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A Hydrogeochemical Study of Contaminant Attenuation and Remobilization in the Big Swamp Overburden near Picton, Ontario

D.E.J. Creasy, R.J. Patterson and W.A. Gorman

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NATIONAL HYDROLOGY RESEARCH INSTITUTE
INLAND WATERS DIRECTORATE
OTTAWA, CANADA, 1981



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* The authors are with the Department of Geological Sciences, Queen's University, Kingston, Ontario. The study was conducted using funds from the Water Resources Research Support Program of the Inland Waters Directorate.

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nHRI

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Abstract

Contamination of ground water has been recognized as a frequent problem at sanitary landfill sites used for the disposal of municipal and industrial wastes. Most of the current hydrogeologic research concerning waste disposal has focused on the migration of contaminants through inorganic sediments. To increase our understanding of the interactions between potential contaminants and organic sediments, a detailed study of both organic-rich and inorganic surficial sediments from a location designated as a potential landfill site was conducted. From the data obtained in this study, the effectiveness of organic sediments for attenuating potential contaminants in landfill leachate could be evaluated relative to fine-grained clastic materials.

The attenuation capacity of the organic materials with respect to Ca, Mg, Na, Fe, Mn, NH₄, Cl, HCO₃, SO₄, PO₄ and NO₃-NO₂ was similar to that found in the inorganic sediments tested. The attenuation experiments were conducted using the same bulk volumes of organic and inorganic sediment; hence on a dry weight basis, the organic sediments are two to three times more effective in attenuating potential contaminants. The relatively high hydraulic conductivity of the organic sediments (10^{-1} to 10^{-2} cm/s) would favour selective channelling of landfill leachate through these materials, and since the rate of ground water flow would be relatively rapid, the significance of dispersion and dilution would be increased. Clastic sediments with similar hydraulic conductivities would likely have much lower attenuation capacities than organic sediments, even when compared on a volume basis.

Résumé

La contamination des eaux souterraines est fréquente dans les lieux d'enfouissement des déchets urbains et industriels. La plupart des recherches hydrogéologiques actuelles sur l'élimination des déchets sont axées sur la migration des contaminants dans les sédiments minéraux. Pour mieux comprendre les interactions entre les contaminants éventuels et les sédiments organiques, on a étudié en détail un endroit désigné comme lieu de décharge éventuelle, à l'aide de sédiments riches en matériaux organiques et de sédiments minéraux de surface. On a pu ainsi comparer l'efficacité des sédiments organiques à réduire la concentration de contaminants dans les percolats à celle des matériaux clastiques fins.

L'efficacité des matériaux organiques à réduire la concentration de Ca, Mg, Na, Fe, Mn, NH₄, Cl, HCO₃, SO₄, PO₄, et NO₃-NO₂ était similaire à celle des sédiments minéraux éprouvés. On a utilisé les mêmes volumes apparents de sédiments organiques et minéraux; par conséquent, pour un poids sec donné de sédiments organiques, ceux-ci sont de 2 à 3 fois plus efficaces. La perméabilité relative élevée des sédiments organiques (de 10^{-1} à 10^{-2} cm/s) pourrait favoriser des cheminements préférentiels des percolats, et, comme le débit des eaux souterraines serait relativement élevé, la dispersion et la dilution seraient augmentées. Même à volume égal, les sédiments clastiques, d'une perméabilité similaire, seraient moins efficaces que les sédiments organiques.

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INTRODUCTION

Contamination of ground water has been recognized as a frequent problem at sanitary landfill sites that are used for the disposal of municipal and industrial wastes. As a result, particularly since the early 1970's, there has been a dramatic increase in research on ground water contamination resulting from solid and liquid waste disposal in soil. To date, most of the hydrogeologic research has focused on the migration of contaminants through predominantly inorganic sediments, which in Canada are commonly glacial deposits. In contrast, little research concerning organic-rich sediments (e.g. peat) has been carried out, even though these deposits are relatively common in Ontario and Quebec and may represent potentially significant hydrogeochemical sinks for heavy metals and other toxic substances.

OBJECTIVES

To increase our understanding of interactions between typical contaminants and organic sediments, a detailed study using organic-rich surficial sediments from a location designated as a potential landfill site has been conducted. The specific objectives of the research were:

- (1) To conduct attenuation experiments in which contaminated water would be passed through columns of undisturbed organic sediment.
- (2) To evaluate the extent of contaminant remobilization from organic sediments.
- (3) To assess, on the basis of experimental results and field data, the likely impact of a proposed landfill site on ground water quality.

STUDY AREA

Location and Access

The field study was carried out in the Big Swamp, which covers an area of about 14.2 km² in the southwestern portion of Sophiasburgh Township and the north-central portion of Hallowell Township, Prince Edward County, Ontario (Fig. 1). The swamp is traversed by three public roads: Highway 14, County Road 4 and a township road.

The location of the detailed study area is shown in Figure 1. Access to and within the study area is limited to dirt roads and bush trails.

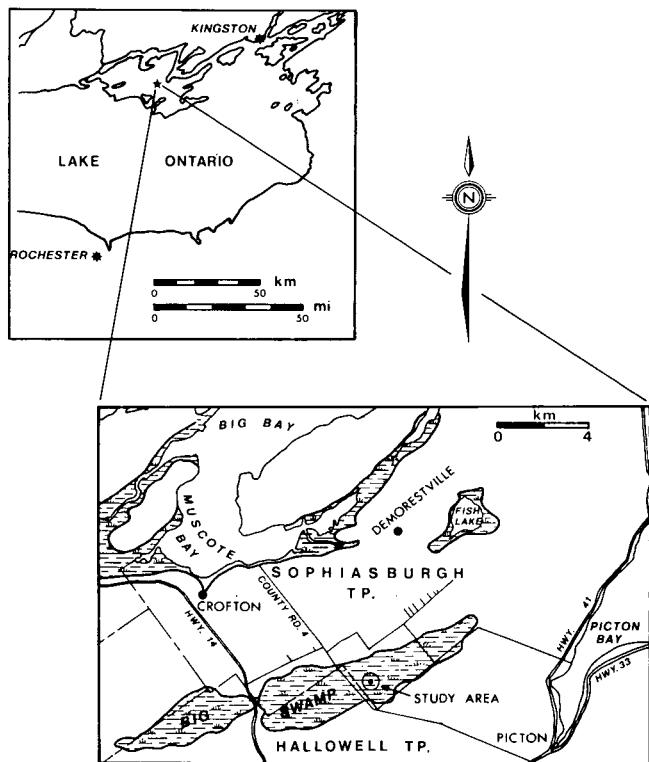


Figure 1. Location of study area.

Geology

Bedrock in the Big Swamp area comprises Paleozoic limestones which lie unconformably on the Precambrian basement (Liberty, 1960). The Paleozoic sequence is divided into two groups, the Black River and the overlying Trenton. Only rocks of the Trenton group outcrop in Prince Edward County.

During the Wisconsin Stage of the Pleistocene Epoch, all of Prince Edward County was covered by an ice sheet several thousands of metres thick. Melting of this ice sheet commenced about 20 000 years before the present (B.P.) and resulted in the deglaciation of the county by approximately 12 000 B.P. (Watt *et al.*, 1973). As a consequence

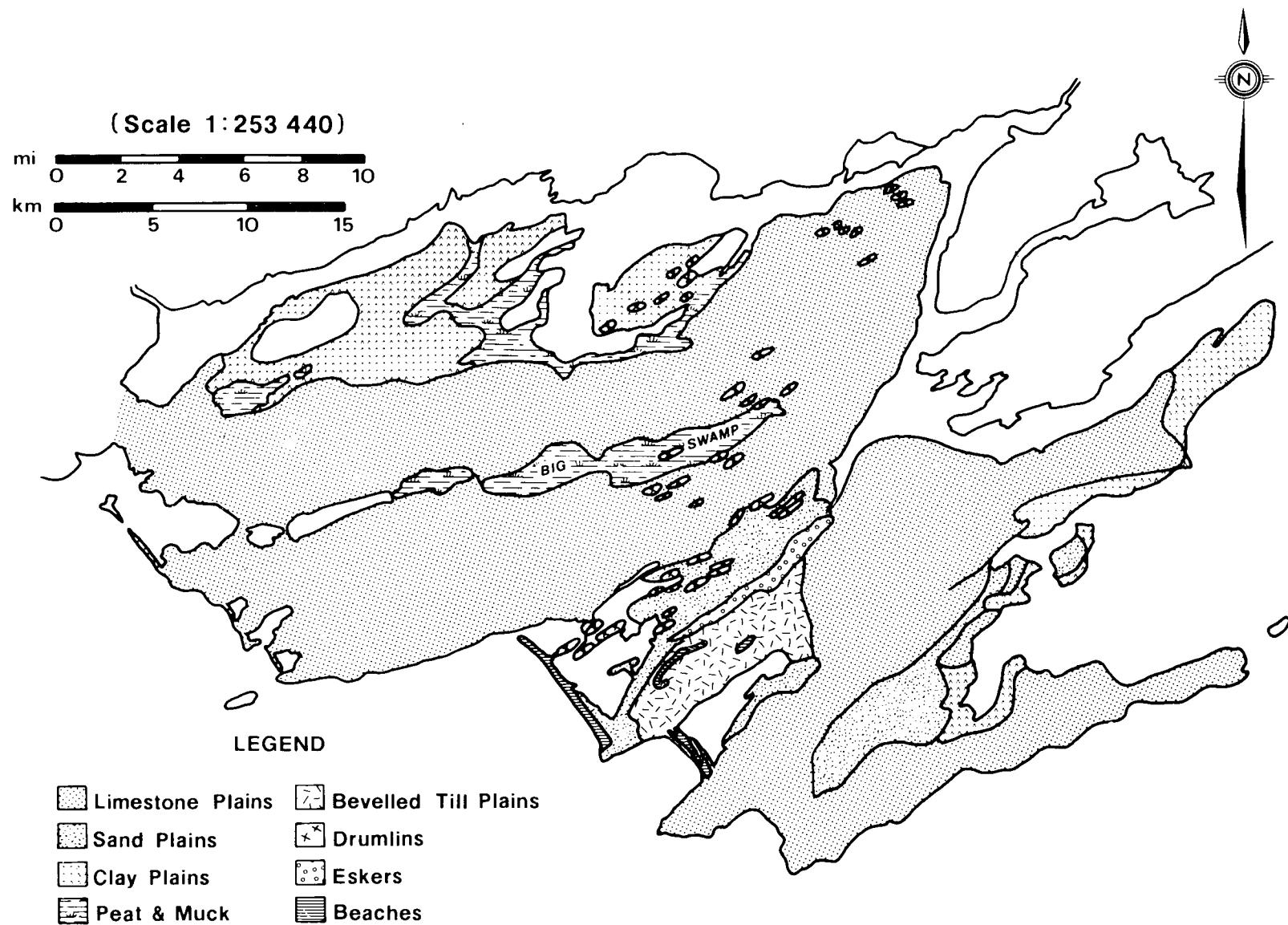


Figure 2. Physiography of Prince Edward County (after Chapman and Putnam, 1972).

of this glacial episode, a generally thin veneer of glacially derived sediments was deposited over the bedrock. Peat bogs and marshes, the largest of which is the Big Swamp, have developed in low-lying areas that are underlain by relatively impervious silts, clays or bedrock (Mirynech, 1962). Figure 2 illustrates the physiography of Prince Edward County (Chapman and Putnam, 1972).

Soil Type and Vegetation

The Big Swamp area is mostly underlain by organic-rich muck, varying in thickness from 30 to 100 cm (Fig. 3). This layer is in turn underlain by mottled clay containing a relatively large percentage of sand- and silt-sized particles. Practically no agricultural development has taken place on the muck soil, and at present, the swampland is heavily wooded with sugar and black maples, and elms. The abundance of hard maple species suggests that flooded conditions do not predominate within the Big Swamp basin.

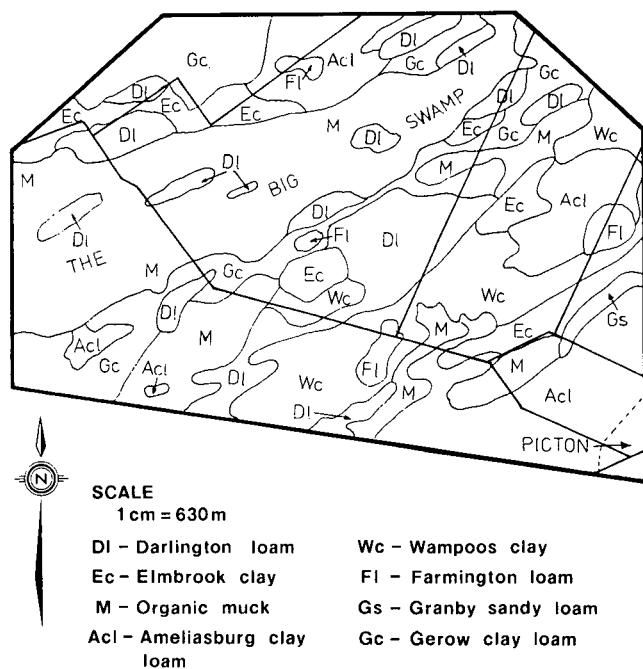


Figure 3. Soil types in the Big Swamp and surrounding area (after Richards and Morwick, 1948).

The only other major soil type within the Big Swamp is found on several elevated drumlin features, one of which occurs in the detailed study area. The drumlins are characterized by Darlington loam (Richards and Morwick, 1948); a typical profile of this soil is shown in Figure 4. The loam contains approximately 50% sand and 50% silt and clay, and is well drained both internally and externally.

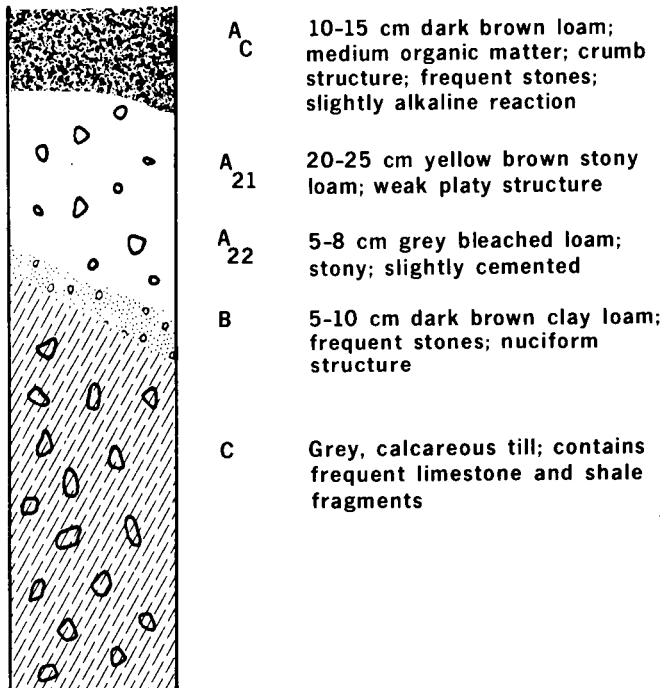


Figure 4. Typical soil profile of Darlington loam (after Richards and Morwick, 1948).

STUDY METHODS

Preliminary Studies

Topographic information for the Big Swamp area was obtained from the examination of topographic maps with a scale of 1:25 000. Regional hydrogeologic data were derived from drillers' logs for private wells that are on file at the Ontario Ministry of the Environment Office in Kingston, Ontario.

Field Methods

Topography in the detailed study area was mapped, employing plane table surveying techniques and a Hilger-Watts Mountain alidade.

Twenty-four piezometers were installed to depths of up to 2 m in the study area to permit sampling of the ground water and monitoring of the water-table elevations. The piezometers were constructed of ABS plastic pipe, 5.08 cm (2 in.) in diameter, and had 30-cm screened intervals. Installation of the piezometers was carried out using a portable-powered continuous flight auger. Piezometer installation on the topographically higher drumlin was not possible because the auger was unable to penetrate the soil more than 1 m. Ground elevations at all piezometer locations were measured after well installation had been completed.

Water levels in the piezometers were measured with an electric A. Ott meter. Samples of ground water for chemical analysis were collected with a hand-operated suction pump after the well had been thoroughly flushed. The pH measurements were made at the time of collection using a combination glass electrode and a Metrohm E488 meter. Initially, the ground water samples that were collected were filtered ($0.45\text{ }\mu\text{m}$) and acidified in the field in preparation for major ion, iron and manganese analyses. Subsequent experiments to evaluate the benefits of acidification revealed that for major ion analysis, the procedure was unnecessary. Additional studies showed that results of analyses for iron and manganese, whether using unfiltered-acidified or filtered-acidified samples (pH 2.0), were identical within the limit of analytical error. On the basis of these results, waters collected subsequently for iron and manganese analysis were simply acidified at the time of collection. Samples of major ion determination were filtered in the laboratory but not acidified.

To carry out laboratory experiments using soils from the Big Swamp, cores were collected. Since cores in excess of about 50 cm in length could not be recovered on the

drumlin in the study area, soil pits measuring approximately 5 m long, 0.6 m wide and up to 2.4 m deep were dug. In each pit a vertical series of cores was obtained in clear acrylic tubes, 30 cm long and 8.02 cm in diameter (Fig. 5A). A second set of sediment samples was collected in 40-dram plastic vials, which were pressed into the pit wall at 10-cm intervals (Fig. 5A). In the lower parts of the area, where organic sediments occur at the surface, 30-cm lengths of the clear acrylic tubing (8.02 cm in diameter) were driven vertically into the ground (Fig. 5B). After withdrawal of the sediment-filled tube, a set of sediment samples was collected in 40-dram vials that were pressed into the side of the hole from which the plastic core had been taken (Fig. 5B).

LABORATORY

Attenuation Experiments

Experiments using cores (30 cm long) were carried out to evaluate the attenuation capacity of the soils mentioned above for major ions and trace metals. In each experiment, five core segments were stacked vertically to form a single column. The columns were charged periodically with 1-L aliquots of leachate obtained from a well at an abandoned landfill site in Kingston, Ontario. Samples of each aliquot of leachate were filtered ($0.45\text{ }\mu\text{m}$), acidified and retained for chemical analysis. In total, 25 L of leachate was added to each column. Leachate that passed through the columns after the addition of each 1-L aliquot was collected and filtered, with vacuum assist, through a $0.45\text{-}\mu\text{m}$ Millipore membrane. A 500-mL sample was sent to the Ontario Ministry of the Environment Laboratory in Kingston for chemical analysis. An additional 125-mL sample was acidified to less than pH 2.0 by the addition of nitric (HNO_3) acid and stored at 5°C until chemical analysis could be carried out at Queen's University.

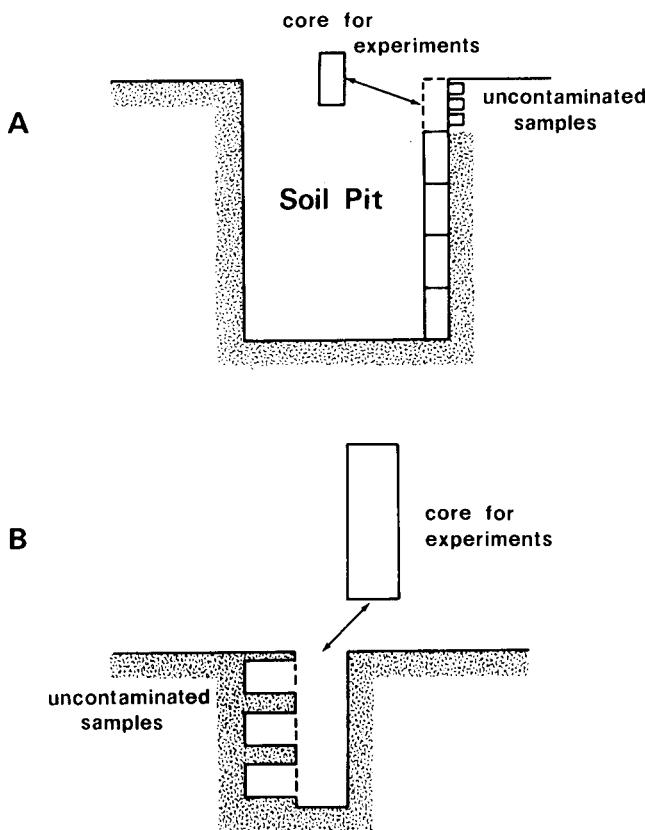


Figure 5. Sediment core collection procedure: A – sampling technique used in sandy loam sediments; B – sampling technique used in organic-rich sediments.

The first two columns (S1 and S2) tested consisted of five sequential core segments representing the upper 150 cm of section at the site. In these experiments it was found that due to the deeper low-permeability materials at the site, percolation rates were too slow to permit completion of the tests. As a result, subsequent experiments were carried out employing columns consisting of cores representing only the upper 30 cm of the soil profile. Five separate samples of the same upper 30 cm of the soil profile were collected and then stacked vertically so that a column 150 cm long was formed (Fig. 6). Two of these columns (S3 and S4) contained soil material from the drumlin area; the other four columns (S5, S6, S7 and S8) contained organic-rich soils from the lower part of the site.

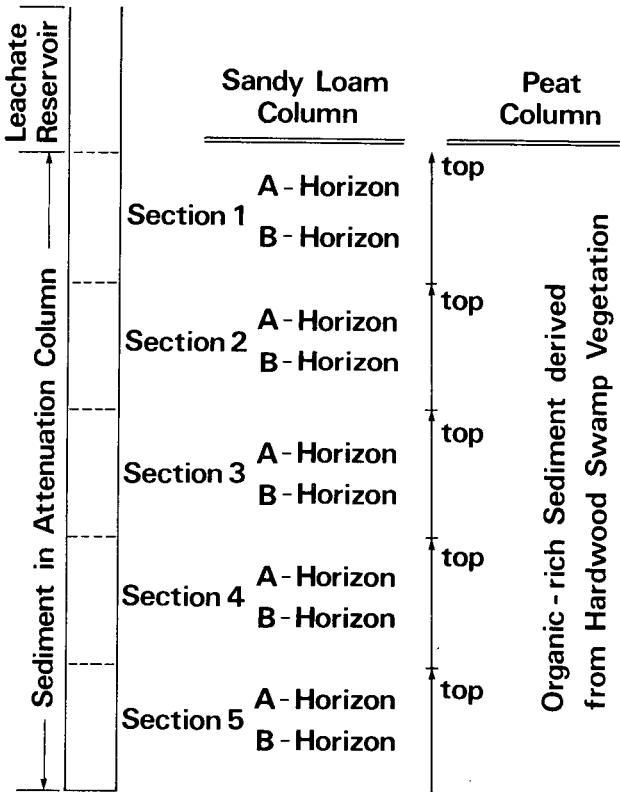


Figure 6. Sediment core stacking arrangement used to construct experiment columns.

