same Ra values (similar ^{15}N).

b) <u>To calculate % Ab. ^{15}N when the sample and reference have different Ra values.</u>

As a general practice, it is best to use a reference gas with an ^{15}N content close to that of the sample. This is sometimes not possible though. In this situation, $d^{15}N$ values are meaningless and are not calculated. Offset should be zero.

Atom % Ab. ^{15}N values are calculated directly using A = 100/(2R+1) as previously defined, using the following logic:

Sample 28/29 ratio = Ma/([Ra sample +(S/1E6)]xMi)
Reference 28/29 ratio = Ma/([Ra ref +(R/1E6)]xMi)
Absolute reference 28/29 ratio = 136
Absolute sample 28/29 = 136xSample(28/29)/Ref.(28/29)
= R

Thus:

R=[136xMa/Mix[Ra sample+(S/1E6)])]/[Ma/Mix[Ra ref+(R/1E6)])]
= (136[Ra ref+(R/1E6)])/[Ra sample+(S/1E6)]

The Mi and Ma cancel out because their ranges are the same for sample and reference. Otherwise the instrument has to be re-zeroed and the reference no longer relates to the sample.

Note that the 28/29 ratios are calculated here rather than 29/28 ratios as was done when d^{15}N values were also calculated.

Thus:

A=100/([(2x136x[Ra ref+(R/1E6)])/[Ra sample+(S/1E6)]+1)

Example:

Analysis No. 1400 Soil sample: B-17
Reference: High purity Nitrogen gas

	Reference	Sample
Ma =	5E-9	5E-9
Mi =	1E-10	1E-10
Ratio (Ra)	0.144	0.454
Offset	0.00	0.00
Integrator values:		
	4973	6724
	4954	6749
	4932	6761
	4930	6749
	R = 4947	S = 6745

A=100/([272x(0.144+0.004947)/(0.0454+0.006745)]+1)

A = 1.12447 % Ab. ^{15}N.

8.4. APPENDIX D. EVALUATION OF POSSIBLE FRACTIONATION OF ^{15}N IN DIGESTED SAMPLES DURING DISTILLATION, TITRATION AND EVAPORATION.

During $^{15}N/^{14}N$ ratio determinations, samples are normally distilled by steam distillation into boric acid, titrated to pH 4.8, and, following addition of one ml 0.1N H_2SO_4, evaporated to 2-3 ml for isotope ratio analysis. This involves two steps where volatile losses can occur. If this happens, the ^{14}N NH_3 will normally escape more rapidly than the ^{15}N NH_3. The result is enrichment in the sample relative to ^{15}N and invalidation of results. Similarly, the error in replicate isotope ratio analysis of a single sample must be determined. This experiment was conducted to determine variability in analysing the same sample several times, and to determine whether ^{15}N enrichment occurred during normal sample processing and whether it caused a significant shift away from the true mean. One non-enriched and two enriched samples were used. These were $(NH_4)_2SO_4$, either analysed directly, or subjected to one or two normal sets of processing operations. Samples were replicated 5 times; raw data appear in Appendix Table 30.

The data for the non-enriched samples (Appendix Table 30) indicate no significant change in $d^{15}N$ during normal processing. Processing the same sample twice, however, resulted in a significant increase in $d^{15}N$ at the 99% probability level. Thus, if proper care is exercised no significant enrichment or fractionation occurs during normal processing of non-enriched samples.

Enriched samples demonstrated a slight trend towards increased ^{15}N enrichment with one processing, but this was not significant at the 95% probability level (Appendix Table 31) Processing the same N twice, however, produced a significant fractionation at the 95% level.

These data do not support the conclusion that a significant change in $^{15}N/^{14}N$ ratio occurs during normal sample processing for isotope analysis. Doubling the number of operations, however, results in significant fractionation. Normally a d^{15}N value must be at least 0.5% larger or smaller than another to be considered different. According to the formula now used to convert d^{15}N to Atom % abundance ^{15}N, this translates to a difference of 0.00018 atom % abundance ^{15}N. Thus, the analytical accuracy is such that changes in the fourth decimal place are valid.

Appendix Table 30. Effect of distillation, titration and evaporation on d^{15}N of reagent $(NH_4)_2SO_4$.

AVERAGE d^{15}N %0 NUMBER OF TIMES SAMPLE PROCESSED		
0	1	2
2.08	2.01	2.51 **

** significantly different from the mean of 0 processing at the 99% probability level.

Appendix Table 31. Effect of distillation, titration and evaporation on d^{15}N of ^{15}N labelled $(NH_4)_2SO_4$.

	AVERAGE d^{15}N %0 NUMBER OF TIMES SAMPLE PROCESSED		
	0	1	2
SERIES 1	35.58	36.00	
SERIES 2	35.40		32.26*

* significantly different from the mean of 0 processing at the 95% probability level.

Appendix Table 32. Raw ^{15}N data.

Times processed**	delta ^{15}N in replicates (0/00) 1	2	3	4	5
			Non enriched sample*		
0	2.07	1.96	2.14	2.06	2.16
1	1.93	1.95	2.14	2.05	2.00
2	2.58	2.51	2.10	2.67	2.69
			Enriched sample* 1		
0	35.04	35.69	35.49	35.55	36.13
1	35.76	35.82	36.13	35.95	36.32
			Enriched sample* 2		
0	35.44	35.69	35.37	35.17	35.34
2	36.36	36.09	36.12	36.48	-

* Non enriched samples consisted of reagent grade ammonium sulphate.
Enriched samples contained ^{15}N-labelled ammonium sulphate.

** Non processed samples were ammonium sulphate analysed directly on the Mass Spectrometer. Processing consisted of steam distillation, titration and evaporation prior to analysis on the mass spectrometer.