Contaminant Remobilization Experiments

The reversibility of attenuation processes in the sediments from the Big Swamp was evaluated by passing simulated rainwater through the columns used in the attenuation experiments. Elution with simulated rainwater commenced after the columns had drained for a period of several days following the addition of the 25th litre of leachate. During the period of drainage, combination electrodes to measure Eh and pH, respectively, were secured into probe ports drilled through the plastic core tube at 30-cm intervals. The electrodes were connected to a Metrohm E488 meter through an Orion multi-junction electronic channel selector (model 605). Elution with simulated rainwater was begun by pumping the rainwater upward through the column until a 15-cm head was achieved above the top of the sediment. This procedure ensured that as much air as possible was removed from the pore spaces. The flow direction in the column was then reversed, and the rate of addition of simulated rainwater by a peristaltic pump was regulated to maintain the 15-cm head at the top of the column. As the rainwater passed down the column the pH and Eh at each probe port location were monitored. The effluent from the bottom of the column was collected in 1-L plastic bottles during the experiment. After each 1-L

sample was obtained, the pH and Eh of the water were measured, and an aliquot of nitric acid was added to reduce the pH to less than 2.0. All samples were then stored at 5°C until chemical analyses could be performed. Figure 7 shows the complete apparatus employed in the elution experiments.

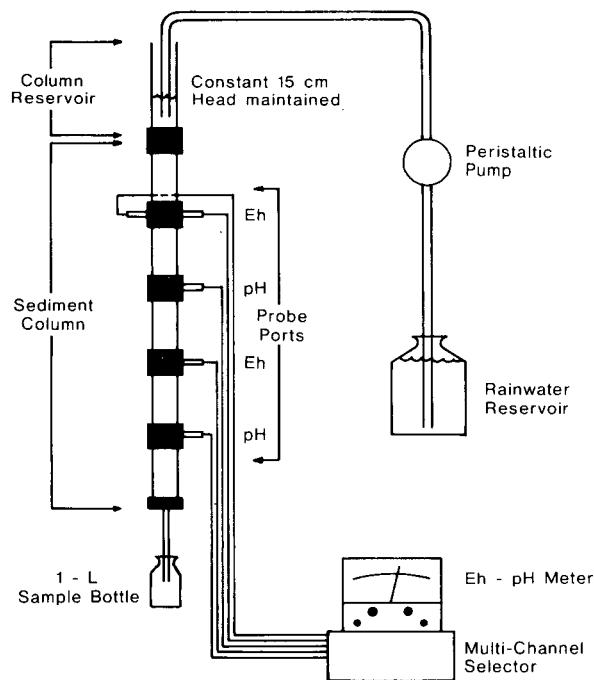


Figure 7. Schematic diagram of apparatus employed in contaminant remobilization experiments.

Analytical Techniques — Sediments

Measurements of hydraulic conductivity on sediment samples were carried out in conjunction with the contaminant remobilization experiments. In these experiments, water was passed through the sediment column at a uniform rate under constant head conditions. A hydraulic conductivity value (centimetres per second) for the sediment in each column was calculated using the following expression of Darcy's law:

$$K = \frac{Ql}{Ah}$$

where K = hydraulic conductivity,
 Q = flow rate through column (cm^3/s),
 l = path length (cm),
 h = hydraulic head loss (cm), and
 A = cross-sectional area of column (cm^2).

For each sediment column, a minimum of five values of hydraulic conductivity were calculated.

Sediment subsamples for physical and geochemical analysis were placed in pre-weighed 40-dram plastic vials. The vial plus sediment was weighed again, frozen and freeze-dried using a Virtus 10-100 Unitrap freeze-drying unit. Disaggregation of the freeze-dried sediment was then carried out using a modified Red-Devil paint shaker. Each sample was shaken for 15 min, producing a homogeneous mixture.

After freeze-drying and disaggregation, the samples were re-weighed to determine water content as a weight percent. Detailed grain-size analysis was then carried out on selected sediment samples from each core site by employing the Fast Analysis of Sediment Texture (F.A.S.T.) method developed by Rukavina and Duncan (1970). The mineralogy of several samples from each core site was investigated using a Picker 2822-C X-Ray Diffractometer; each sample was ground to a fine powder in an agate mortar and then smeared onto a clear glass slide. Diffractograms spanning the range from 4° to 45° (2θ) were recorded and each X-ray peak was identified. Standard petrographic methods were also used to verify the presence of each mineral.

Organic matter content in the sediments was determined by Loss-on-Ignition (L.O.I.) at 450°C . With this method, some water and volatiles are lost in addition to the organic matter. Coker (1974), however, found that these losses are generally small. Frape (1979) also noted that a strong correlation existed between L.O.I. and organic carbon in several study areas in southeastern Ontario. The L.O.I. results, therefore, are considered to be a reliable indication of organic content. The extent of organic matter decomposition in uncontaminated samples taken from core sites S5, S6, S7 and S8 was determined using a saturated sodium pyrophosphate solution (Kaila, 1956).

The heavy metal content of sediments was determined at three stages during the experimental procedure: prior to exposure to leachate, immediately following contamination by leachate, and after elution with simulated rainwater. Samples (250 mg) of freeze-dried sediment were exposed to 5 mL of concentrated HNO_3 acid, which breaks down the majority of components except silicates (Foster, 1973). The mixture was then dried and another 5-mL aliquot of concentrated HNO_3 was added. Following the drying of this mixture, 5 mL of concentrated HCl was added. The acid-sediment mixture was again dried and leached in 10 mL of 10% HCl on a sand bath at about 50°C for 30 min. The resultant solution was analyzed using an IL251 atomic absorption spectrophotometer (A.A.S.) for copper, nickel, lead, zinc, manganese, iron, cobalt and cadmium.

Exchangeable major cation (Ca, Mg, Na, K) concentrations were determined at three stages in the experiments as with the heavy metals. Samples (250 mg) of freeze-dried sediment were agitated for 5 min in 8 mL of 0.1 N NH_4OAc at pH 7.0. The mixture was then centrifuged and the supernatant decanted. This procedure was repeated to yield a second aliquot of supernatant. A third, larger (9 mL instead of 8 mL) aliquot of supernatant was similarly collected. The three aliquots of supernatant were combined and analyzed by A.A.S. for calcium, magnesium, sodium and potassium. Hesse (1971) has shown that the triple extraction technique is superior to single extraction methods.

Analytical Techniques — Waters

As indicated earlier, the pH values for ground waters were obtained in the field at the time of collection. The Eh and pH measurements for waters employed in the laboratory attenuation and elution studies were taken as the experiments proceeded.

All of the ground-water, leachate and simulated rainwater samples were analyzed for major ions and trace metals by the techniques that are summarized in Table 1.

Table 1. Summary of Techniques Used for Water Analysis

Parameter	Analytical technique
HCO_3^-	Alkalinity titration* using 0.020 N sulphuric acid; Fisher titralyzer†
Cl^-	Vohland argentometric titration*
SO_4^{2-}	Turbidimetric method, Sulfaver IV, Hach Chemical Co.*
$\text{NO}_3^- + \text{NO}_2^-$	Technicon AutoAnalyzer†
BOD_5	Dissolved oxygen membrane probe†
Eh	Orion 407A specific ion meter; Orion 96-78 combination redox platinum electrode*
pH	E 488 Metrohm meter; EA 152 Metrohm combination glass electrode*
NH_4^+	Technicon AutoAnalyzer†
Ca^{2+}	Atomic absorption spectrophotometry*
Mg^{2+}	Atomic absorption spectrophotometry*
Na^+	Atomic absorption spectrophotometry*
K^+	Atomic absorption spectrophotometry*
Fe^{2+}	Atomic absorption spectrophotometry*
Mn^{2+}	Atomic absorption spectrophotometry*

*Samples analyzed at Queen's University, Department of Geological Sciences.

†Samples analyzed by Ministry of the Environment.

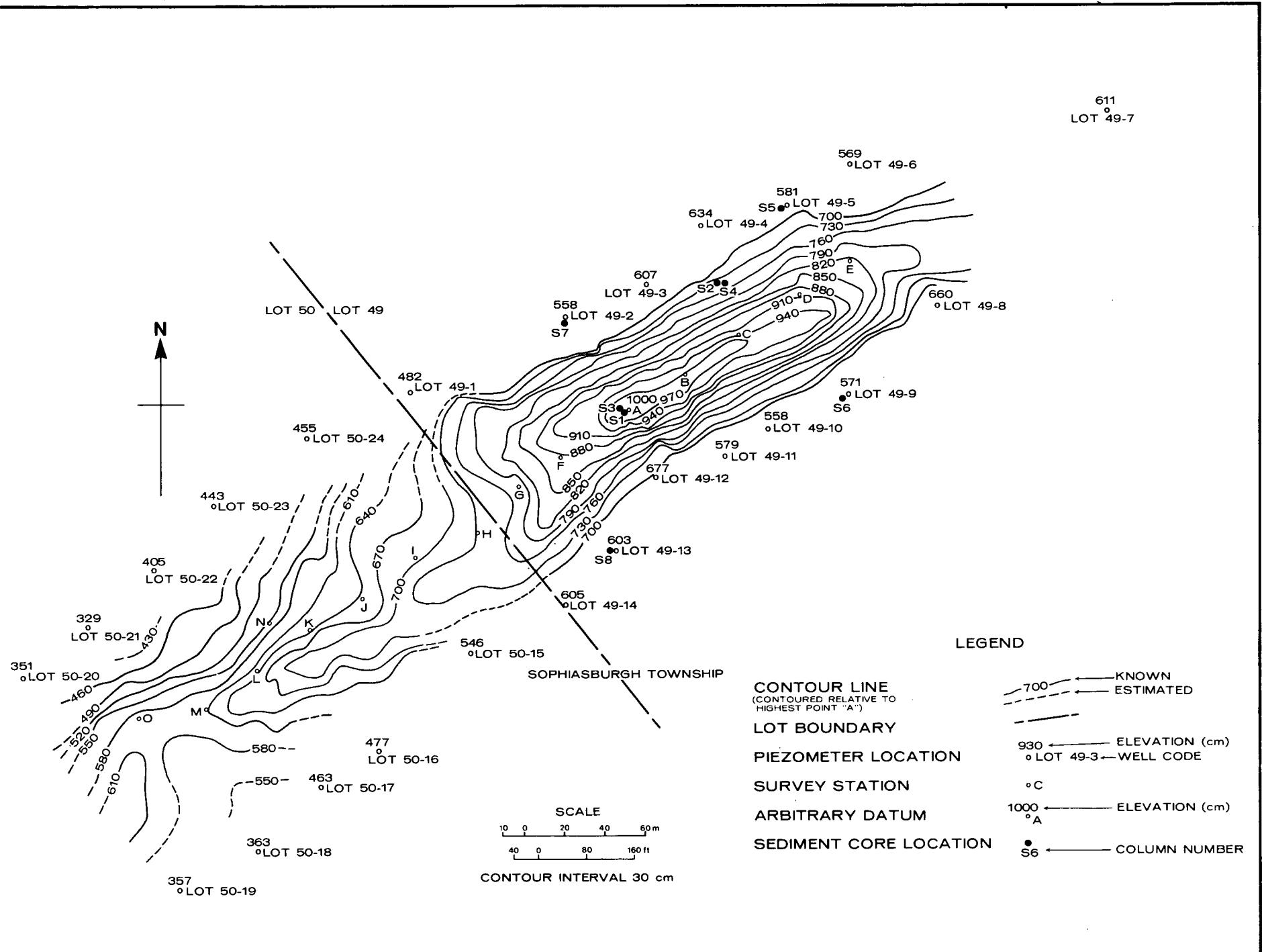


Figure 8. Topography of the study site.

RESULTS AND DISCUSSION

Site Topography

The topography of the study site, as determined by plane table surveying, is illustrated in Figure 8. Due to the absence of any topographic bench marks nearby, all elevations have been calculated relative to station A, the highest point on the drumlin. Station A has been assigned an arbitrary elevation of 1000 cm.

Hydrogeology

Analysis of materials recovered during piezometer installation (locations shown in Figure 8) indicates that the lower portions of the site are underlain by up to 1.2 m of organic-rich muck derived from surrounding vegetation. This surficial material, which has a relatively high hydraulic conductivity [$\sim 10^{-1}$ to 10^{-2} cm/s (Appendix A)], is underlain by more than 5 m (maximum depth of penetration achieved by augering) of relatively impermeable clay and clay till, which likely rests on limestone bedrock. On

the topographically higher drumlin, the surficial material is stony clay till that could not be penetrated more than a metre by the auger. Some sandy-clay lenses were noted along the flank of the drumlin.

Surface drainage in the Big Swamp area is generally toward the west-southwest (Fig. 2). The elevation difference along the drainage course in the swamp is about 9 m, resulting in an average gradient of 1.7 m/km. Four small streams which have gradients of approximately 1 m/km enter the Big Swamp from the north. No surface drainage is apparent on the steeper south slope, which has an average gradient of approximately 12 m/km. Minor gulleying, however, indicates that overland flow does occur periodically.

Static elevation data obtained from drillers' logs for private wells in the Big Swamp area are shown in Figure 9. Figure 10 illustrates static water elevation along the profile A2-B2. Although there appears to be a potential gradient toward the Big Swamp, it is not well defined because not all of the static level measurements had been obtained at the same time and the wells had been completed at different depths. The one well drilled in the Big Swamp shows a static level about 5 m below ground level.

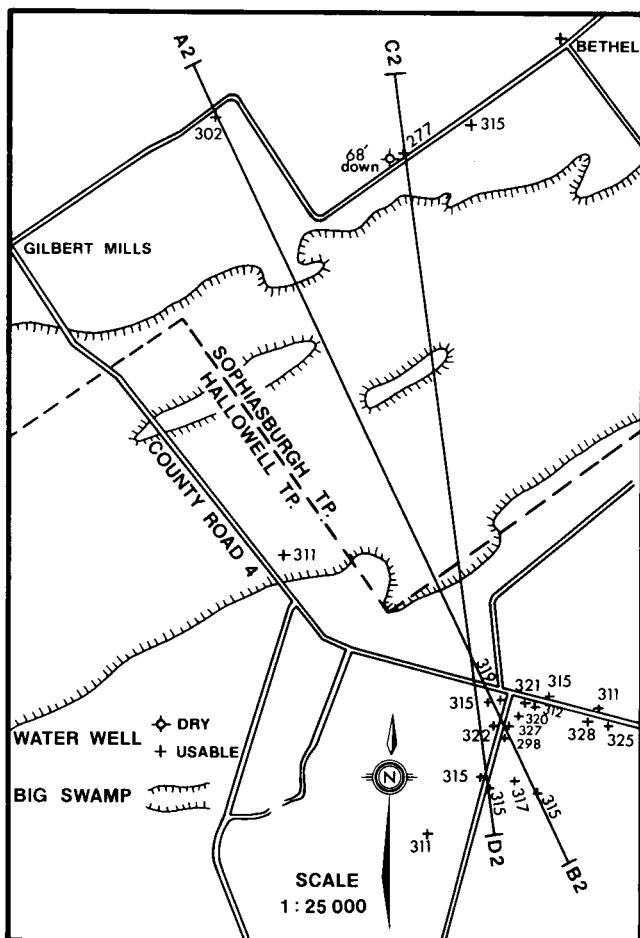


Figure 9. Static water elevation data for private wells in the Big Swamp area.

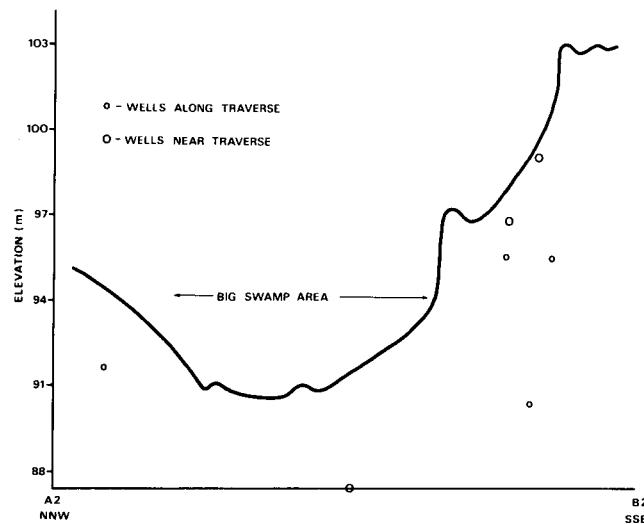


Figure 10. Static water elevation along profile A2-B2 taken perpendicular to the long axis of the Big Swamp.

Static elevation results (Table 2) for the piezometers installed at the study site show that the water table is near the surface in areas underlain by organic materials. From August 3 to November 1, 1977, the water table rose by up to 157 cm, indicating that seasonal fluctuations in level may be as large as 2 m. Since there is an almost linear relationship between surface elevation and static elevation (Fig. 11), the probable direction of shallow ground

Table 2. Water-Table Elevations Adjacent to Study Area, 1977

Piezometer number	Ground elevation (cm)	Water-table elevation (cm)				
		77 - 08 - 03	77 - 09 - 20	77 - 10 - 03	77 - 10 - 19	77 - 11 - 01
Lot 49-1	482	292	393	426	453	449
Lot 49-2	558	549	436	489	507	502
Lot 49-3	607	510	515	562	589	581
Lot 49-4	634	535	547	588	616	609
Lot 49-5	581	469	483	522	552	545
Lot 49-6	569	480	487	526	553	550
Lot 49-7	611	516	527	566	593	580
Lot 49-8	660	500	495	585	580	582
Lot 49-9	571	469	507	544	562	577
Lot 49-10	558	434	492	535	550	568
Lot 49-11	579	496	497	539	551	561
Lot 49-12	677	486	477	540	562	557
Lot 49-13	603	522	462	524	550	542
Lot 49-14	605	489	561	593	608	621
Lot 50-15	546		477	514	526	533
Lot 50-16	477		378	434	442	443
Lot 50-17	463		350	399	402	405
Lot 50-18	363		301	342	350	350
Lot 50-19	357		310	347	352	363
Lot 50-20	351		285	330	362	361
Lot 50-21	329		266	311	342	342
Lot 50-22	405		295	379	384	382
Lot 50-23	443		368	406	433	430
Lot 50-24	455		353	405	420	419

Note: All ground elevations are relative to station A (1000 cm).

water flow at the site is down gradient in terms of surface topography.

The elevation of the water table throughout the study area is more than 4 m above the static level reported for the private well located in the swamp (Fig. 10). This difference suggests that the shallow ground water flow system in the Big Swamp is perched with respect to the deeper aquifer in the limestone from which private water supplies are obtained.

Preliminary Sediment Analysis

The major minerals present in the clastic sediments and the detrital fraction of the organic sediments are quartz, plagioclase, calcite and dolomite. Higher relative concentrations of calcite and dolomite are noted in the B- and C-horizons of the sandy loam samples (columns S1, S2, S3 and S4). Representative X-ray diffractograms for sandy loam and organic-rich sediments from the Big Swamp area are shown in Figures 12A and 12B, respectively. A broad background peak extending from about 10° to 36° (2θ) that is associated with the organic-rich sediment samples disappeared after heating to 450°C . This broad peak is believed to have been produced by the organic matter.

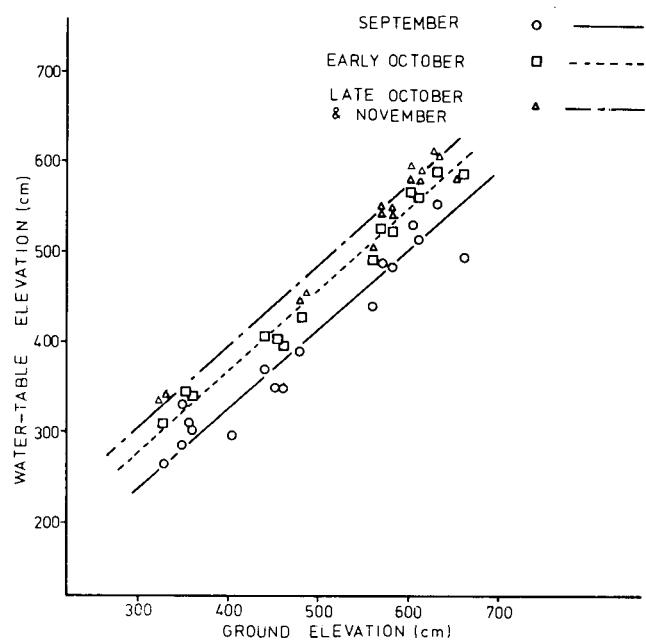


Figure 11. Surface elevation vs. static elevation plot of data collected from Big Swamp drumlin piezometers during the fall of 1977.

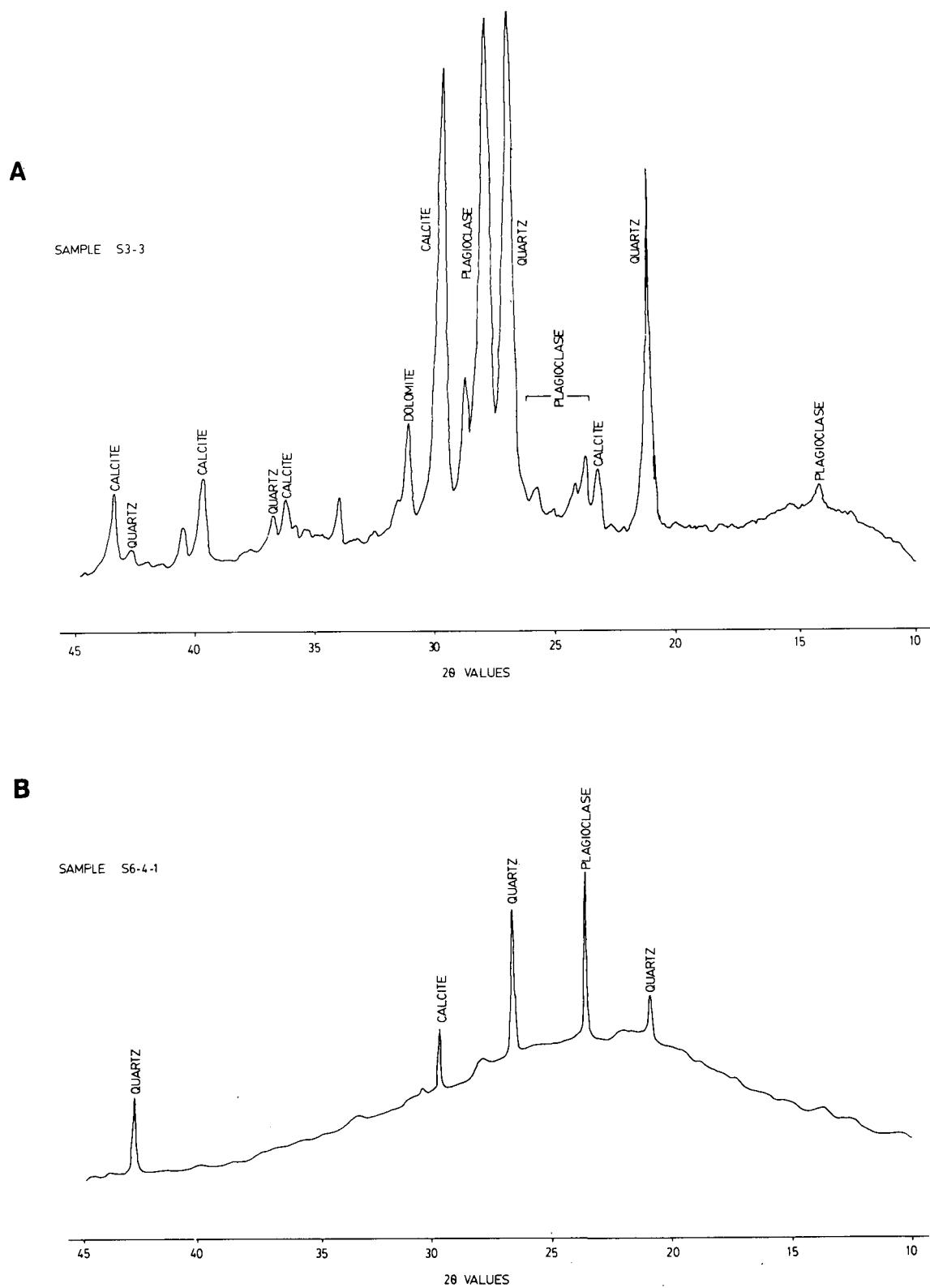


Figure 12. Typical X-ray diffractograms of soil samples in study area: A – sandy loam sediment; B – organic-rich sediment.

Loss-on-Ignition, heavy metal concentration and exchangeable major cation results for the soil columns are listed in Tables 3, 4 and 5, respectively. The highest values of nickel, copper, iron, manganese and cobalt in columns S1 and S2 occur in the B-horizon (samples S1-4, S1-5, S1-6, S2-4, S2-5 and S2-6), whereas maximum concentrations of lead and zinc are found in the overlying A-horizon. Comparison of these heavy metal results with the loss-on-ignition values (Fig. 13) indicates that the lead-zinc maxima are

associated with higher organic matter concentrations. The other heavy metals (Ni, Cu, Fe, Mn and Co) appear to have been concentrated by illuvial processes. Similar heavy metal trends are also noted in the results for individual sections of columns S3 and S4.

In each of the sections of columns S5, S7 and S8 that contain organic sediments, no trends in the concentrations of nickel, copper, lead, iron, cobalt and cadmium

Table 3a. Loss on Ignition Values for Sandy Loam Sediments from the Big Swamp Area

Column S1		Column S2		Column S3		Column S4	
Sample number	L.O.I. (%)	Sample number	L.O.I. (%)	Sample number	L.O.I. (%)	Sample number	L.O.I. (%)
S1-01	3.9	S2-01	3.7	S3-1-1	4.7	S4-1-1	3.8
S1-02	4.0	S2-02	2.7	S3-1-2	1.9	S4-1-2	2.1
S1-03	1.5	S2-03	0.9	S3-1-3	1.4	S4-1-3	2.2
S1-04	2.6	S2-04	3.1	S3-2-1	1.2	S4-2-1	6.7
S1-05	1.7	S2-05	1.8	S3-2-2	1.6	S4-2-2	4.0
S1-06	2.2	S2-06	2.3	S3-2-3	1.7	S4-2-3	16.8
S1-07	0.6	S2-07	0.9	S3-3-1	2.3	S4-3-1	1.3
S1-08	0.8	S2-08	0.9	S3-3-2	2.7	S4-3-2	3.0
S1-09	0.6	S2-09	0.9	S3-3-3	2.1	S4-3-3	3.0
S1-10	0.6	S2-10	1.2	S3-4-1	2.4	S4-4-1	3.9
S1-11	0.8	S2-11	1.0	S3-4-2	1.3	S4-4-2	1.4
S1-12	0.6	S2-12	0.9	S3-4-3	1.4	S4-4-3	13.0
S1-13	0.5	S2-13	0.8	S3-5-1	1.2	S4-5-1	4.5
S1-14	0.9	S2-14	0.9	S3-5-2	1.2	S4-5-2	2.8
S1-15	0.6	S2-15	0.9	S3-5-3	—	S4-5-3	1.3
Mean (\bar{x})	1.46		1.47		1.94		4.56

Table 3b. Loss on Ignition Values for Organic-Rich Sediments from the Big Swamp Area

Column S5		Column S6		Column S7		Column S8	
Sample number	L.O.I. (%)	Sample number	L.O.I. (%)	Sample number	L.O.I. (%)	Sample number	L.O.I. (%)
S5-1-1	35.6	S6-1-1	78.7	S7-1-1	22.6	S8-1-1	51.4
S5-1-2	26.1	S6-1-2	78.7	S7-1-2	21.2	S8-1-2	43.8
S5-1-3	6.5 (till)	S6-1-3	82.8	S7-1-3	20.1	S8-1-3	41.7
S5-2-1	32.9	S6-2-1	78.6	S7-2-1	26.5	S8-2-1	46.7
S5-2-2	29.3	S6-2-2	79.0	S7-2-2	24.1	S8-2-2	49.3
S5-2-3	11.9	S6-2-3	80.0	S7-2-3	26.5	S8-2-3	47.0
S5-3-1	37.1	S6-3-1	77.3	S7-3-1	26.9	S8-3-1	49.9
S5-3-2		S6-3-2	81.3	S7-3-2	21.7	S8-3-2	46.0
S5-3-3	21.1	S6-3-3	83.4	S7-3-3	23.4	S8-3-3	49.4
S5-4-1	36.1	S6-4-1	77.7	S7-4-1	28.1	S8-4-1	50.4
S5-4-2	31.3	S6-4-2	80.3	S7-4-2	32.9	S8-4-2	54.9
S5-4-3	30.5	S6-4-3	78.8	S7-4-3	26.3	S8-4-3	33.7
S5-5-1	37.5	S6-5-1	78.9	S7-5-1	26.5	S8-5-1	48.1
S5-5-2	28.1	S6-5-2	78.3	S7-5-2	26.0	S8-5-2	—
S5-5-3	29.7	S6-5-3	78.8	S7-5-3	27.4	S8-5-3	12.0 (till)
Mean (\bar{x})	28.1		79.5		25.3		44.0

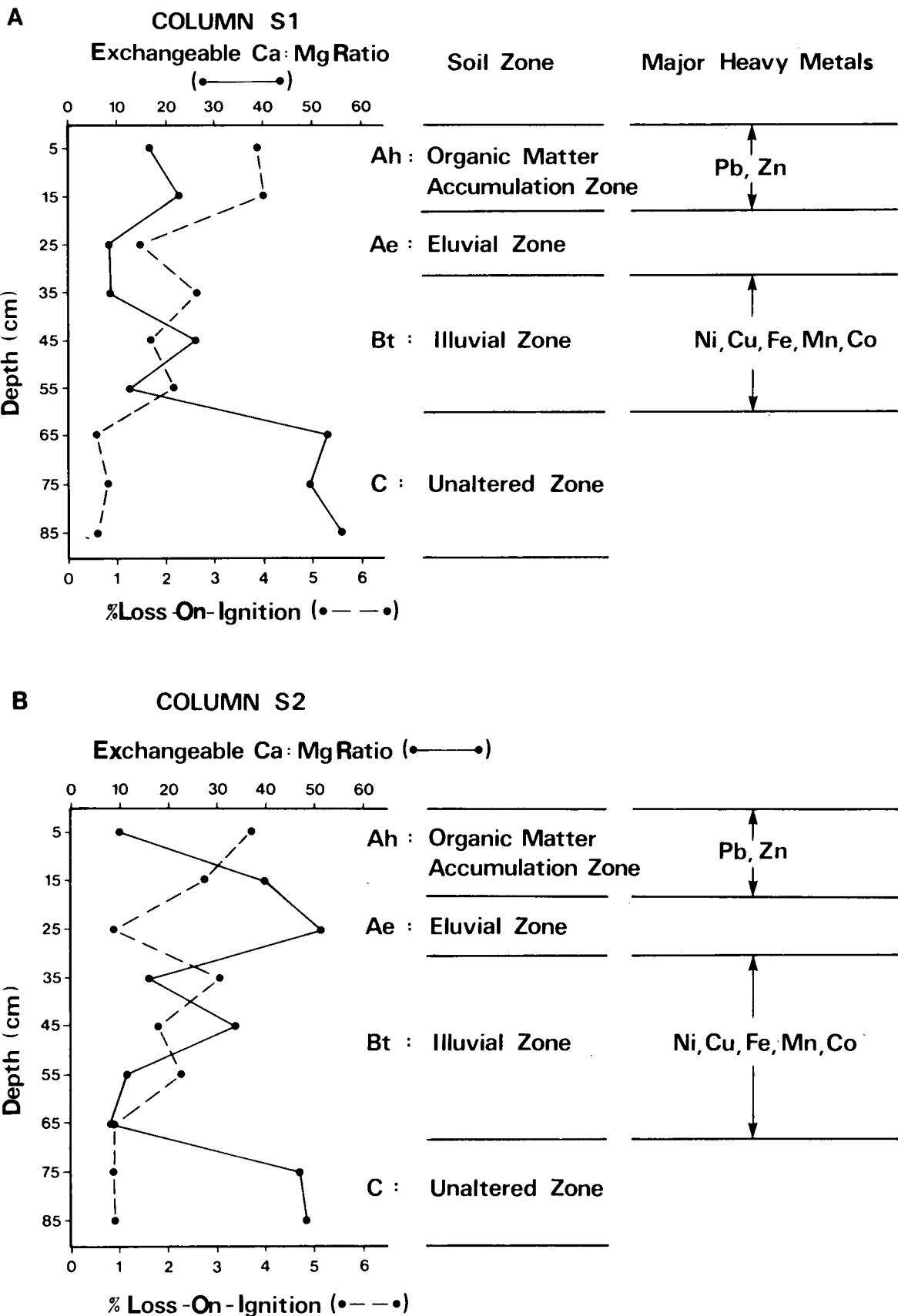


Figure 13. Distribution of heavy metals in Darlington loam soil profile prior to contamination.

Table 4. Heavy Metal Concentration for Uncontaminated Sediments from the Big Swamp Area

Sample code	Nickel (ppm)	Copper (ppm)	Zinc (ppm)	Lead (ppm)	Iron (%)	Manganese (ppm)	Cobalt (ppm)	Cadmium (ppm)
S1-1	5	4	43	7	1.6	568	5	<0.4
S1-2	5	<4	44	4	2.0	348	5	<0.4
S1-3	7	4	26	<4	1.8	504	6	<0.4
S1-4	12	10	29	<4	2.5	982	7	<0.4
S1-5	14	14	29	<4	2.2	528	7	<0.4
S1-6	15	14	33	<4	2.4	436	8	<0.4
S1-7	9	9	17	<4	1.3	364	5	<0.4
S1-8	6	9	19	<4	1.3	348	5	<0.4
S1-9	6	8	18	<4	1.2	340	4	<0.4
S1-10	7	10	17	<4	1.2	328	4	<0.4
S1-11	6	8	20	<4	1.2	344	4	<0.4
S1-12	6	7	19	<4	1.2	324	4	<0.4
S1-13	8	7	18	<4	1.2	324	5	<0.4
S1-14	6	8	18	<4	1.2	296	4	<0.4
S1-15	8	8	22	<4	1.3	324	6	<0.4
S2-1	13	8	50	6	2.2	576	7	<0.4
S2-2	18	13	47	4	2.8	702	8	<0.4
S2-3	9	9	20	<4	1.4	384	5	<0.4
S2-4	25	20	50	15	3.4	1324	11	<0.4
S2-5	14	10	26	<4	1.8	448	6	<0.4
S2-6	17	15	36	4	2.4	588	7	<0.4
S2-7	9	9	18	<4	1.3	360	5	<0.4
S2-8	8	9	17	<4	1.3	352	4	<0.4
S2-9	7	9	18	<4	1.3	344	5	<0.4
S2-10	4	10	18	<4	1.3	336	4	<0.4
S2-11	<4	10	18	<4	1.2	320	5	<0.4
S2-12	6	10	35	<4	1.2	332	4	<0.4
S2-13	5	21	18	<4	1.2	302	4	<0.4
S2-14	5	8	19	<4	1.3	320	5	<0.4
S2-15	4	8	18	<4	1.2	328	5	<0.4
S3-1-1	7	6	58	11	2.1	600	7	<0.4
S3-1-2	9	5	39	<4	2.3	432	10	<0.4
S3-1-3	10	6	31	<4	2.0	408	8	<0.4
S3-2-1	7	5	43	4	2.2	520	7	<0.4
S3-2-2	12	8	38	5	2.4	592	8	<0.4
S3-2-3	14	11	38	<4	2.4	560	8	<0.4
S3-3-1	12	9	39	7	2.4	608	8	<0.4
S3-3-2	19	16	53	6	2.9	684	9	<0.4
S3-3-3	15	13	39	4	2.5	616	8	<0.4
S3-4-1	7	5	42	5	2.0	452	8	<0.4
S3-4-2	9	5	28	4	1.9	396	6	<0.4
S3-4-3	8	6	30	4	1.9	600	8	<0.4
S3-5-1	8	6	48	6	2.0	504	7	<0.4
S3-5-2	8	<4	34	<4	1.7	500	7	<0.4
S3-5-3	10	7	34	6	2.0	640	8	<0.4
S4-1-1	11	5	50	6	2.2	440	6	<0.4
S4-1-2	7	<4	29	<4	1.8	428	6	<0.4
S4-1-3	8	<4	30	<4	2.0	544	8	<0.4
S4-2-1	6	<4	54	13	2.1	484	7	<0.4
S4-2-2	9	5	44	5	2.0	696	7	<0.4
S4-2-3	10	<4	28	<4	2.1	1360	9	<0.4
S4-3-1	6	<4	24	<4	1.6	876	6	<0.4
S4-3-2	13	10	46	<4	2.6	2360	10	<0.4
S4-3-3	17	12	42	<4	2.6	1124	8	<0.4
S4-4-1	7	5	44	7	2.0	420	6	<0.4
S4-4-2	6	<4	25	<4	1.9	404	7	<0.4
S4-4-3	8	5	23	<4	1.9	504	6	<0.4
S4-5-1	8	<4	45	7	2.1	424	5	<0.4
S4-5-2	7	<4	34	5	1.9	420	7	<0.4
S4-5-3	6	5	23	<4	1.8	644	6	<0.4

Table 4. Continued

Sample code	Nickel (ppm)	Copper (ppm)	Zinc (ppm)	Lead (ppm)	Iron (%)	Manganese (ppm)	Cobalt (ppm)	Cadmium (ppm)
S5-1-1	13	16	87	28	2.1	484	7	0.7
S5-1-2	13	11	69	14	2.2	268	6	<0.4
S5-1-3	11	7	47	4	2.3	284	10	<0.4
S5-2-1	11	15	76	26	2.0	416	6	0.7
S5-2-2	12	13	78	22	2.2	384	8	0.5
S5-2-3	14	10	67	10	2.6	316	10	<0.4
S5-3-1	11	16	85	26	2.3	440	8	0.6
S5-3-2	11	14	75	17	2.4	308	8	0.6
S5-3-3	12	11	70	18	2.4	400	8	0.6
S5-4-1	13	15	84	27	2.5	456	7	0.5
S5-4-2	13	15	79	23	2.5	436	8	0.6
S5-4-3	14	15	77	21	2.6	436	8	0.4
S5-5-1	12	18	87	27	2.5	556	8	0.7
S5-5-2	10	15	76	16	2.7	556	8	0.6
S5-5-3	11	14	77	18	2.6	604	9	0.5
S6-1-1	7	27	66	50	1.1	128	<4	1.0
S6-1-2	7	20	47	20	1.3	136	<4	0.7
S6-1-3	6	17	40	7	1.2	130	<4	0.6
S6-2-1	10	25	73	51	1.2	120	<4	1.1
S6-2-2	4	19	46	9	1.8	152	<4	0.5
S6-2-3	5	18	31	4	1.0	140	<4	0.5
S6-3-1	8	25	64	45	1.1	132	<4	0.9
S6-3-2	5	24	51	19	1.4	132	<4	0.9
S6-3-3	6	20	33	7	0.9	120	<4	0.6
S6-4-1	8	26	75	58	1.2	128	<4	1.1
S6-4-2	7	20	53	27	1.3	132	<4	0.9
S6-4-3	7	22	32	5	1.2	164	<4	0.6
S6-5-1	7	23	85	60	1.1	120	<4	1.1
S6-5-2	5	18	47	14	1.1	124	<4	0.9
S6-5-3	7	19	33	5	1.1	144	<4	0.6
S7-1-1	12	17	78	20	2.2	400	7	0.6
S7-1-2	12	14	63	15	2.1	352	7	<0.4
S7-1-3	13	14	70	17	2.1	368	7	0.4
S7-2-1	14	20	79	20	2.3	400	7	0.6
S7-2-2	11	17	76	20	2.2	392	7	0.5
S7-2-3	14	18	77	19	2.1	380	8	0.4
S7-3-1	15	24	83	19	2.3	364	8	0.6
S7-3-2	12	18	69	14	2.1	304	7	0.6
S7-3-3	13	21	81	19	2.2	376	7	0.6
S7-4-1	13	22	80	18	2.2	332	6	0.7
S7-4-2	12	20	80	21	2.2	364	7	0.5
S7-4-3	14	22	89	24	2.3	396	7	0.5
S7-5-1	12	20	86	26	2.3	396	9	0.7
S7-5-2	12	20	84	24	2.4	360	8	0.4
S7-5-3	13	24	86	19	2.4	380	8	0.6
S8-1-1	6	17	66	23	2.0	536	4	0.5
S8-1-2	6	14	53	15	1.6	400	<4	0.4
S8-1-3	6	14	53	14	1.6	504	4	0.4
S8-2-1	5	15	57	20	1.7	468	4	0.6
S8-2-2	6	15	58	19	2.0	516	4	0.6
S8-2-3	4	14	54	16	1.8	432	4	0.6
S8-3-1	5	15	61	20	1.9	500	<4	0.6
S8-3-2	5	14	51	15	1.8	436	5	0.5
S8-3-3	6	15	59	19	1.9	540	<4	0.6
S8-4-1	6	16	64	20	2.1	524	4	0.7
S8-4-2	5	15	61	18	1.9	460	<4	0.7
S8-4-3	4	10	47	11	1.5	324	4	0.5
S8-5-1	6	19	66	20	2.1	528	4	0.7
S8-5-2	5	14	58	19	1.9	444	4	0.6
S8-5-3	5	<4	30	<4	1.5	172	5	<0.4

Table 5. Exchangeable Major Cation Concentration Values on Uncontaminated Sediments from the Big Swamp Area

Sample code	Ca (%)	Ca (meq)	Mg (ppm)	Mg (meq)	Na (ppm)	Na (meq)	K (ppm)	K (meq)
S1-1	0.17	8.5	60	0.49	50	0.22	75	0.19
S1-2	0.15	7.5	40	0.33	50	0.22	70	0.18
S1-3	0.13	6.5	95	0.78	<50	<0.22	55	0.14
S1-4	0.17	8.5	120	0.99	<50	<0.22	60	0.15
S1-5	0.55	27.4	130	1.07	<50	<0.22	75	0.19
S1-6	0.21	10.5	95	0.78	<50	<0.22	75	0.19
S1-7	1.70	84.8	195	1.60	<50	<0.22	40	0.10
S1-8	1.65	82.3	200	1.65	<50	<0.22	45	0.12
S1-9	1.68	83.8	185	1.52	<50	<0.22	60	0.15
S2-1	0.27	13.5	160	1.32	<50	<0.22	65	0.17
S2-2	0.94	46.9	145	1.19	<50	0.22	75	0.19
S2-3	1.70	84.8	200	1.65	75	0.33	105	0.27
S2-4	0.49	24.5	185	1.52	<50	<0.22	110	0.28
S2-5	0.98	48.9	175	1.44	60	0.26	115	0.29
S2-6	0.29	14.5	150	1.23	<50	0.22	95	0.24
S2-7	0.31	15.5	220	1.81	100	0.44	90	0.23
S2-8	1.60	79.8	205	1.69	50	0.22	85	0.22
S2-9	1.73	86.3	215	1.77	<50	<0.22	80	0.20
S3-1-1	0.15	7.5	100	0.82	<50	<0.22	70	0.18
S3-1-2	0.13	6.5	60	0.49	<50	<0.22	40	0.10
S3-1-3	0.09	4.5	15	0.12	95	0.41	120	0.31
S3-2-1	0.11	5.5	70	0.58	100	0.44	135	0.35
S3-2-2	0.15	7.5	95	0.78	115	0.50	140	0.36
S3-2-3	0.17	8.5	100	0.82	<50	0.22	90	0.23
S3-3-1	0.17	8.5	105	0.86	105	0.46	130	0.33
S3-3-2	0.27	13.4	130	1.07	<50	<0.22	85	0.22
S3-3-3	0.63	31.4	140	1.15	<50	<0.22	105	0.27
S3-4-1	0.21	10.5	65	0.53	<50	<0.22	30	0.08
S3-4-2	0.11	5.5	25	0.21	<50	<0.22	40	0.10
S3-4-3	0.11	5.5	65	0.53	<50	<0.22	25	0.06
S3-5-1	0.15	7.5	90	0.74	<50	<0.22	40	0.10
S3-5-2	0.09	4.5	30	0.25	<50	<0.22	15	0.04
S3-5-3	0.13	6.5	40	0.33	<50	<0.22	45	0.12
S4-1-1	0.23	11.5	50	0.41	<50	<0.22	30	0.08
S4-1-2	0.09	4.5	80	0.66	<50	<0.22	25	0.06
S4-1-3	0.17	8.5	46	0.38	<50	<0.22	30	0.08
S4-2-1	0.17	8.5	75	0.62	50	0.22	70	0.18
S4-2-2	0.13	6.5	55	0.45	60	0.26	100	0.26
S4-2-3	0.11	5.5	30	0.25	<50	<0.22	40	0.10
S4-3-1	0.11	5.5	35	0.29	<50	<0.22	40	0.10
S4-3-2	0.19	9.5	90	0.74	<50	<0.22	70	0.18
S4-3-3	0.27	13.5	115	0.95	<50	<0.22	65	0.17
S4-4-1	0.15	7.5	45	0.37	<50	<0.22	40	0.10
S4-4-2	0.07	3.5	15	0.12	<50	<0.22	20	0.05
S4-4-3	0.13	6.5	66	0.54	<50	<0.22	50	0.13
S4-5-1	0.15	7.5	62	0.51	<50	<0.22	40	0.10
S4-5-2	0.09	4.5	10	0.08	<50	<0.22	20	0.05
S4-5-3	0.09	4.5	34	0.28	<50	<0.22	25	0.06
S5-1-1	1.30	64.9	720	5.92	<50	<0.22	110	0.28
S5-1-2	0.99	49.4	630	5.18	<50	<0.22	90	0.23
S5-1-3	0.31	15.5	240	1.97	<50	<0.22	30	0.08
S5-2-1	1.30	64.9	780	6.42	<50	<0.22	105	0.27
S5-2-2	1.00	49.9	630	5.18	<50	<0.22	95	0.24
S5-2-3	0.46	23.0	330	2.71	<50	<0.22	50	0.13
S5-3-1	1.22	60.9	780	6.42	<50	<0.22	100	0.26
S5-3-2	—	—	—	—	—	—	—	—
S5-3-3	7.70	384.2	490	4.03	<50	<0.22	65	0.17
S5-4-1	1.40	69.9	870	7.16	<50	<0.22	155	0.40
S5-4-2	1.18	58.9	770	6.33	<50	<0.22	90	0.23
S5-4-3	1.22	60.9	770	6.33	60	0.26	130	0.33

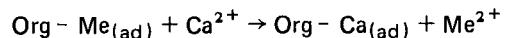
Table 5. Continued

Sample code	Ca (%)	Ca (meq)	Mg (ppm)	Mg (meq)	Na (ppm)	Na (meq)	K (ppm)	K (meq)
S5-5-1	1.35	67.4	830	6.83	<50	<0.22	110	0.28
S5-5-2	1.12	55.9	750	6.17	<50	<0.22	90	0.23
S5-5-3	1.14	56.9	710	5.84	50	0.22	85	0.22
S6-1-1	2.55	127.2	770	6.33	50	0.22	240	0.61
S6-1-2	2.75	137.2	840	6.91	55	0.24	180	0.46
S6-1-3	2.53	126.2	780	6.42	55	0.24	135	0.35
S6-2-1	2.65	132.2	790	6.50	<50	<0.22	225	0.58
S6-2-2	2.75	137.2	840	6.91	<50	<0.22	135	0.35
S6-2-3	3.00	149.7	900	7.40	<50	<0.22	105	0.27
S6-3-1	2.45	122.3	770	6.33	50	0.22	240	0.61
S6-3-2	2.85	142.2	850	6.99	<50	<0.22	265	0.68
S6-3-3	2.92	145.7	890	7.32	50	0.22	120	0.31
S6-4-1	2.55	127.2	780	6.42	<50	<0.22	205	0.52
S6-4-2	2.60	129.7	780	6.42	60	0.26	210	0.54
S6-4-3	2.92	145.7	900	7.40	50	0.22	105	0.27
S6-5-1	2.60	129.7	750	6.17	<50	<0.22	220	0.56
S6-5-2	2.40	119.8	720	5.92	<50	<0.22	130	0.33
S6-5-3	2.85	142.2	870	7.16	<50	<0.22	80	0.20
S7-1-1	0.85	42.4	440	3.62	<50	<0.22	85	0.22
S7-1-2	0.82	40.9	440	3.62	<50	<0.22	80	0.20
S7-1-3	0.76	37.9	420	3.45	<50	<0.22	70	0.18
S7-2-1	0.95	47.4	470	3.87	<50	<0.22	105	0.27
S7-2-2	0.95	47.4	470	3.87	<50	<0.22	105	0.27
S7-2-3	1.10	54.9	500	4.11	<50	<0.22	100	0.26
S7-3-1	1.05	52.4	570	4.69	<50	<0.22	110	0.28
S7-3-2	0.86	42.9	460	3.78	<50	<0.22	100	0.26
S7-3-3	0.98	48.9	570	4.69	<50	<0.22	95	0.24
S7-4-1	1.15	57.4	580	4.77	<50	<0.22	120	0.31
S7-4-2	1.30	64.9	620	5.10	<50	<0.22	95	0.24
S7-4-3	0.95	47.4	530	4.36	<50	<0.22	85	0.22
S7-5-1	1.00	49.9	480	3.95	<50	<0.22	85	0.22
S7-5-2	0.90	44.9	450	3.70	<50	<0.22	70	0.18
S7-5-3	0.95	47.4	490	4.03	<50	<0.22	95	0.24
S8-1-1	1.40	69.9	540	4.44	<50	<0.22	80	0.20
S8-1-2	1.75	87.3	770	6.33	<50	<0.22	95	0.24
S8-1-3	1.70	84.3	690	5.68	<50	<0.22	80	0.20
S8-2-1	1.65	82.3	630	5.18	<50	<0.22	80	0.20
S8-2-2	1.77	88.3	750	6.17	<50	<0.22	100	0.26
S8-2-3	1.61	80.3	710	5.84	<50	<0.22	80	0.20
S8-3-1	1.77	88.3	750	6.17	<50	<0.22	120	0.31
S8-3-2	1.67	83.3	750	6.17	<50	<0.22	100	0.26
S8-3-3	1.77	88.3	750	6.17	<50	<0.22	100	0.26
S8-4-1	1.72	85.8	690	5.68	<50	<0.22	100	0.26
S8-4-2	1.67	83.3	660	5.43	<50	<0.22	100	0.26
S8-4-3	1.32	65.9	500	4.11	<50	<0.22	65	0.17
S8-5-1	—	—	—	—	—	—	—	—
S8-5-2	—	—	—	—	—	—	—	—
S8-5-3	<0.05	<0.005	30	0.25	<50	<0.22	5	0.01

are apparent with depth. In contrast, within each section of organic sediment in column S6 there is generally a decrease in metal concentration with depth. Average iron and manganese concentrations are also lower in column S6 than in columns S5, S7 and S8. Comparison of hydraulic conductivity (Appendix A), L.O.I. (Table 3) and Pyrophosphate Index (Appendix C) values indicates that the iron and manganese concentrations are related to the degree of

organic matter decomposition and the local physiographic environment. The relatively low iron and manganese concentrations in column S6 are associated with high L.O.I. and hydraulic conductivity values and a high degree of decomposition (sapric material). In contrast, the organic sediments rich in iron and manganese have lower L.O.I. and hydraulic conductivity values and an intermediate degree of decomposition (sapric/hemic material). Observations

made in the field indicate that seasonal flooding is more persistent within the areas where sediments deficient in iron and manganese are present [columns S6 and S8 (?)] than in places where sediments rich in iron and manganese (columns S5 and S7) are found. Increased contact between the organic sediments and ground water, exchange processes and organic complex formation may account for the deficiency of heavy metals in the more frequently flooded areas. The exchange reaction likely taking place, as deduced from exchangeable cation and heavy metal data, can be summarized as follows:



where $\text{Org - Me}_{(\text{ad})}$ = the adsorbed heavy metal-organic matter complex,
 Ca^{2+} = the major exchanging cation in the ground water system,
 $\text{Org - Ca}_{(\text{ad})}$ = the adsorbed major cation-organic matter complex, and
 Me^{2+} = the dissociated "free" heavy metal cation (e.g. Fe, Mn).

The "free" heavy metal cation likely becomes complexed by soluble organics and is transported in the ground waters from the organic horizon. A similar process or the sapric nature of the organic-rich sediments may account for the lower values of copper, lead, zinc and cadmium (?) in sediments deficient in iron and manganese.

Ground Water Quality

The results of chemical analyses of ground water samples collected on August 3, September 20 and October 19, 1977, from the piezometers installed at the study site are listed in Table 6. On August 3, 1977, only 14 of the wells could be sampled, but in September and October, all 24 piezometers were available for sampling. The high calcium and bicarbonate and relatively high magnesium con-

centrations in the ground waters reflect the presence of calcite and dolomite in the detrital fraction of the organic soils and clay and clay till units beneath the organic materials. Calculations of solubility indices indicate that the ground water is supersaturated with respect to calcite and also saturated with respect to dolomite (Appendix B). High values for ammonium (NH_4^+) and biological oxygen demand (BOD) and low concentrations of nitrate plus nitrite ($\text{NO}_3^- + \text{NO}_2^-$) may be attributed to the decay of organic materials in an environment low in oxygen.

Iron and manganese concentrations in the filtered ($0.45 \mu\text{m}$) samples generally fall in the ranges from 2 to 7 mg/L and 0.1 to 0.4 mg/L, respectively. The concentrations of these metals in the sediments, especially the organics, are relatively high (Table 5). Studies on peat deposits by Casagrande and Erchull (1976, 1977) have shown that plant material may contain significant quantities of metals such as iron and manganese and that metal concentrations in a given sample are related to the type of plant materials which produced the peat. In other studies, selective extraction techniques have been employed to identify the fractions of organic matter that contain the heavy metals (e.g., Szalay and Szilagyi, 1968; Szalay, 1973; Rashid, 1974; Senesi *et al.*, 1977; Green and Manahan, 1977; Cheshire *et al.*, 1977). Significant quantities of iron and manganese may be mobilized by the decay of accumulated plant material (Levanidov, 1957; Crerar *et al.*, 1972). Following release, the metals probably form organo-metallic complexes with available humic acid, fulvic acid and humin moieties. Research by Crerar *et al.* (1972), Picard and Felbeck (1976), Reuter and Perdue (1977) and Davis and Leckie (1978) suggests that the stabilities of metal-humic complexes in natural waters are higher than those of the corresponding inorganic metal complexes. The authors conclude from these observations that the iron and manganese measured in the Big Swamp ground water were derived

Table 6a. Chemical Analyses of Big Swamp Ground Water Samples, August 3, 1977

Observation well	NH_3 (mg/L)	$\text{NO}_3^- + \text{NO}_2^-$ (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)
1	1.0	0.2	100	17	8.3	1.7	0.8
2	1.0	0.6	53	27	4.0	3.2	0.7
3	1.0	0.3	86	20	7.8	1.6	0.6
4	1.1	0.4	100	20	7.5	2.0	0.7
5	1.3	0.5	56	29	5.0	2.9	<0.5
6	1.4	0.3	105	17	6.5	2.0	0.6
7	0.8	0.2	77	17	4.5	2.7	<0.5
8	0.7	0.4	103	19	6.3	1.7	<0.5
9	1.2	0.3	105	19	6.3	1.7	<0.5
10	1.2	0.5	89	13	5.5	1.6	<0.5
11	0.9	0.4	107	21	7.3	13.6	<0.5
12	1.1	0.5	85	13	5.0	9.6	<0.5
13	0.8	0.8	93	21	10.5	15.2	<0.5
14	1.1	0.4	155	24	6.5	16.0	<0.5

Table 6b. Chemical Analyses of Big Swamp Ground Water Samples, September 20, 1977

Parameter	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)	Fe (mg/L)	Mn (mg/L)	pH
Observation well								
1	119	17	7.5	6.2	0.5	7.8	0.16	7.5
2	130	34	3.8	11.6	0.5	4.4	0.27	7.6
3	102	22	7.0	7.2	0.5	1.6	0.16	7.5
4	135	23	6.5	6.4	0.5	3.2	0.29	7.6
5	198	42	4.5	10.6	0.5	3.9	0.46	7.9
6	136	19	5.8	7.8	0.5	6.1	0.32	7.8
7	115	18	3.8	9.0	0.5	3.6	0.35	7.8
8	—	—	—	—	—	—	—	—
9	126	16	7.0	7.0	0.5	5.7	0.46	7.9
10	93	15	4.5	5.0	0.5	4.1	0.34	7.5
11	143	22	6.5	7.8	0.5	4.7	0.32	7.6
12	162	21	3.5	6.8	0.5	3.0	0.52	7.7
13	177	25	5.0	4.2	0.5	4.1	0.37	7.9
14	110	24	11.0	33.0	0.5	3.4	0.23	7.4
15	192	25	5.8	6.4	0.5	11.4	0.41	7.4
16	560	34	4.3	7.8	0.5	7.1	1.22	7.8
17	109	15	2.8	3.6	0.5	4.0	0.19	7.6
18	152	16	5.8	5.4	0.5	5.9	0.25	7.6
19	69	16	9.8	5.4	0.5	1.7	0.10	7.6
20	106	20	5.3	7.2	0.5	2.5	0.08	7.5
21	50	19	8.8	6.0	0.5	1.3	0.12	7.6
22	715	44	5.0	10.6	2.0	0.4	1.30	7.7
23	168	20	6.3	10.0	0.5	5.3	0.28	7.6
24	720	23	8.3	15.0	0.5	3.1	1.26	7.6
Parameter	Hardness (mg/L CaCO ₃)	Alkalinity (mg/L HCO ₃)	Conductivity (μS/cm)	NH ₃ (mg/L)	NO ₃ + NO ₂ (mg/L)	BOD ₅ (mg/L)	SO ₄ (mg/L)	Cl (mg/L)
Observation well								
1	328	368	600	3.2	0.14	<4	13	16
2	238	256	430	1.6	0.20	10	21	5
3	324	371	580	1.9	0.16	<4	15	7
4	310	354	570	1.9	0.20	10	14	8
5	254	295	460	2.5	0.14	20	24	7
6	356	410	630	2.1	0.74	15	5	10
7	266	290	475	2.9	0.40	22	15	6
8	—	—	—	—	—	—	—	—
9	336	385	620	8.0	0.22	8	15	11
10	284	317	510	1.9	0.14	11	13	8
11	260	290	490	2.1	0.22	10	20	7
12	220	244	415	6.6	0.22	>24	14	8
13	224	244	420	3.0	0.26	21	18	8
14	336	512	920	69.6	0.02	95	10	13
15	388	419	690	8.5	0.16	26	32	9
16	262	322	510	4.6	0.14	26	18	4
17	292	312	520	9.5	0.04	>24	17	5
18	364	290	630	7.9	0.10	31	18	8
19	238	293	490	4.4	0.04	19	7	12
20	372	417	730	2.0	0.10	<8	21	8
21	278	315	550	4.0	0.44	>24	17	10
22	202	290	475	7.4	0.18	>24	6	5
23	560	466	760	12.0	0.06	63	12	14
24	254	334	580	4.2	0.06	21	11	15

Table 6c. Chemical Analyses of Big Swamp Ground Water Samples, October 19, 1977

Parameter	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)	Fe (mg/L)	Mn (mg/L)	pH
Observation well								
1	105	16	6.5	5.8	0.5	9.0	0.10	7.9
2	47	25	2.5	8.6	—	1.2	0.05	7.9
3	85	21	6.3	6.0	0.5	2.1	0.14	7.8
4	90	20	6.5	7.0	—	2.6	0.16	7.9
5	52	29	3.8	9.2	—	1.4	0.07	8.0
6	103	16	5.0	6.8	0.5	7.4	0.24	8.0
7	71	16	3.5	8.4	—	1.5	0.14	7.9
8	—	—	—	—	—	—	—	—
9	97	13	7.3	6.6	0.5	2.9	0.30	8.0
10	82	13	4.8	6.1	—	1.8	0.28	8.0
11	74	15	6.3	6.1	0.5	2.4	0.15	8.0
12	63	11	3.0	5.6	—	0.9	0.13	7.6
13	63	13	5.0	4.0	<0.5	2.6	0.13	7.8
14	80	16	8.3	7.6	—	4.1	0.16	—
15	106	16	5.3	5.4	0.5	6.8	0.16	7.4
16	69	16	4.0	3.8	—	1.4	0.14	7.8
17	85	12	2.8	3.2	<0.5	3.8	0.14	7.4
18	107	11	5.3	4.6	—	8.8	0.20	7.5
19	60	17	10.0	8.4	0.5	3.8	0.09	7.6
20	111	20	5.3	6.8	—	6.8	0.09	7.7
21	72	19	9.0	6.8	<0.5	2.3	0.07	7.8
22	38	34	5.3	7.8	—	1.6	0.12	8.1
23	119	13	5.3	6.2	0.5	6.9	0.18	7.8
24	94	16	7.0	5.4	0.5	3.5	0.09	7.8
Parameter	Hardness (mg/L CaCO ₃)	Alkalinity (mg/L HCO ₃)	Conductivity (μS/cm)	NH ₃ (mg/L)	NO ₃ + NO ₂ (mg/L)	BOD ₅ (mg/L)	SO ₄ (mg/L)	Cl (mg/L)
Observation well								
1	336	410	640	1.3	0.04	<2	17	15
2	236	268	430	1.2	0.10	<2	19	5
3	320	380	580	1.7	0.22	<2	13	8
4	322	390	600	1.5	0.04	2	10	9
5	254	299	470	1.2	0.04	2	20	4
6	344	430	640	1.8	0.46	2	9	11
7	260	305	475	1.0	0.20	3	16	5
8	—	—	—	—	—	—	—	—
9	322	390	600	2.2	0.26	<2	12	9
10	270	334	510	1.8	0.30	<2	6	4
11	268	317	495	1.4	0.08	<2	18	4
12	216	249	400	3.0	0.80	15	12	4
13	224	256	420	0.9	0.66	2	17	5
14	—	—	—	27.5	—	—	11	—
15	356	419	660	3.0	0.02	15	23	9
16	252	295	465	2.1	<0.18	22	18	5
17	270	315	495	3.6	<0.02	28	22	3
18	332	366	600	5.6	<0.02	25	10	5
19	234	278	450	1.6	<0.02	5	7	5
20	344	349	700	3.4	0.06	>6	9	5
21	270	298	520	5.2	0.04	30	16	8
22	236	273	430	2.5	<0.02	30	9	5
23	368	402	680	3.8	0.04	34	10	9
24	322	334	600	1.7	0.06	2	18	8

Table 7. Water Quality Data from Leachate Attenuation Experiments

SAMPLE	HCU3	Mg	Na	Ca	K	Fe	Mn	CL	NO3	NH4	SO4	PO4	LITRE	CATSUM	ANISUM	CHABAL	
-----MEQ/LITRE-----																	
3UC125	2.04	0.00	0.00	0.00	0.00	0.34	0.00	2.62	0.00	0.04	0.13	0.00	1	0.388	4.789	*****	
3UC126	0.00	0.06	0.39	21.46	0.23	0.01	0.00	0.00	0.00	0.01	0.17	0.00	26.158	0.170	98.710		
3UC131	9.99	2.06	4.35	12.97	0.03	0.02	0.00	1.84	0.00	0.28	0.46	0.01	3	19.709	23.296	-8.342	
3UVU01	11.91	7.24	0.53	13.47	0.03	0.01	0.00	2.55	0.01	0.01	0.23	0.00	4	27.286	24.701	-4.971	
3UVU15	9.95	1.81	0.61	12.48	0.03	0.01	0.01	1.69	0.07	0.02	0.06	0.00	5	21.962	22.807	-1.886	
3UVU16	12.39	1.04	0.44	10.98	0.03	0.06	0.02	1.13	0.13	0.03	0.04	0.00	6	23.949	22.4716	-1.575	
3UVU17	13.43	2.30	0.35	15.97	0.05	0.02	0.03	1.85	0.03	0.31	0.08	0.00	7	28.031	25.396	4.932	
3UVU18	11.83	2.47	0.57	16.47	0.05	0.03	0.03	1.57	0.00	0.03	0.04	0.00	8	28.649	23.440	10.000	
3UVU27	15.910	2.30	0.57	15.47	0.08	0.01	0.04	0.01	1.72	0.00	0.02	0.00	10	27.673	27.857	-0.331	
3UVU28	16.317	2.14	0.14	13.72	0.13	0.04	0.05	1.57	0.02	0.03	0.15	0.00	11	23.128	10.848	36.144	
3UVU29	15.600	2.30	0.79	14.97	0.13	0.04	0.04	0.11	1.85	0.00	0.17	0.00	13	25.244	28.044	-5.254	
3UVU30	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	14	27.990	27.515	0.856	
3UVU31	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	15	27.687	0.000	*****	
3UVU32	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	16	25.913	0.000	*****	
3UVU33	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	17	14.040	0.000	*****	
3UVU34	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	18	15.765	0.000	*****	
3UVU35	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	19	16.381	0.000	*****	
3UVU36	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	20	17.932	0.000	*****	
3UVU37	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	21	14.673	0.000	*****	
3UVU38	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	22	15.867	0.000	*****	
3UVU39	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	23	16.465	0.000	*****	
3UVU40	0.000	0.000	0.000	0.000	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.00	24	18.478	0.000	*****	
4UVU120	1.00	0.49	0.17	4.24	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	25	17.527	0.000	*****	
4UVU131	1.208	1.32	0.48	8.98	0.03	0.03	0.02	0.01	12.41	0.00	0.04	0.19	0.00	26	14.957	31.154	*****
4UVU132	3.084	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27	10.827	16.460	-9.671	
4UVU133	3.085	1.15	0.53	6.74	0.03	0.09	0.09	1.41	0.08	0.00	0.14	0.21	28	10.827	16.460	-9.671	
4UVU134	4.048	1.65	0.48	8.98	0.03	0.00	0.00	0.00	1.13	0.00	0.00	0.17	0.00	29	14.884	15.696	-2.658
4UVU135	7.033	1.73	0.57	9.98	0.15	0.00	0.05	12.13	0.00	0.08	0.08	0.00	30	19.256	16.831	-6.722	
4UVU136	9.433	0.82	1.27	9.98	0.13	0.01	0.01	0.05	12.13	0.00	0.08	0.08	0.00	31	21.572	19.380	-5.353
4UVU137	12.663	1.81	1.35	10.98	0.05	0.01	0.04	1.41	0.00	0.02	0.06	0.00	32	21.573	21.755	-1.121	
4UVU138	15.51	2.14	1.14	12.72	0.13	0.04	0.05	1.85	0.00	0.17	0.15	0.00	33	22.025	25.149	-6.096	
4UVU139	15.67	1.97	0.70	12.23	0.13	0.04	0.09	1.28	0.02	0.19	0.10	0.00	34	25.382	27.507	-4.019	
4UVU140	16.47	2.71	0.79	14.22	0.13	0.04	0.11	1.57	0.11	0.06	0.10	0.00	35	24.054	27.074	-5.323	
4UVU141	13.51	3.13	1.035	13.97	0.13	0.04	0.07	1.26	0.03	0.24	0.00	0.00	36	27.926	22.251	-2.164	
4UVU142	13.51	3.13	0.83	13.47	0.13	0.04	0.06	1.85	0.03	0.47	0.00	0.00	37	26.119	24.457	6.621	
4UVU143	15.23	3.21	11.01	12.97	0.13	0.04	0.05	1.26	0.05	0.53	0.00	0.00	38	27.929	26.559	2.513	
4UVU144	0.000	3.23	0.00	8.23	0.05	0.04	0.11	0.00	0.00	0.00	0.00	0.00	39	11.662	0.000	*****	
4UVU145	0.000	3.96	0.00	13.47	0.08	0.04	0.25	0.00	0.00	0.00	0.00	0.00	40	17.798	0.000	*****	
4UVU146	0.000	3.77	0.00	11.98	0.03	0.04	0.17	0.00	0.00	0.00	0.00	0.00	41	15.980	0.000	*****	
4UVU147	0.000	3.77	0.00	11.48	0.10	0.04	0.15	0.00	0.00	0.00	0.00	0.00	42	15.349	0.000	*****	
4UVU148	0.000	3.13	0.00	8.73	0.05	0.04	0.06	0.00	0.00	0.00	0.00	0.00	43	12.012	0.000	*****	
4UVU149	0.000	3.28	0.00	9.73	0.05	0.04	0.08	0.00	0.00	0.00	0.00	0.00	44	13.176	0.000	*****	
4UVU150	0.000	3.77	0.00	11.48	0.13	0.04	0.07	0.00	0.00	0.00	0.00	0.00	45	15.477	0.000	*****	
4UVU151	0.000	3.66	0.00	11.73	0.10	0.04	0.07	0.00	0.00	0.00	0.00	0.00	46	15.594	0.000	*****	
4UVU152	0.000	3.77	0.00	11.48	0.10	0.04	0.07	0.00	0.00	0.00	0.00	0.00	47	15.455	0.000	*****	

Table 7. Continued

SAMPLE	HCO ₃	Mg	Na	Ca	K	F _t	Mn	Cl	NO ₃	NH ₄	SO ₄	PO ₄	LITRE	CATSUM	ANISUM	CHABAL
MEQ/LITRE																
52	0.84	2.96	0.90	10.58	0.16	0.09	0.00	0.73	0.02	0.09	1.88	0.00	1	14.789	3.472	61.978
22	3.45	0.87	20.96	0.10	0.01	0.01	0.06	0.18	0.06	0.14	1.08	0.00	23	26.548	21.437	10.649
21	4.21	3.45	16.47	0.15	0.01	0.06	0.06	0.17	0.06	0.05	1.04	0.01	24	24.004	25.868	-2.338
11	5.17	0.00	21.46	0.23	0.21	0.13	0.11	1.07	0.09	0.45	2.93	0.01	25	32.472	33.235	-1.538
21	4.20	5.17	0.96	9.23	0.38	0.16	0.09	1.85	0.09	0.00	0.25	0.01	26	32.422	32.049	0.106
21	4.20	0.00	17.96	0.41	0.10	0.10	0.10	1.57	0.09	0.00	0.25	0.01	27	31.518	31.430	***
11	4.20	3.6	0.40	17.47	0.28	0.10	0.09	1.57	0.09	0.00	0.25	0.01	28	31.434	33.258	-5.510
21	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	29	31.864	30.389	-6.929
21	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	30	31.804	30.389	-2.856
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	31	28.586	30.389	-5.061
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	32	29.633	31.527	-1.343
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	33	29.258	30.180	-5.907
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	34	25.884	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	35	26.924	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	36	22.947	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	37	23.254	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	38	25.413	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	39	23.725	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	40	22.193	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	41	20.603	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	42	20.247	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	43	9.680	14.565	14.565
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	44	21.474	18.736	8.941
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	45	18.864	22.172	3.545
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	46	23.123	22.134	2.768
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	47	23.067	21.162	2.761
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	48	21.711	22.543	3.389
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	49	22.386	22.075	3.490
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	50	21.574	21.330	1.483
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	51	21.330	22.3840	4.962
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	52	22.460	22.3621	0.225
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	53	23.172	24.126	0.095
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	54	24.173	24.665	2.462
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	55	13.542	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	56	14.088	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	57	13.128	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	58	13.769	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	59	12.903	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	60	14.036	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	61	14.768	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	62	15.079	0.000	*****
11	4.20	0.00	18.46	0.46	0.09	0.09	0.09	1.41	0.09	0.00	0.25	0.01	63	14.899	0.000	*****

Table 7. Continued

SAMPLE	HCO ₃	Mg	Na	Ca	K	F _L	Mn	Cl	NO ₃	NH ₄	SO ₄	PO ₄	LITRE	CATSUM	ANISUM	CHABAL	
	MEQ/LITRE													MEQ/LITRE			
ZNUV125	12.23	2.47	0.35	9.88	0.28	0.01	0.00	2.06	0.01	0.08	1.04	0.00	1	13.069	15.347	-8.016	
ZNUV126	12.31	2.88	1.22	21.96	0.13	0.01	0.03	7.90	0.07	0.08	0.25	0.00	26.305	20.528	12.336		
ZNUV131	16.39	3.04	1.44	14.97	0.10	0.09	0.09	0.04	0.11	0.10	0.29	0.01	19.830	24.727	***★★★		
ZNUV01	17.01	3.70	1.87	18.96	0.13	0.08	0.10	0.73	0.11	0.03	0.27	0.01	25.865	27.127	-2.382		
ZNUV115	23.90	5.02	3.96	25.95	0.26	0.04	0.17	10.72	0.11	0.39	0.27	0.01	35.697	34.930	1.086		
ZNUV116	21.42	4.28	5.44	22.95	0.26	0.38	0.15	11.28	0.11	0.25	0.25	0.00	33.842	33.072	1.151		
ZNUV117	20.30	4.03	5.07	20.46	0.28	0.03	0.12	12.13	0.03	0.29	0.29	0.01	31.146	30.193	-2.528		
ZNUV118	19.98	4.09	5.31	20.46	0.28	0.12	0.14	12.00	0.06	0.23	0.23	0.01	28.204	30.193	16.600		
ZNUV119	20.54	4.89	6.18	19.46	0.23	0.08	0.12	12.13	0.06	0.40	0.17	0.00	29.412	32.858	-5.535		
ZNUV120	19.82	4.29	6.19	17.96	0.33	0.01	0.12	12.57	0.10	0.36	0.25	0.00	29.000	32.218	-5.252		
ZNUV125	19.02	3.37	7.31	17.96	0.33	0.39	0.12	11.28	0.05	0.33	0.21	0.00	29.866	30.891	-1.687		
ZNUV126	20.62	3.21	6.05	17.96	0.33	0.25	0.12	11.28	0.11	0.37	0.25	0.00	30.277	32.166	-3.033		
ZNUV127	19.66	2.96	9.95	18.21	0.26	0.04	0.12	11.85	0.08	0.49	0.00	0.00	30.351	31.313	-1.559		
ZDEC06	21.10	3.29	9.55	18.21	0.26	0.04	0.12	11.85	0.08	0.54	0.00	0.00	32.689	33.031	-0.520		
ZDEC07	20.38	3.13	11.09	16.97	0.59	0.04	0.11	12.69	0.10	0.40	0.00	0.00	32.442	31.805	0.991		
ZDEC08	19.74	2.88	10.40	15.97	0.59	0.04	0.12	12.69	0.10	0.40	0.00	0.00	28.476	31.438	-6.503		
ZJAN17	0.00	4.36	0.00	20.21	0.54	0.14	0.14	0.00	0.00	0.00	0.00	0.00	25.389	0.000	*****		
ZJAN19	0.00	4.49	0.00	20.21	0.54	0.11	0.16	0.00	0.00	0.00	0.00	0.00	26.759	0.000	*****		
ZJAN20	0.00	4.18	0.00	19.71	0.84	0.04	0.13	0.00	0.00	0.00	0.00	0.00	24.890	0.000	*****		
ZJAN21	0.00	3.80	0.00	18.46	0.84	0.07	0.13	0.00	0.00	0.00	0.00	0.00	23.574	0.000	*****		
ZFEB09	0.00	4.24	0.00	19.21	0.89	0.11	0.12	0.00	0.00	0.00	0.00	0.00	24.500	0.000	*****		
ZFEB10	0.00	4.03	0.00	19.71	1.05	0.07	0.14	0.00	0.00	0.00	0.00	0.00	25.693	0.000	*****		
ZFEB11	0.00	3.73	0.00	18.71	1.05	0.11	0.09	0.00	0.00	0.00	0.00	0.00	22.009	0.000	*****		
ZFEB12	0.00	3.50	0.00	17.22	1.13	0.05	0.11	0.00	0.00	0.00	0.00	0.00	22.099	0.000	*****		
ZFEB13	0.00	3.34	0.00	16.47	1.13	0.05	0.11	0.00	0.01	0.08	0.50	0.00	12.743	10.897	*****		
ZUC125	12.23	1.97	4.99	9.98	0.18	0.07	0.01	0.01	0.04	0.99	1.67	0.00	12.743	10.659	8.336		
ZUC126	11.23	1.20	8.87	20.96	0.18	0.01	0.01	0.01	0.06	0.66	1.67	0.00	24.417	22.742	**.563		
ZUC131	13.07	0.16	1.13	15.97	0.08	0.03	0.03	0.06	0.59	0.06	1.77	0.00	17.421	22.556	**.563		
ZNUV01	14.87	3.04	1.04	18.96	0.13	0.03	0.03	0.06	0.59	0.06	1.04	0.00	24.291	22.556	-2.563		
ZNUV15	17.98	3.62	2.65	22.95	0.13	0.08	0.10	10.72	0.02	0.12	0.25	0.00	29.651	28.973	-1.157		
ZNUV16	18.86	3.62	3.74	22.45	0.20	0.14	0.10	11.57	0.10	0.23	0.23	0.00	30.522	30.759	-0.386		
ZNUV17	17.59	3.45	4.79	20.46	0.23	0.08	0.14	12.41	0.13	0.23	0.23	0.00	29.370	30.359	-1.655		
ZNUV18	16.79	1.40	5.66	18.46	0.28	0.03	0.08	10.00	0.00	0.34	0.13	0.00	25.910	24.911	-2.015		
ZNUV19	17.51	2.71	6.09	17.96	0.38	0.04	0.07	11.85	0.11	0.27	0.19	0.00	27.560	29.735	-3.795		
ZNUV20	17.21	2.63	5.53	17.96	0.38	0.04	0.07	11.85	0.11	0.27	0.19	0.00	27.930	29.431	-2.601		
ZNUV25	16.15	2.39	6.22	16.72	0.38	0.04	0.07	11.13	0.08	0.29	0.00	0.00	26.090	28.546	-4.494		
ZNUV26	17.11	2.30	7.31	16.47	0.49	0.05	0.08	11.57	0.06	0.29	0.31	0.00	26.850	28.127	-4.065		
ZNUV27	17.11	2.22	8.05	15.72	0.56	0.05	0.07	11.57	0.06	0.29	0.00	0.00	26.951	28.052	-3.736		
ZULE06	17.90	2.22	8.70	15.72	0.72	0.09	0.09	11.80	0.08	0.44	0.00	0.00	27.941	22.769	-3.168		
ZULE07	17.27	1.14	7.96	14.47	0.77	0.04	0.07	11.28	0.10	0.40	0.00	0.00	25.880	28.627	-5.035		
ZULE09	16.79	1.97	7.83	14.22	0.82	0.04	0.06	11.13	0.10	0.40	0.00	0.00	25.367	29.013	-6.712		
ZJAN17	0.00	3.50	0.00	20.46	0.84	0.18	0.11	0.00	0.00	0.00	0.00	0.00	25.090	0.000	*****		
ZJAN19	0.00	3.59	0.00	19.96	1.05	0.14	0.12	0.00	0.00	0.00	0.00	0.00	24.965	0.000	*****		
ZJAN20	0.00	3.28	0.00	19.21	1.25	0.11	0.10	0.00	0.00	0.00	0.00	0.00	23.950	0.000	*****		
ZJAN21	0.00	2.74	0.00	16.47	1.13	0.07	0.08	0.00	0.00	0.00	0.00	0.00	20.510	0.000	*****		
ZFEB09	0.00	3.35	0.00	16.46	1.33	0.21	0.10	0.00	0.00	0.00	0.00	0.00	24.455	0.000	*****		
ZFEB10	0.00	3.98	0.00	9.71	1.43	0.11	0.19	0.00	0.00	0.00	0.00	0.00	23.728	0.000	*****		
ZFEB11	0.00	2.57	0.00	18.46	1.43	0.11	0.09	0.00	0.00	0.00	0.00	0.00	23.050	0.000	*****		
ZFEB12	0.00	2.34	0.00	15.22	1.46	0.07	0.08	0.00	0.00	0.00	0.00	0.00	24.447	0.000	*****		
ZFEB13	0.00	2.34	0.00	17.72	1.41	0.07	0.08	0.00	0.00	0.00	0.00	0.00	17.625	0.000	*****		

from the decaying organic material and are likely complexed with soluble organic compounds also produced during the decay processes.

Attenuation Experiments

Water quality data obtained in the leachate attenuation experiments for sediment columns S3, S4, S5, S6, S7 and S8 are tabulated in Table 7. Charge balance error values were calculated for samples with complete analytical data using the following formula (Hem, 1970):

$$\frac{\text{MEQ cation} - \text{MEQ anion}}{\text{MEQ cation} + \text{MEQ anion}} \times 100$$

For most samples the charge balance is within $\pm 5\%$.

The results of the sediment contamination experiment are tabulated in Appendix D and illustrated in Figures 14 through 20. Relative concentration is the ratio of the column influent concentration (C_0) to effluent concentration (C) for each 1-L aliquot. In Figures 14 to 20, the relative concentration (C/C_0) of the various elements or ions is plotted against the volume of effluent added. The

"breakthrough" point for a given element is defined as the point at which the column effluent concentration equals half the influent concentration (i.e., $C/C_0 = 0.5$) according to Griffin *et al.* (1976).

Chloride and Major Cations

Figure 14 shows results for chloride analyses. The C/C_0 values quickly rose to unity and remained stable at this value after the addition of no more than 6 L of leachate. The lower initial C/C_0 values are not considered to indicate uptake by the sediment but rather dilution by pore fluids that were present in the sediments. Since the organic sediments (S5, S6, S7, S8) have a higher initial water content, the effect of dilution was more pronounced in these materials.

The major cations calcium, magnesium, sodium and potassium behaved differently from the cation chloride. The sandy loam attenuation columns (S3 and S4) representing the drumlin and, especially, the organic-rich sediment columns (S5, S6, S7 and S8) all released Ca when leachate was applied to the sediments (Fig. 15A). In contrast, magnesium was attenuated to varying degrees in the contamination

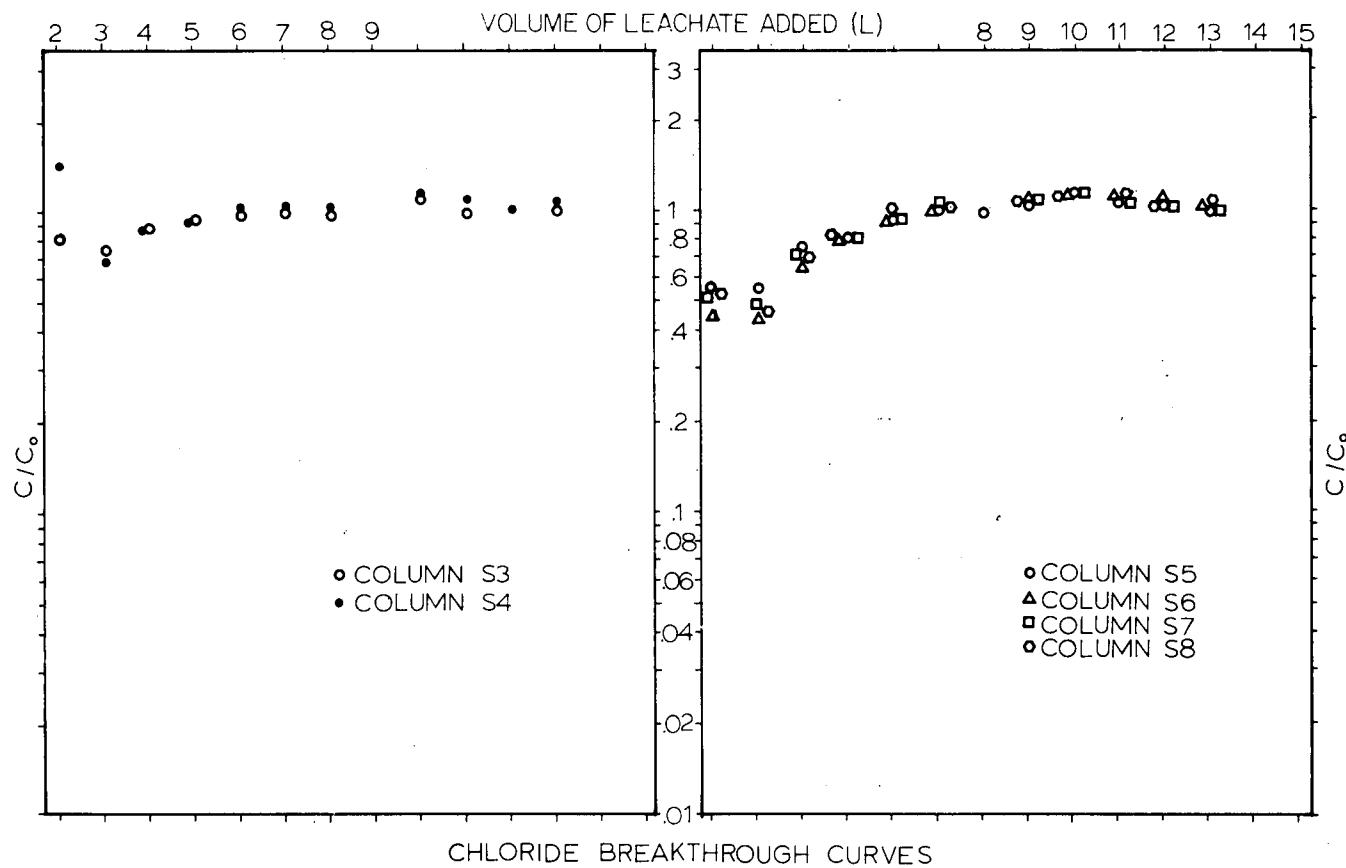


Figure 14. Chloride breakthrough curves for leachate attenuation experiments.

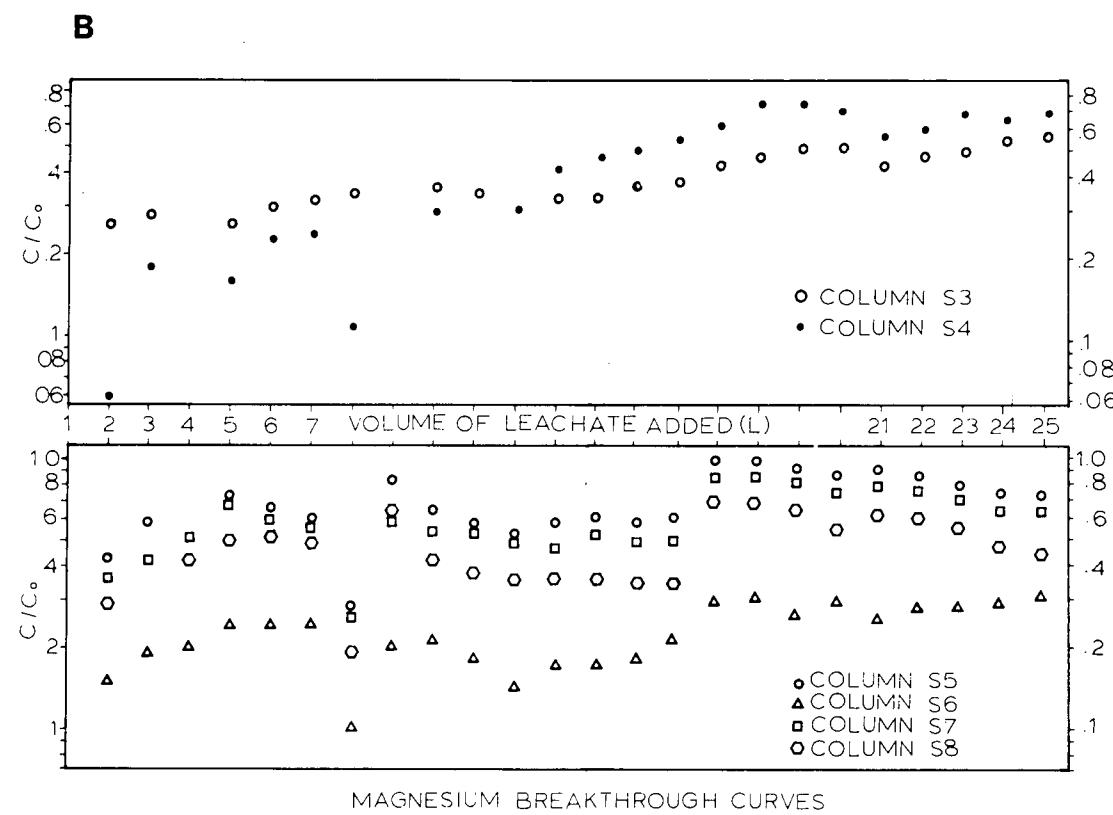
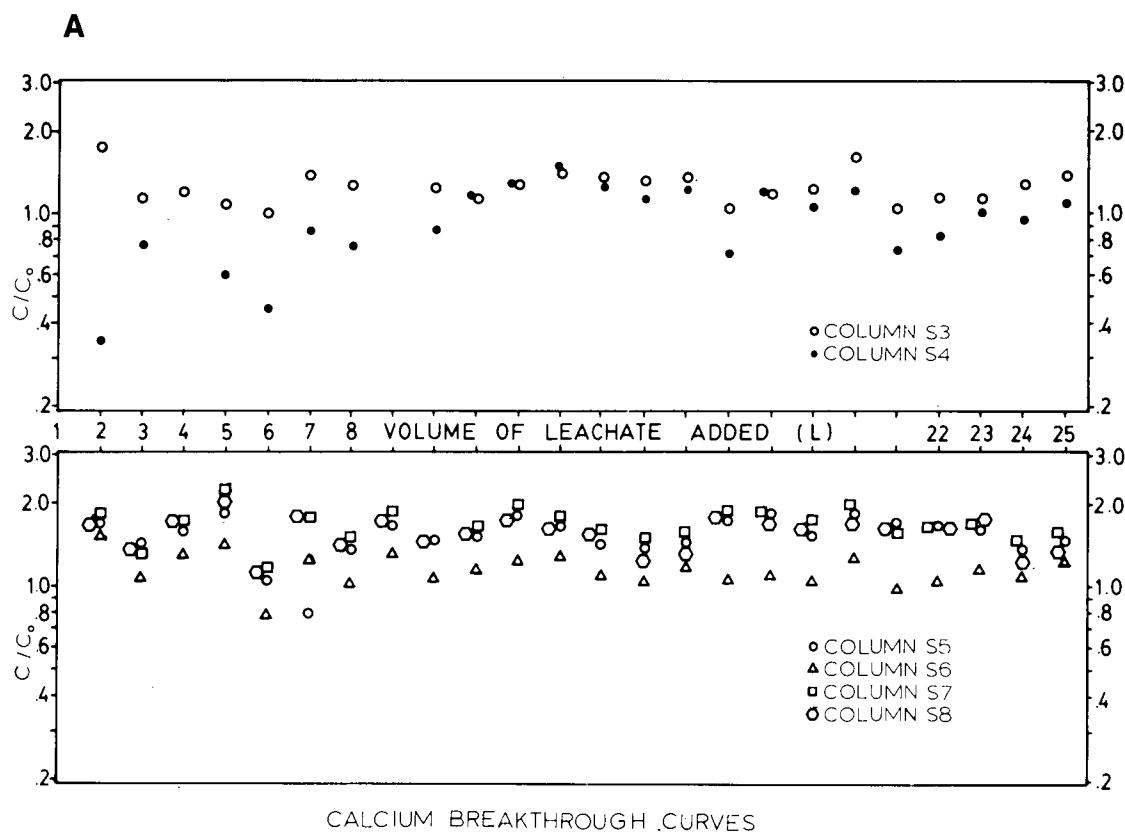


Figure 15. Calcium and magnesium breakthrough curves for leachate attenuation experiments.

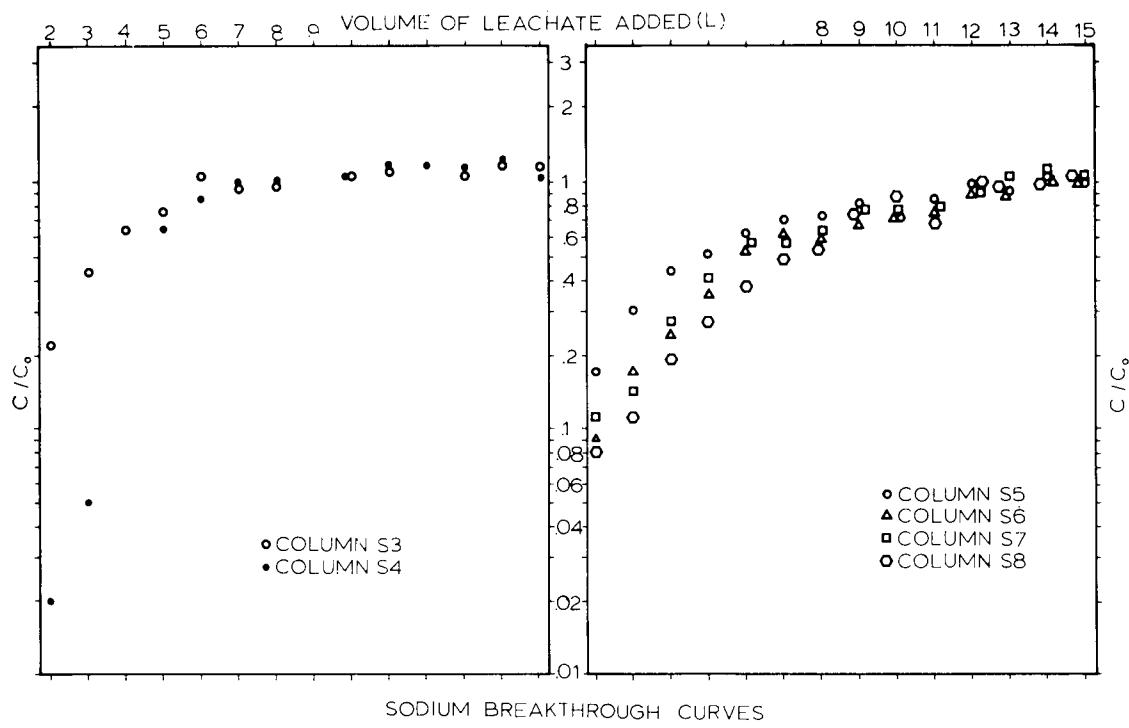
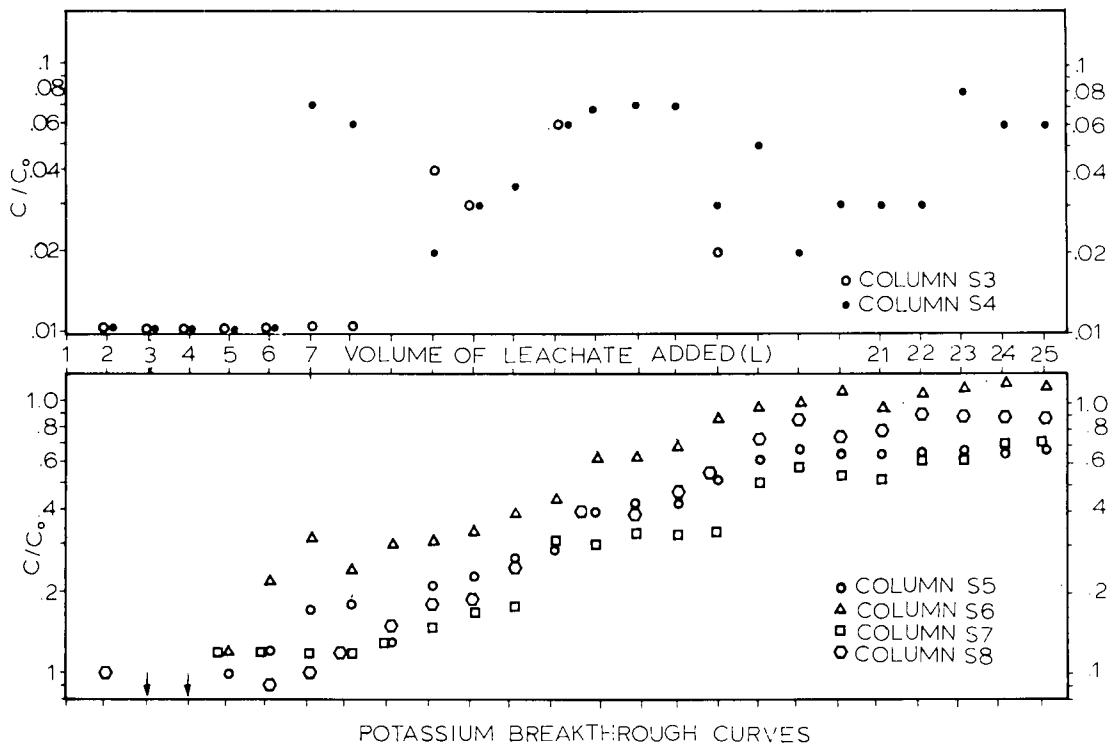
A**B**

Figure 16. Sodium and potassium breakthrough curves for leachate attenuation experiments.

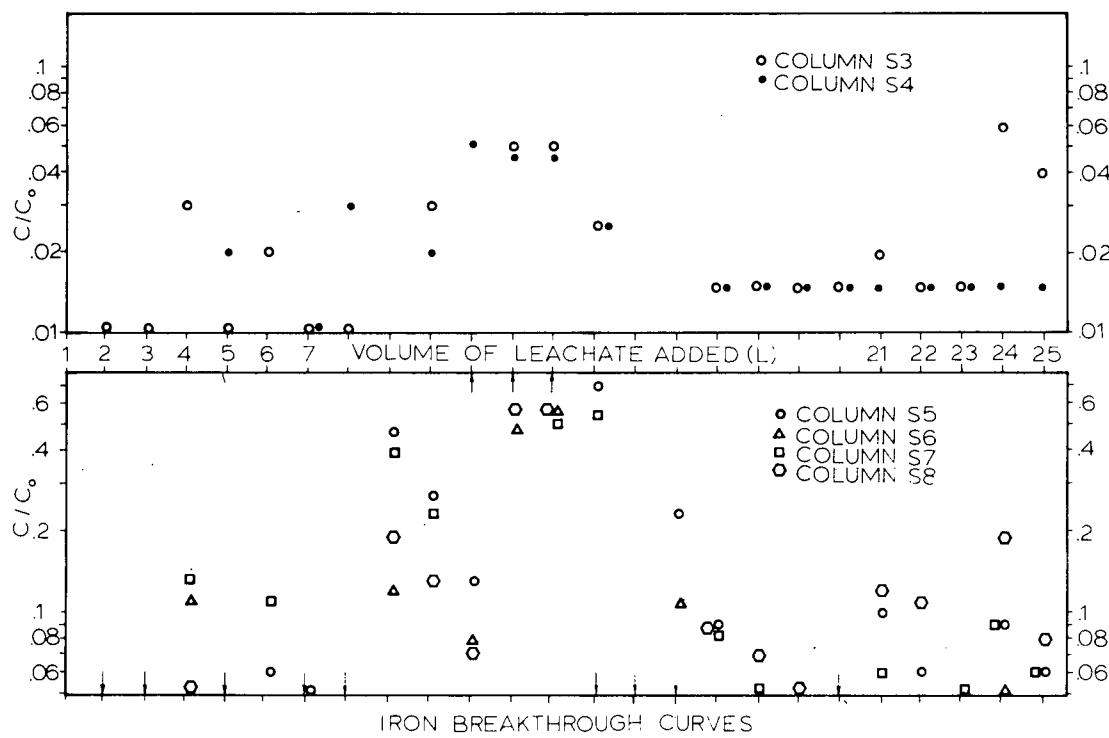
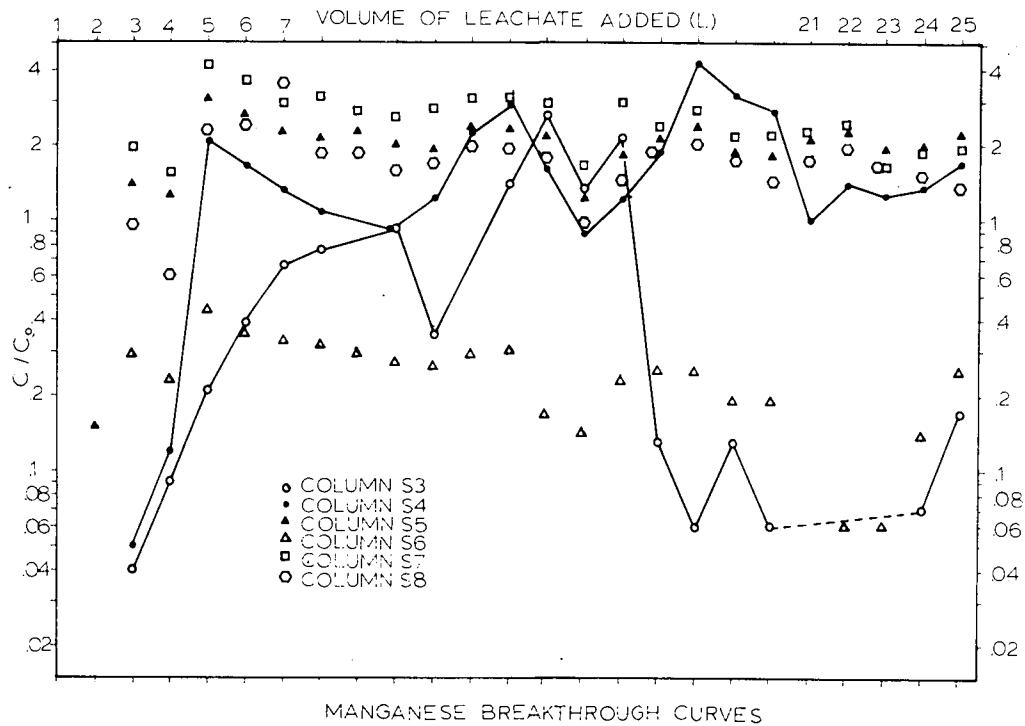
A**B**

Figure 17. Iron and manganese breakthrough curves for leachate attenuation experiments.

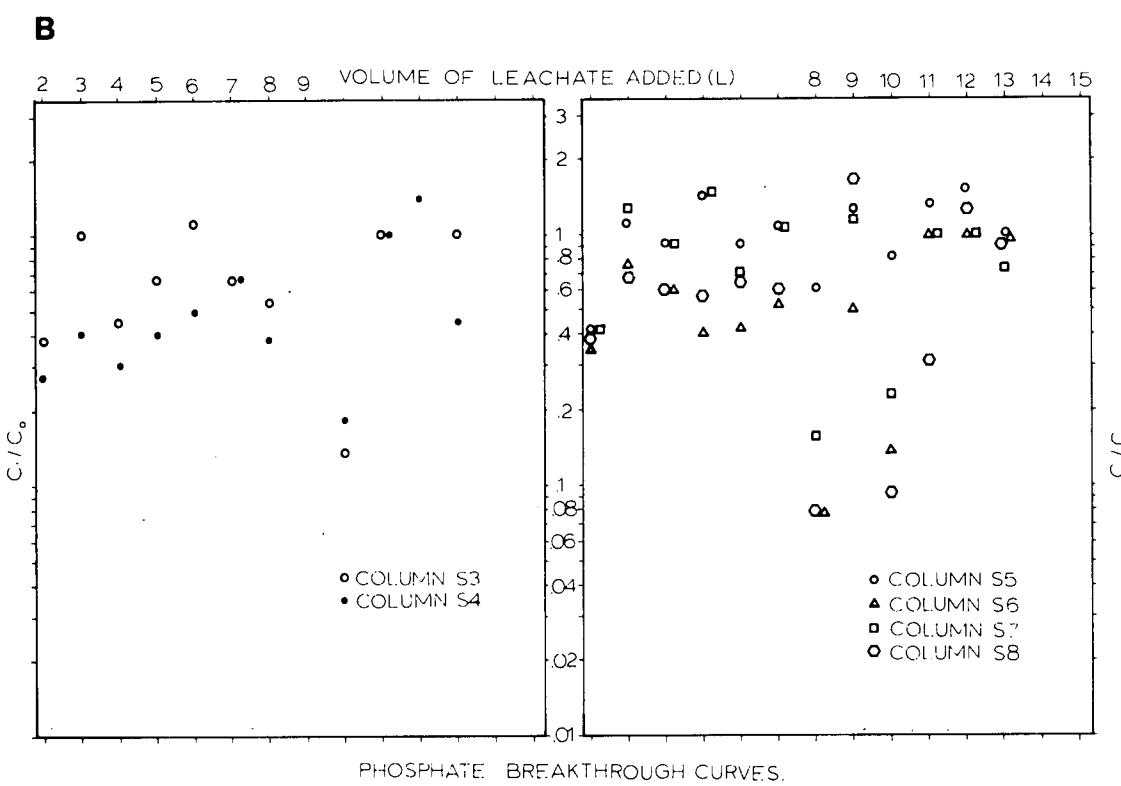
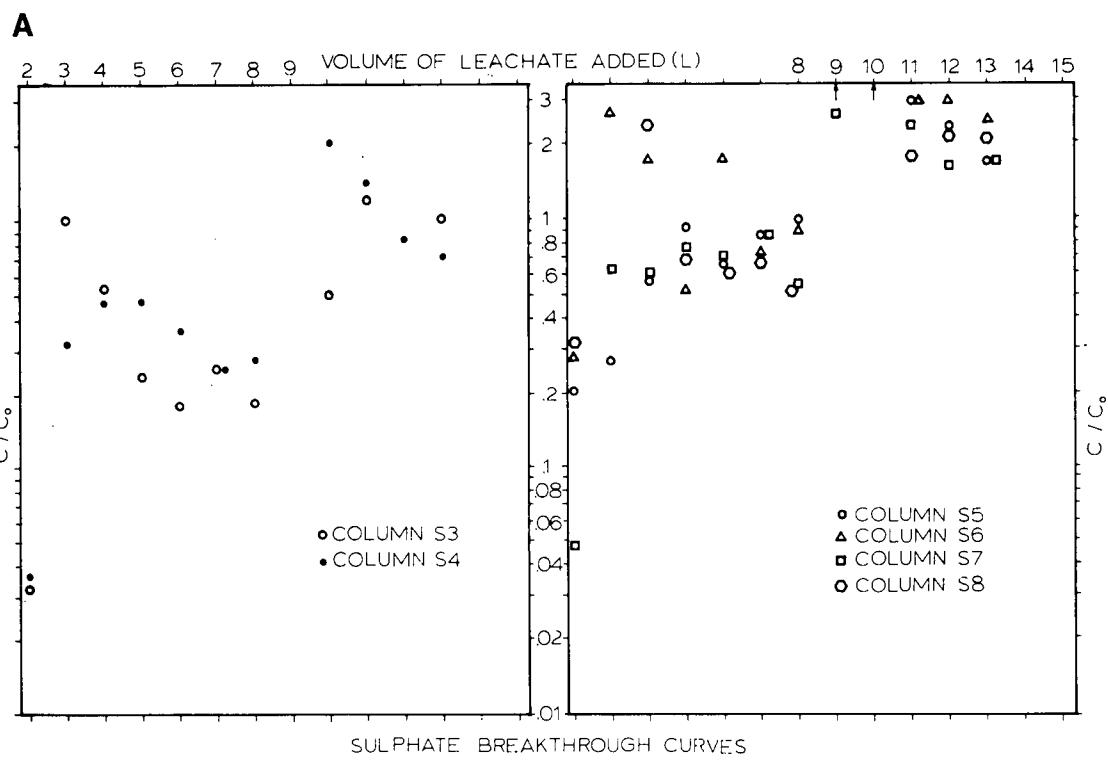


Figure 18. Sulphate and phosphate breakthrough curves for leachate attenuation experiments.

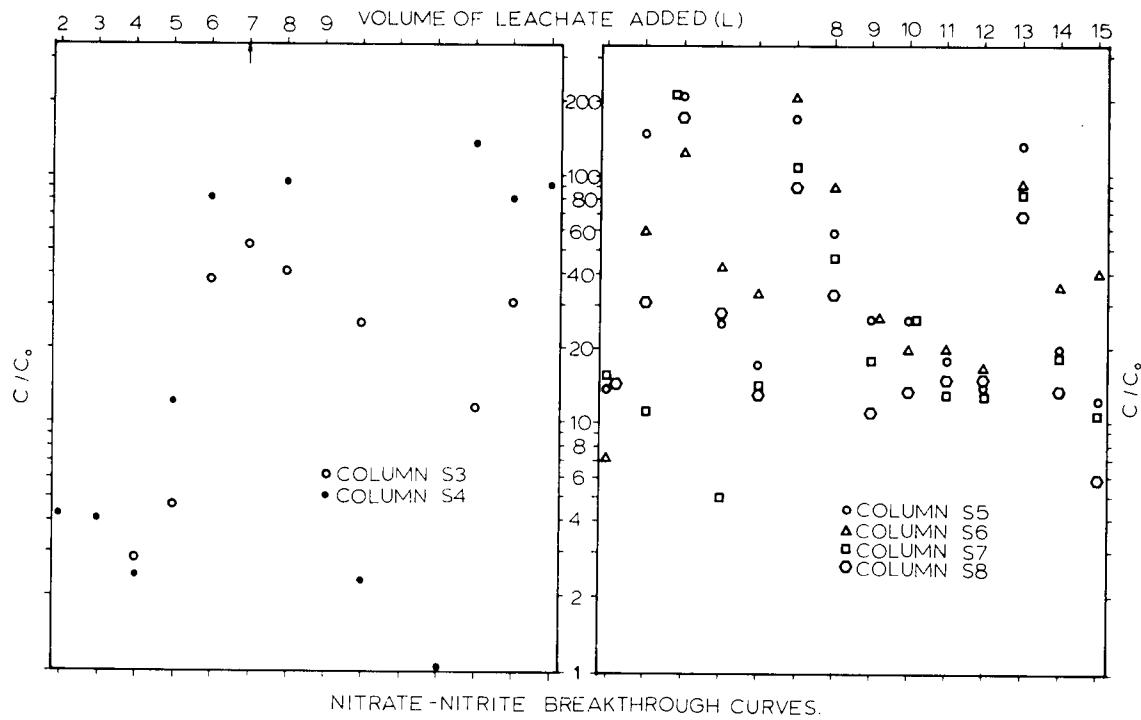
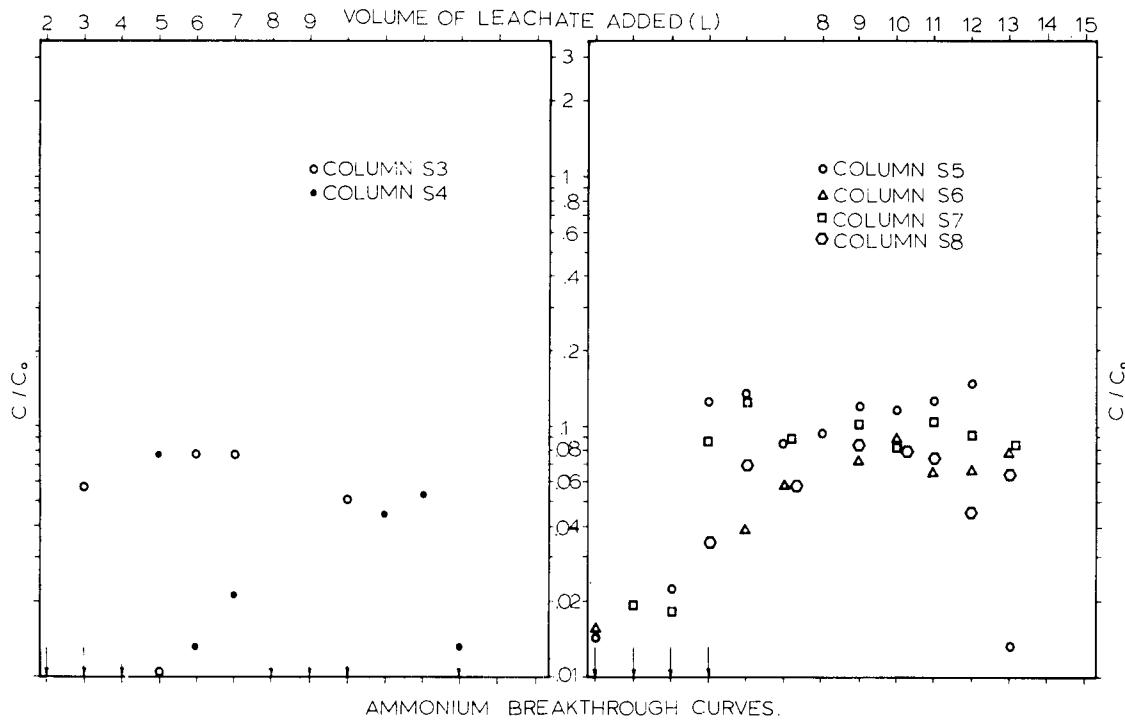
A**B**

Figure 19. Nitrate-nitrite and ammonium breakthrough curves for leachate attenuation experiments.

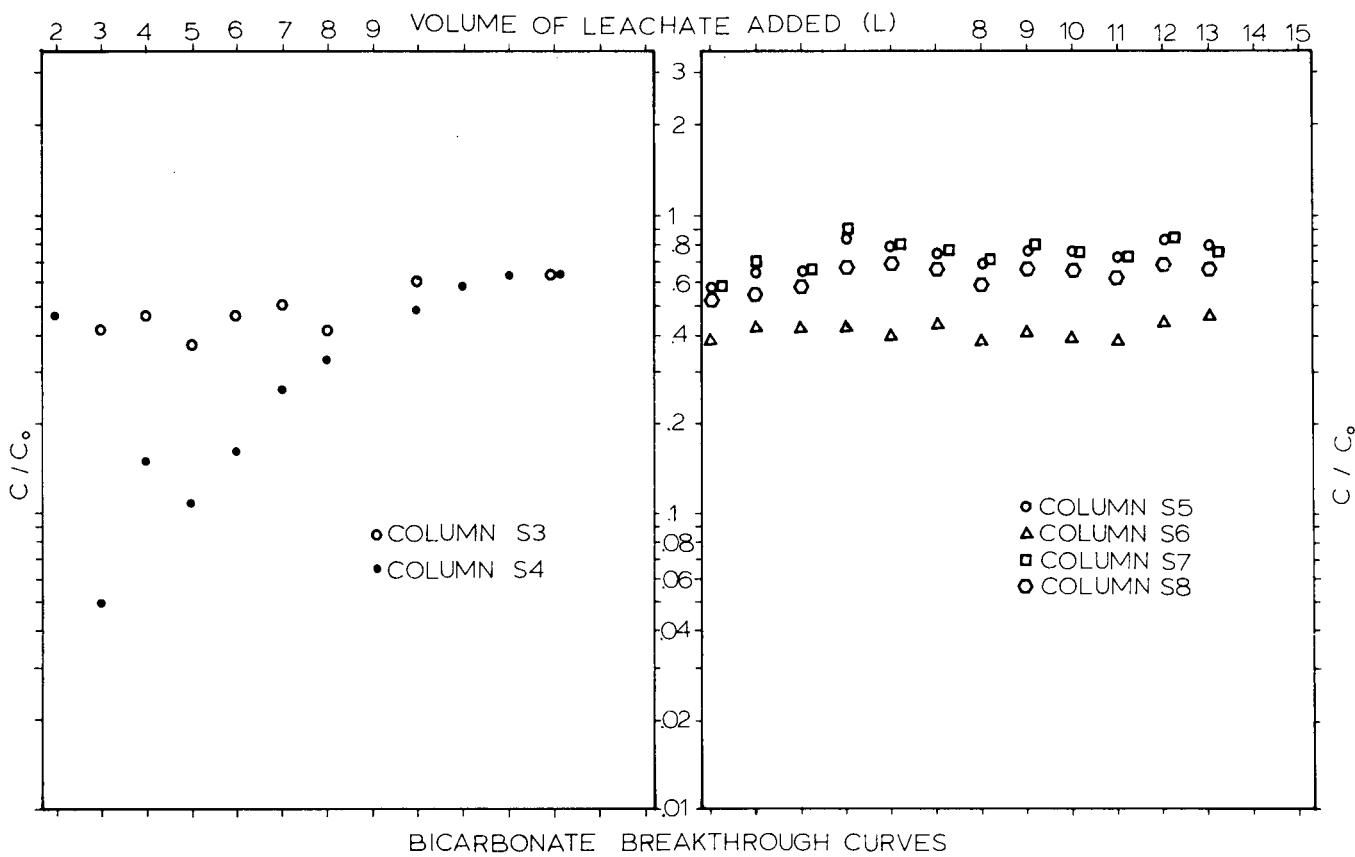


Figure 20. Bicarbonate breakthrough curves for leachate attenuation experiments.

experiments (Fig. 15B). The concentration of dissolved magnesium was most significantly reduced in effluent collected from column S6. Sodium breakthrough curves (Fig. 16A) reveal that the ability of the sediments to attenuate this metal was variable. The sandy loam attenuation columns (S3 and S4) reached $C/C_0 = 1.0$ after the application of 7 L of leachate, while the non-attenuation level in the organic-rich sediments was obtained only after the addition of 14 L. Throughout the sediment contamination experiment, potassium attenuation exceeded the 90% level in both columns S3 and S4 (Fig. 16B). It would appear, therefore, that the Darlington loam developed on the drumlins in Prince Edward County has a large capacity for potassium fixation. Attenuation of potassium in the organic soils of the Big Swamp was not as significant. At the end of the experiments, columns S5, S6, S7 and S8 were unable to attenuate any more potassium.

The release of calcium and the attenuation of magnesium, sodium and potassium can be explained in terms of ion exchange processes. On all of the sediments used in the experiments, calcium was the major exchangeable cation (Table 5). Also, calcium, compared with magnesium, sodium and potassium, is the major cation in the ground

waters at the field site (Table 6). In contrast with the ground water, the leachate that was used in the attenuation experiments had much higher sodium, magnesium and potassium concentrations compared with those of calcium. Thus, contact between the leachate and the sediments resulted in the exchange of magnesium, sodium and potassium for calcium on the sediments.

Iron and Manganese

Throughout the experiments no appreciable quantities of heavy metals, except for iron and manganese, were observed in the attenuated leachate effluent samples. The concentration values for iron (Fig. 17A) are erratic and suggest significant attenuation. Attenuation of iron is probably a result of the precipitation of iron oxyhydroxides, which are then removed by filtration. Yet it should be noted that if the experiments had been conducted under anoxic conditions, iron precipitation and removal might not have occurred.

Attenuation columns S3, S4, S5, S7 and S8 released manganese after the application of a few litres of leachate

(Fig. 17B). The presence of elevated manganese concentration values in the effluent suggests that desorption or dissolution could be occurring. In contrast, column S6 showed more than 50% attenuation of manganese throughout the leachate attenuation experiments. The ability of the sediments in column S6 to attenuate manganese may be a consequence of their very high organic content (Table 4) and degree of organic decomposition (Appendix C). Results for columns S3 and S4 were erratic, showing no discernible trends.

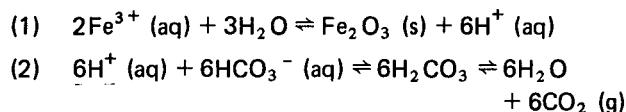
Sulphate, Phosphate, Nitrate-Nitrite, Ammonium and Bicarbonate

Attenuated leachate data for sulphate, phosphate, nitrate-nitrite, ammonia and bicarbonate are illustrated in Figures 18, 19 and 20. The breakthrough curves for these ionic complexes are poorly defined for all of the sediment types studied.

Sulphate and phosphate concentrations in the effluent from the columns were not consistently increased or decreased compared with initial values in the leachate (Fig. 18). Although the sulphate results for columns S5, S6, S7 and S8 after the addition of 8 L of leachate might indicate that sulphate was being released, this increase in C/C₀ was largely the result of a decrease in the concentration of sulphate in the raw leachate.

The concentration of nitrate-nitrite was significantly increased in the effluent from the columns relative to the concentration present in the leachate (Fig. 19A). Much of the nitrate-nitrite was probably produced as a result of ammonium nitrification, because the ammonium concentrations were greatly reduced during passage of the leachate through the columns (Fig. 19B). Some ammonium may have been lost due to volatilization as NH₃, but since the pH remained nearly neutral (pH 7.0 ± 0.5) throughout the experiments, this process was not likely significant (Haan and Zberman, 1976).

Bicarbonate C/C₀ ratios are illustrated in Figure 20. After the application of only a few litres of leachate, a relatively stable C/C₀ ratio of less than 1.0 was achieved. For columns S5, S6, S7 and S8, there appears to be a direct relationship between the magnitude of HCO₃⁻ attenuation and the loss-on-ignition (Table 3b). Iron oxidation and carbon dioxide formation in the sediments could be responsible for the decrease in bicarbonate concentration. This process may be represented by the following reaction:



Other biochemical-geochemical reactions possibly involving carbonate minerals may also affect the bicarbonate concentration.

Remobilization Experiments

The analytical results for all samples collected during the remobilization experiments are tabulated in Appendix E.

The pH of the simulated rainwater rose from 3.6 to about 7 as the solution migrated toward the base of each column. In all of the organic sediment columns tested (S5, S6 and S8), the pH stabilized at pH 7.0 within the upper 60 cm. Initial Eh values of rainwater (400 mV) were reduced to 250-320 mV within the upper 30 cm of each column containing organic-rich sediment, while Eh values declined to 200-220 mV in the sandy loam sediment (column S3).

Rainwater elution data from columns S3, S5, S6 and S8 are graphically presented in Figure 21. The concentrations of calcium, magnesium, sodium and potassium have been plotted as a function of the volume of solution eluted from the base of each column. In general, it was noted that the concentrations of the major elements rise initially, reach a peak after the passage of a few litres of simulated rainwater, and then decline steadily until completion of the experiment. The initial increase in concentration is a result of the experimental method. Before beginning the experiments, the columns were saturated with simulated rainwater by filling from the bottom. Thus, when the experiments commenced, the first samples obtained at the base of columns comprised the filling water. The concentrations of components rose initially because the filling water at the top of the column had contacted the sediments first and therefore had eluted the greatest amounts of components. Elution concentration profiles, in form similar to those in Figure 21, were noted for bicarbonate, sulphate and iron. In all of the columns tested, iron and manganese concentrations were less than 1 mg/L, suggesting that remobilization of these elements was not significant under the experimental conditions.

Differences in hydraulic conductivity in columns S5, S6 and S8 (Appendix A) resulted in different rates of flow of simulated rainwater through the columns. Nevertheless, the concentration of major ions in the eluent was similar for all of the columns (compare Figures 21B, 21C and 21D). The results suggest that the elution processes occur relatively rapidly.

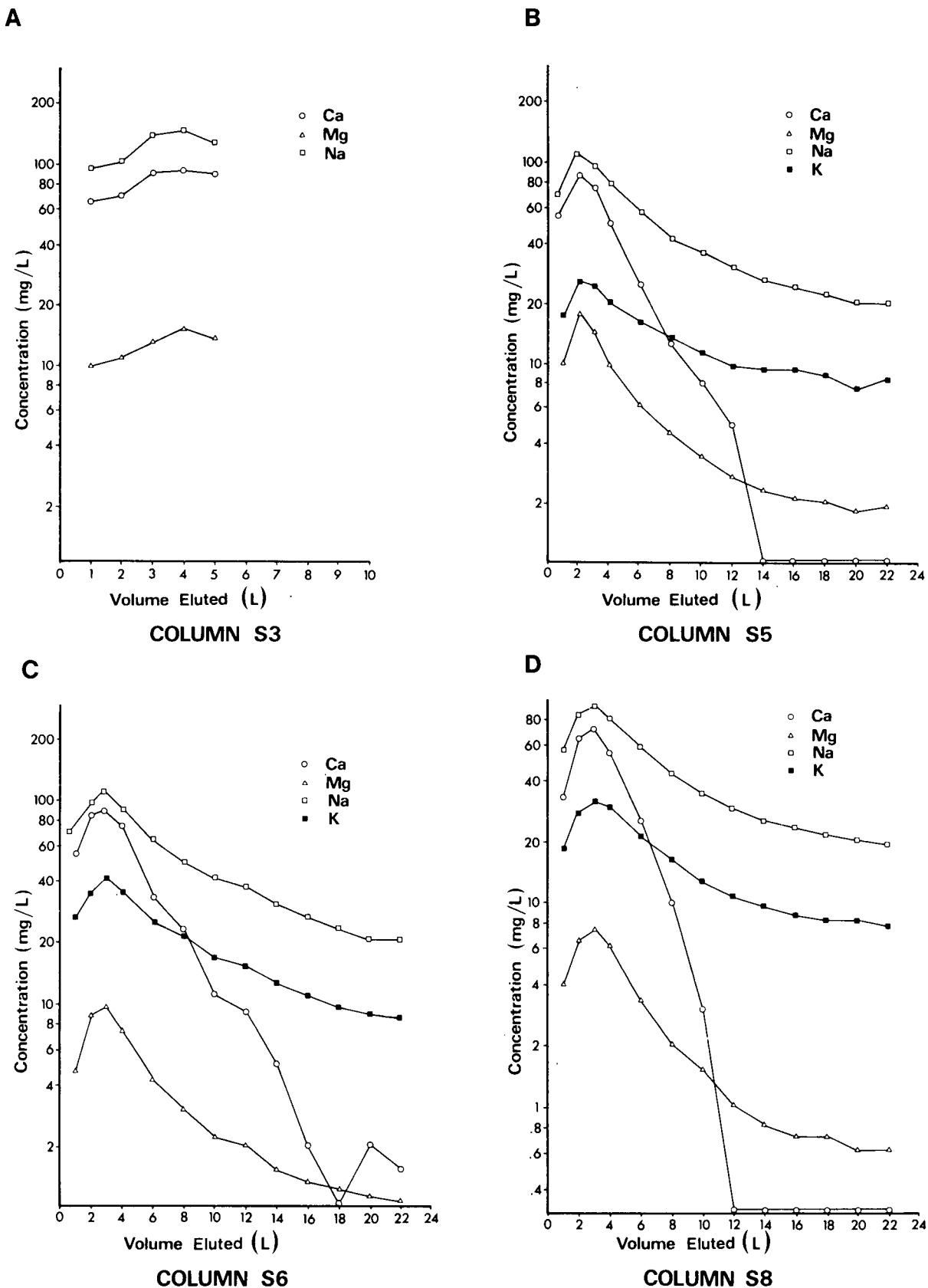
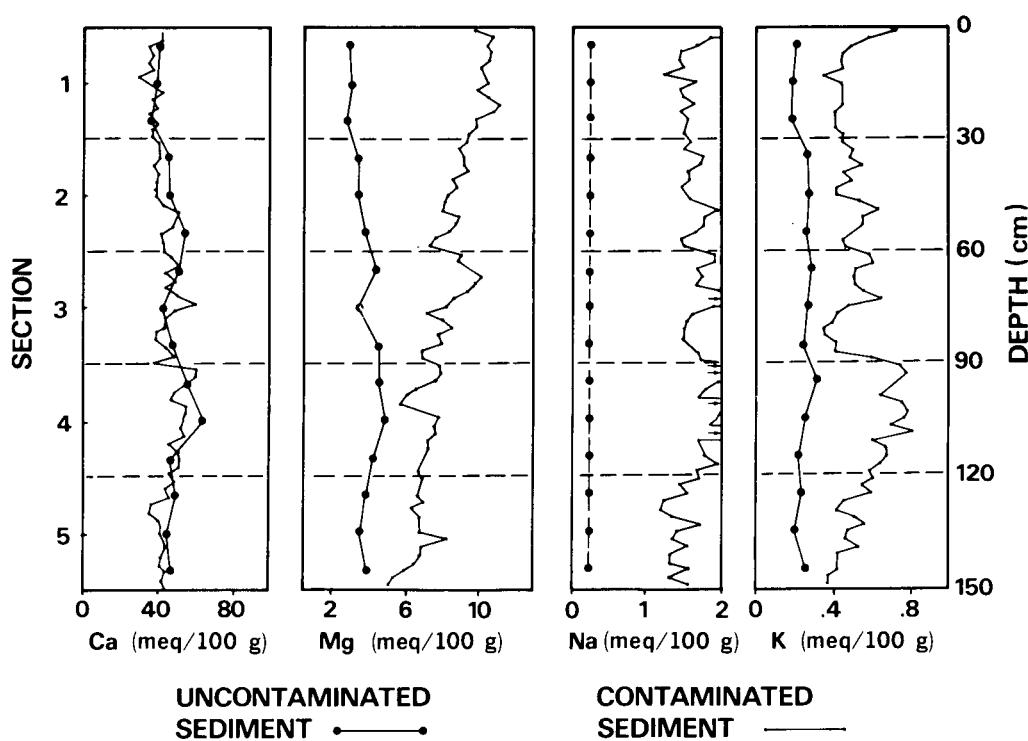


Figure 21. Contaminant remobilization water quality values for columns S3, S5, S6 and S8.

A

COLUMN S7



B

COLUMN S5

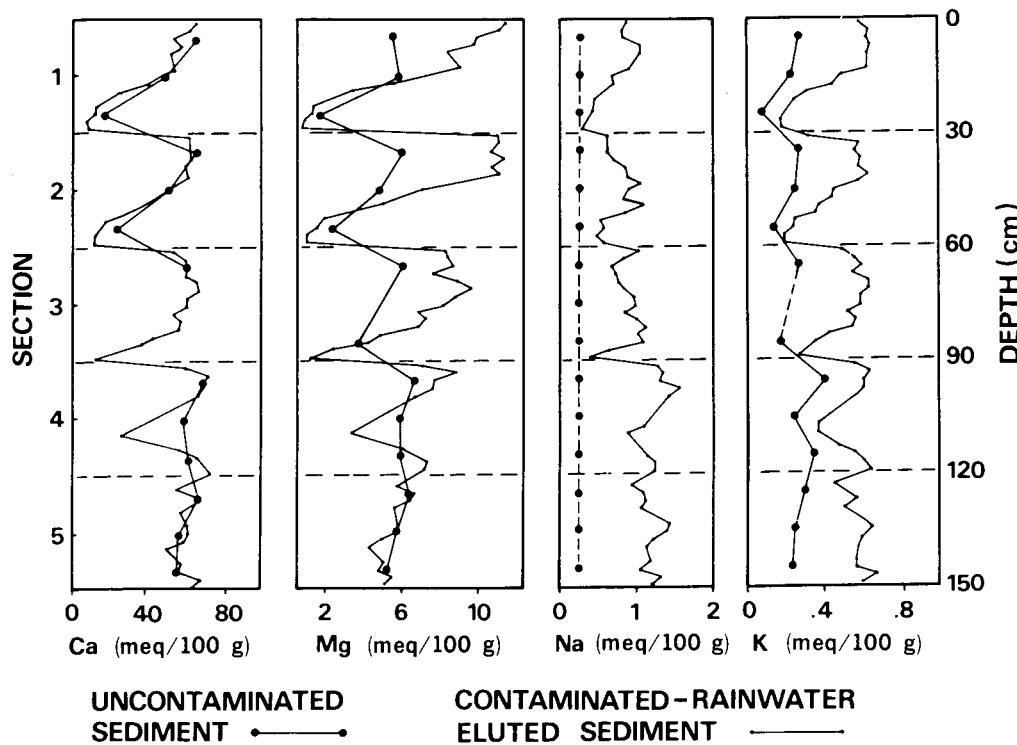


Figure 22. Variations in exchangeable major cation concentrations at different stages of the attenuation and remobilization experiments: A – uncontaminated and fully contaminated sediment; B – uncontaminated and rainwater-leached sediment.

Exchangeable Major Cations

Exchangeable calcium, magnesium, sodium and potassium data for columns S5 and S7, which were obtained from sediment samples taken at various stages of the attenuation and remobilization experiments, have been plotted in Figure 22. No statistically significant differences in exchangeable calcium concentrations were noted between fully contaminated, rainwater-leached and uncontaminated sediments, although calcium was released during both the attenuation and remobilization experiments. The loss of calcium was not detected in the exchangeable calcium results, because the amount of calcium released was very small compared with the total amount contained in the sediments. In contrast, exchangeable magnesium, sodium and potassium values were significantly larger in the contaminated sediments than in the corresponding uncontaminated sediments (Fig. 22A). Even after elution with simulated rainwater, the exchangeable magnesium, sodium and potassium concentrations were still larger than those for uncontaminated sediments, but the average difference, especially for sodium, was reduced (Fig. 22B).

Potential Effects of Landfill Leachate on Ground Water Quality in the Big Swamp

On the basis of the data obtained in this study, the potential impact, in terms of the quality of ground water, of a proposed sanitary landfill operation at the Big Swamp site may be estimated.

In Figures 23, 24, 25 and 26, the concentrations of different components in the raw leachate and attenuated leachate are compared with those in the natural ground waters at the Big Swamp site. The concentrations of calcium, magnesium, sodium, potassium, ammonium, iron, manganese, bicarbonate and chloride are higher in the raw leachate than in the natural ground waters. Data obtained in the attenuation experiments indicate that chloride will not be retained by the sediments, but that initial contact of the leachate with the organic and inorganic sediments at the Big Swamp site will result in reductions in the concentrations of magnesium, potassium, sodium, ammonium, iron, trace metals and bicarbonate. For sodium, magnesium and, with the exception of the inorganic sediments, potassium, the capacity for attenuation is limited, as indicated by the slow increase in concentrations in the column effluent throughout the course of the attenuation experiments. In addition, results obtained in the remobilization experiments indicated that sodium, potassium and magnesium can be readily removed from the sediments (Figs. 21 and 22). Therefore, these cations will not be permanently removed from leachate upon contact with the sediments, but the rate of migration of each cation will be retarded relative to the rate of flow of the ground water.

Contact between leachate from a landfill and the organic and inorganic sediments should result in increased concentrations of calcium and manganese. In contrast, the concentrations of ammonium, iron and trace metals will be reduced to values similar to or below, average natural levels. Results obtained in the remobilization experiments indicate that iron and trace metal removal will be permanent, at least if oxidizing conditions prevail. The data in Figure 19 suggest that the ammonium will be converted to nitrate-nitrite, which will achieve concentrations that are much greater than natural levels.

Contact between the leachate and the sediments should result in a reduction in bicarbonate concentrations, but not to levels that are characteristic of natural ground waters at the site. The observed reduction in bicarbonate may be a consequence of carbonate precipitation because the leachate is supersaturated with respect to calcite (Table 7).

The passage of leachate through the subsurface environment at the Big Swamp site should not result in significant changes in the concentrations of BOD_5 or phosphate. Sulphate levels, however, might be increased initially upon contact between the leachate and organic sediments.

In summary, the introduction of landfill leachate into the subsurface environment at the Big Swamp site should result in changes in the quality of the local ground waters. Compared with natural levels, chloride, calcium, sodium, potassium, manganese, nitrate-nitrite and bicarbonate concentrations will be increased. Chloride, ammonium, manganese and calcium concentrations may exceed acceptable levels in water used for domestic consumption (McNeely *et al.*, 1979). As the leachate migrates through the sediments the concentration of these latter components will be reduced by dilution and dispersion, which will be most effective during the spring runoff period. If leachate reaches the deeper limestone aquifer, dilution and dispersion will be much less effective. During migration of leachate through the unconsolidated sediments, components such as sodium, potassium and magnesium will chromatographically separate, since their rates of movement will be retarded relative to the flow of ground water. Iron and trace metals should be effectively retained by the sediments and should not move far from the landfill site.

CONCLUSION

The data obtained in this study permit the evaluation of the effectiveness of organic sediments for attenuating potential contaminants in landfill leachate relative to fine-grained clastic materials. For all of the components, except

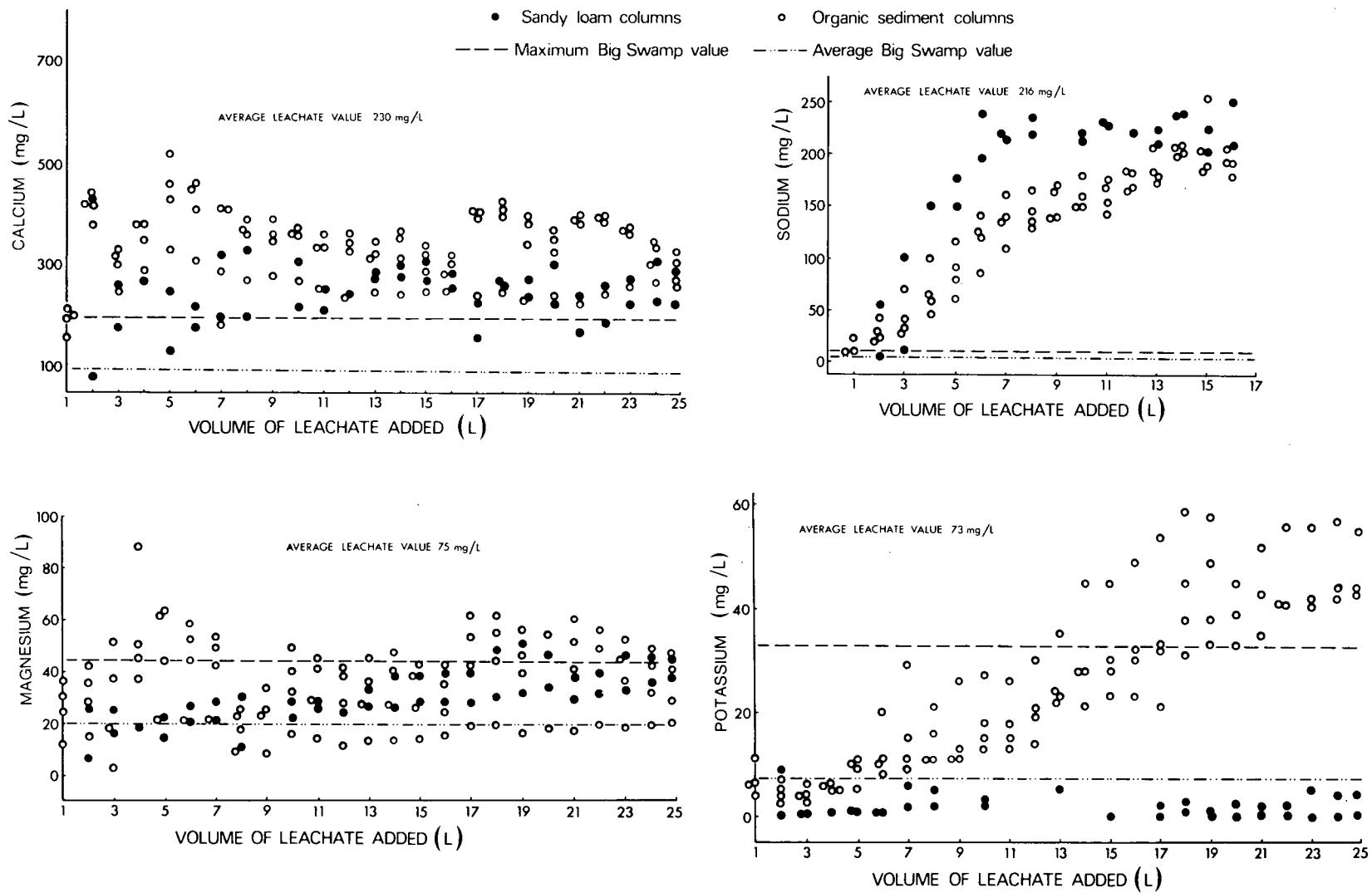


Figure 23. Comparison of raw leachate, attenuated leachate and Big Swamp ground water values of calcium, magnesium, sodium and potassium.

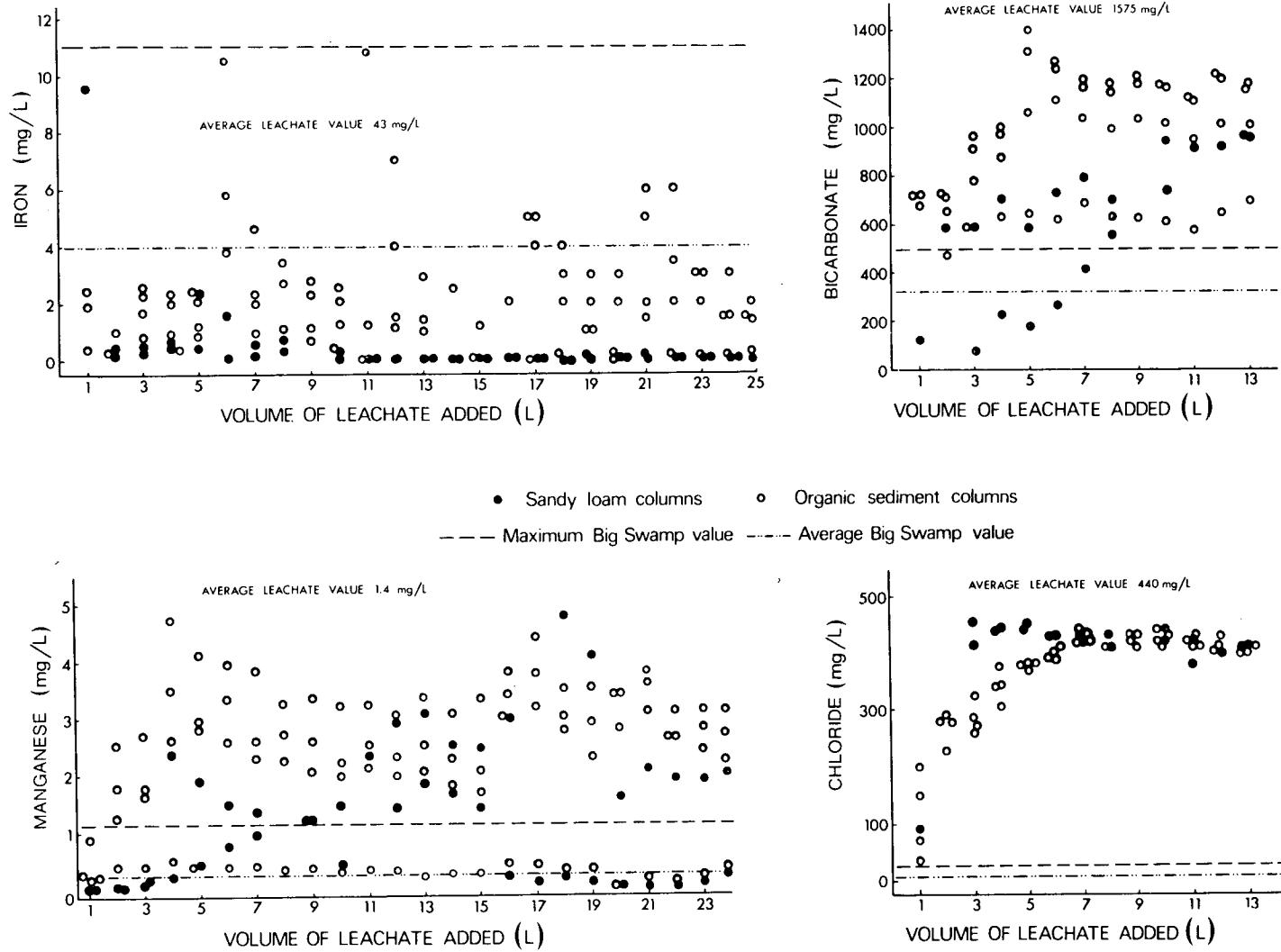


Figure 24. Comparison of raw leachate, attenuated leachate and Big Swamp ground water values of iron, manganese, bicarbonate and chloride.

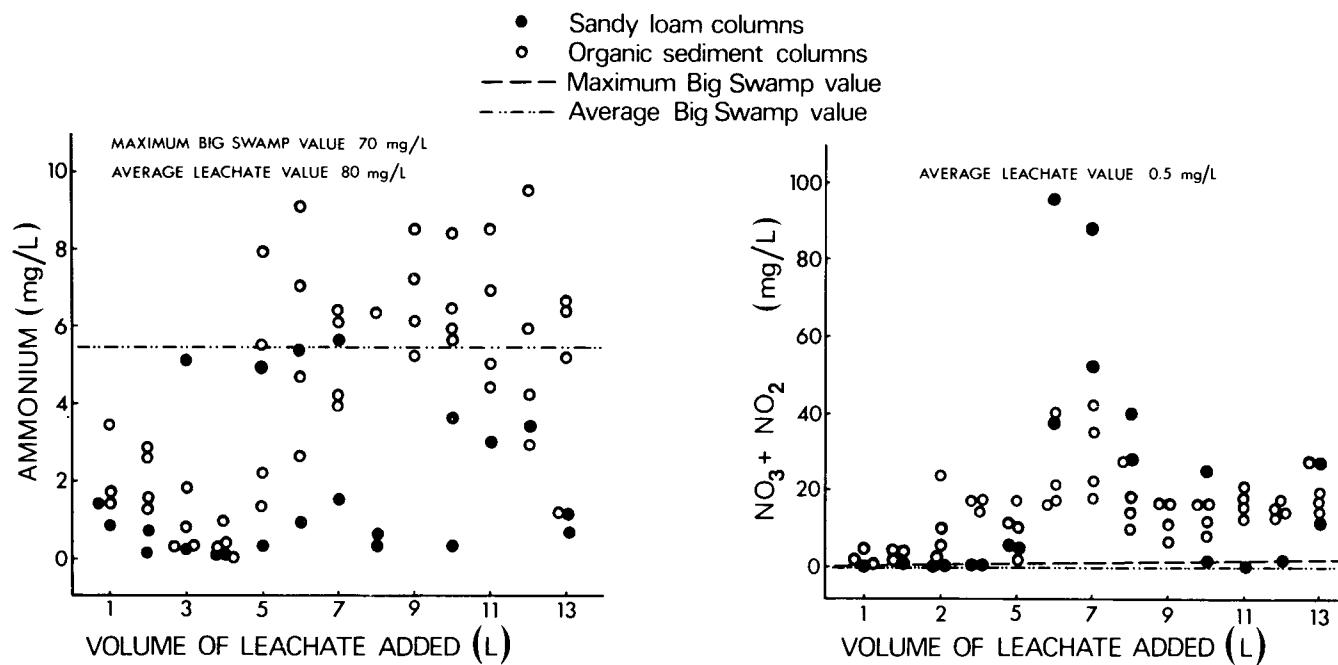


Figure 25. Comparison of raw leachate, attenuated leachate and Big Swamp ground water values of ammonium and nitrate-nitrite.

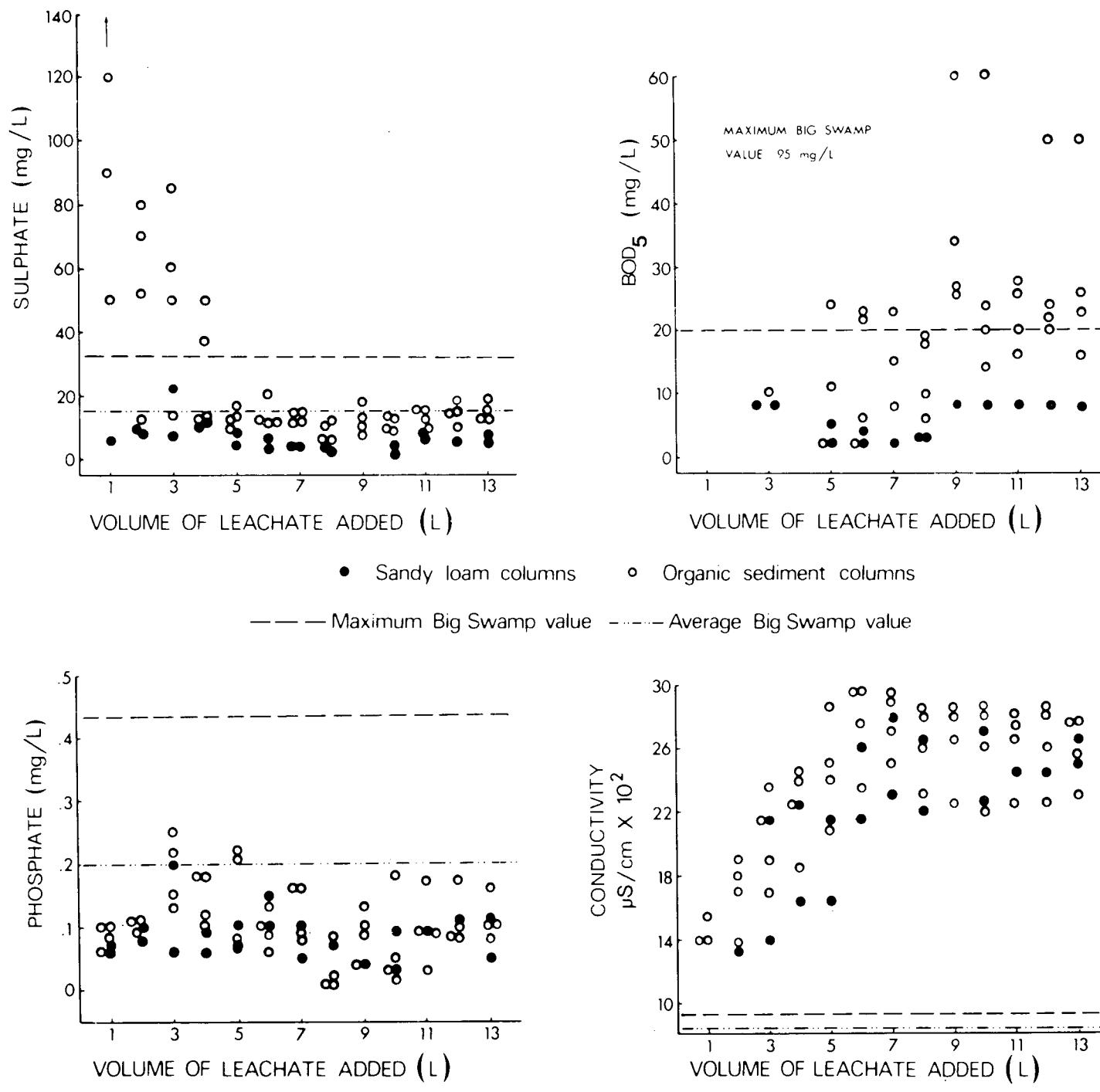


Figure 26. Comparison of raw leachate, attenuated leachate and Big Swamp ground water values of sulphate, phosphate, BOD₅ and conductivity.

potassium, the attenuation capacity of the organic materials was similar to that of the inorganic sediments (Figs. 14 through 20). It must, however, be pointed out that the experiments were conducted using the same bulk volumes of organic and inorganic sediment. In terms of dry weight, the amount of sediment in the inorganic columns was about three times that in the organic columns. Therefore, on a dry weight basis, the organic sediments are much more effective.

Since the hydraulic conductivity of the organic sediments is relatively high, these materials would not be effective in slowing the rate of movement of leachate from landfill. Nevertheless, the presence of organic sediments should not necessarily be considered unfavourable in terms of landfill site selection. Clastic sediments with similar hydraulic conductivities (10^{-1} to 10^{-2} cm/s), which include clean sands (Freeze and Cherry, 1979), would likely have much lower attenuation capacities than organic sediments even on a volume basis. Since leachate movement would be preferentially directed through the more permeable units at a site, it could be advantageous if the most permeable horizons were organic. Leachate would then be selectively channeled through the organic horizons where attenuation would be relatively effective. In addition, since the rate of ground water flow would be relatively rapid in the organic horizons, the significance of dispersion and dilution would be increased.

RECOMMENDATIONS

Results obtained in the experiments carried out during this study showed that organic-rich sediments may effectively attenuate some potential contaminants in sanitary landfill leachate. In addition, the extent to which the attenuation processes are reversible was indicated in the elution experiments. It is recommended that similar experiments should be carried out in the field, employing closed system techniques to ensure that the leachate does not degas or come into contact with the atmosphere. Under these conditions different results might be obtained for components such as iron and possibly other trace metals. Emphasis in future research should also focus on defining the mechanisms whereby attenuation occurs and the geochemical conditions under which these processes take place.

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APPENDIX A

HYDRAULIC CONDUCTIVITY CALCULATIONS FOR SELECTED SEDIMENT COLUMNS

Table A-1

Column	Hydraulic conductivity values		Time since elution commenced
	Q cm ³ /s	K cm/s	
S3	0.008	1.47×10^{-4}	46 min
	0.010	1.84×10^{-4}	126 min
	0.010	1.84×10^{-4}	197 min
	0.015	2.75×10^{-4}	265 min
	0.013	2.39×10^{-4}	337 min
Mean	0.011	2.06×10^{-4}	
S5	4.55	8.19×10^{-2}	10 min
	4.65	8.37×10^{-2}	14 min
	4.76	8.57×10^{-2}	16 min
	4.35	7.83×10^{-2}	28 min
	4.35	7.83×10^{-2}	36 min
	4.26	7.67×10^{-2}	50 min
	4.08	7.34×10^{-2}	54 min
	4.08	7.34×10^{-2}	64 min
	4.00	7.20×10^{-2}	68 min
	3.85	6.93×10^{-2}	72 min
Mean	4.25	7.65×10^{-2}	
S6	16.67	3.00×10^{-1}	1 min
	14.29	2.57×10^{-1}	2 min 10 s
	14.29	2.57×10^{-1}	3 min 20 s
	14.29	2.57×10^{-1}	4 min 30 s
	14.29	2.57×10^{-1}	5 min 40 s
Mean	14.77	2.57×10^{-1}	

Table A-1. Continued

Column	Hydraulic conductivity values		Time since elution commenced
	Q cm ³ /s	K cm/s	
S8	4.17	7.51×10^{-2}	10 min
	2.70	4.86×10^{-2}	16 min 10 s
	3.23	5.81×10^{-2}	21 min 20 s
	3.03	5.45×10^{-2}	26 min 50 s
	3.13	5.63×10^{-2}	32 min 10 s
	3.13	5.63×10^{-2}	37 min 30 s
	3.03	5.45×10^{-2}	43 min 0 s
	3.03	5.45×10^{-2}	48 min 30 s
	3.33	5.99×10^{-2}	53 min 30 s
	2.22	4.00×10^{-2}	60 min 0 s
	5.26	9.47×10^{-2}	63 min 10 s
	4.17	7.51×10^{-2}	67 min 30 s
	3.85	6.93×10^{-2}	71 min 50 s
	3.70	6.66×10^{-2}	76 min 20 s
	3.70	6.66×10^{-2}	80 min 50 s
	4.17	7.51×10^{-2}	85 min 25 s
	3.85	6.93×10^{-2}	71 min 50 s
	3.70	6.66×10^{-2}	76 min 20 s
	3.70	6.66×10^{-2}	80 min 50 s
	3.70	6.66×10^{-2}	85 min 25 s
	3.33	5.99×10^{-2}	90 min 25 s
	3.70	6.66×10^{-2}	94 min 55 s
	3.75	6.75×10^{-2}	99 min 22 s
	3.05	5.49×10^{-2}	104 min 50 s
	3.33	5.99×10^{-2}	109 min 50 s
	3.03	5.45×10^{-2}	115 min 20 s
	3.45	6.21×10^{-2}	120 min 10 s
	3.03	5.45×10^{-2}	125 min 40 s
	3.64	6.55×10^{-2}	130 min 15 s
	3.70	6.66×10^{-2}	144 min 20 s
	2.94	5.29×10^{-2}	160 min 40 s
	3.85	6.93×10^{-2}	166 min 0 s
	3.33	5.99×10^{-2}	171 min 0 s
	3.28	5.90×10^{-2}	176 min 5 s
	3.45	6.21×10^{-2}	180 min 55 s
	3.39	6.10×10^{-2}	185 min 50 s
	3.45	6.21×10^{-2}	190 min 40 s
	3.57	6.43×10^{-2}	195 min 20 s
	3.33	3.99×10^{-2}	200 min 20 s
	3.45	6.21×10^{-2}	205 min 10 s
	3.13	5.63×10^{-2}	210 min 30 s
	2.86	5.15×10^{-2}	216 min 20 s
	3.33	5.99×10^{-2}	221 min 20 s
	2.99	5.38×10^{-2}	226 min 55 s
	3.45	6.21×10^{-2}	231 min 45 s
	3.57	6.43×10^{-2}	236 min 25 s
	3.57	6.43×10^{-2}	241 min 5 s
Mean	3.41	6.14×10^{-2}	245 min 20 s

APPENDIX B

CALCITE AND DOLOMITE SATURATION CALCULATIONS FOR BIG SWAMP GROUND WATER

All calculations were made with an averaged ionic strength value for the Big Swamp ground water system using the equation:

$$I = 1/2 \sum Z_i^2 \cdot C_i$$

where I = the ionic strength of the ground water,
 Z_i = the ionic species charge, and
 C_i = the ionic species concentration in moles per litre.

The ionic strength of the ground water used in all of the preceding determinations was 2×10^{-2} mol/L. Activity coefficients for bicarbonate, calcium and magnesium were

calculated using the extended Debye-Hückel equation; they are:

$$\gamma_{\text{HCO}_3^-} = 0.90$$

$$\gamma_{\text{Ca}^{2+}} = 0.68$$

$$\gamma_{\text{Mg}^{2+}} = 0.69$$

The theoretical ionization association products at 25°C for calcite and dolomite are 0.955×10^2 and 0.912×10^4 , respectively, when using the following equations for calcite and dolomite:

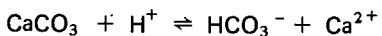


Table B-1. Ionic Concentrations in Big Swamp Ground Water, September 20, 1977

Well number	Field measurements			Calculated solubility products (K)	
	pH	HCO_3^- ($\times 10^{-3}$ mol/L)	Ca^{2+} ($\times 10^{-3}$ mol/L)	Mg^{2+} ($\times 10^{-4}$ mol/L)	CaCO_3 (calc. $\times 10^2$)
1	7.5	6.03	2.98	7.00	3.81
2	7.6	4.20	3.25	13.99	3.64
3	7.5	6.08	2.55	9.05	3.28
4	7.6	5.80	3.38	9.47	5.23
5	7.9	4.84	4.95	17.28	12.75
6	7.8	6.72	3.40	7.82	9.66
7	7.8	4.75	2.88	7.41	5.78
8	—	—	—	—	—
9	7.9	6.31	3.15	6.58	10.58
10	7.5	5.20	2.33	6.17	2.57
11	7.6	4.75	3.58	9.05	4.54
12	7.7	4.00	4.05	8.64	5.44
13	7.9	4.00	4.43	10.29	9.43
14	7.4	8.39	2.75	9.88	3.89
15	7.4	6.87	4.80	10.29	5.55
16	7.8	5.28	1.40	13.99	3.12
17	7.6	5.11	2.73	6.17	3.72
18	7.6	6.39	3.80	6.58	6.48
19	7.6	4.80	1.73	6.58	2.22
20	7.5	6.84	2.65	8.23	3.84
21	7.6	5.16	1.25	7.82	1.72
22	7.7	4.75	1.80	18.11	2.87
23	7.6	7.64	4.20	8.23	8.56
24	7.6	5.48	1.80	9.47	2.63

Table B-2. Ionic Concentrations in Big Swamp Ground Water, October 19, 1977

Well number	Field measurements			Calculated solubility products (K)	
	pH	HCO ₃ ⁻ ($\times 10^{-3}$ mol/L)	Ca ²⁺ ($\times 10^{-3}$ mol/L)	Mg ²⁺ ($\times 10^{-4}$ mol/L)	CaCO ₃ (calc. $\times 10^2$)
1	7.9	6.72	2.63	6.58	9.41
2	7.9	4.39	1.18	10.29	2.75
3	7.8	6.23	2.13	8.64	5.61
4	7.9	6.39	2.25	8.23	7.65
5	8.0	4.90	1.30	11.93	4.27
6	8.0	7.05	2.58	6.58	12.19
7	7.9	5.00	1.78	6.58	4.47
8	—	—	—	—	—
9	8.0	6.39	2.43	5.35	10.41
10	8.0	5.48	2.05	5.35	7.52
11	8.0	5.20	1.85	6.17	6.57
12	7.6	4.08	1.58	4.53	1.72
13	7.8	4.20	1.58	5.35	2.81
14	—	—	2.00	6.58	—
15	7.4	6.87	2.65	6.58	3.06
16	7.8	4.80	1.73	6.58	3.51
17	7.4	5.16	2.13	4.94	1.85
18	7.5	6.00	2.68	4.53	3.40
19	7.6	4.56	1.50	7.00	1.82
20	7.7	5.72	2.78	8.23	5.34
21	7.8	4.89	1.80	7.82	3.72
22	8.1	4.48	0.95	13.99	3.59
23	7.8	6.59	2.98	5.35	8.30
24	7.8	5.48	2.35	6.58	5.44

APPENDIX C

PYROPHOSPHATE INDEX - HISTOSOL CLASSIFICATION OF SELECTED ORGANIC SEDIMENTS FROM THE BIG SWAMP

Table C-1. Uncontaminated Sediments

Sample code	Pyrophosphate Index value	Munsell hue	Colour notation value/chroma	Histosol classification
S5-1-1	3	10 YR	7/4	sapric/hemic
S5-1-2	2	10 YR	6/4	sapric/hemic
S5-1-3	6	10 YR	8/2	clay till
S6-1-1	1	10 YR	4/3	sapric
S6-1-2	1	10 YR	4/3	sapric
S6-1-3	1	10 YR	3/2	sapric
S7-1-1	2	10 YR	6/4	sapric/hemic
S7-1-2	2	10 YR	6/4	sapric/hemic
S7-1-3	2	10 YR	6/4	sapric/hemic
S8-1-1	1	10 YR	4/3	sapric
S8-1-2	2	10 YR	5/3	sapric
S8-1-3	2	10 YR	5/3	sapric

Table C-2. Contaminated Sediments

Sample code	Pyrophosphate Index value	Munsell hue	Colour notation value/chroma	Histosol classification
S5-1-0-2	3	10 YR	7/4	sapric/hemic
S5-1-2-4	3	10 YR	7/4	sapric/hemic
S5-1-4-6	2	10 YR	6/4	sapric/hemic
S5-1-6-8	2	10 YR	6/4	sapric/hemic
S5-1-8-10	2	10 YR	6/4	sapric/hemic
S5-1-10-12	2	10 YR	6/4	sapric/hemic
S5-1-12-14	2	10 YR	6/4	sapric/hemic
S5-1-14-16	2	10 YR	6/4	sapric/hemic
S5-1-16-18	3	10 YR	7/4	sapric/hemic
S5-1-18-20	6	10 YR	8/2	clay till
S5-1-20-22	6	10 YR	8/2	clay till
S5-1-22-24	6	10 YR	8/2	clay till
S5-1-24-26	6	10 YR	8/2	clay till
S5-1-26-28	—	—	—	—
S5-1-28-30	—	—	—	—
S6-1-0-2	1	10 YR	4/3	sapric
S6-1-2-4	1	10 YR	4/3	sapric
S6-1-4-6	1	10 YR	4/3	sapric
S6-1-6-8	1	10 YR	4/3	sapric
S6-1-8-10	1	10 YR	4/3	sapric
S6-1-10-12	1	10 YR	4/3	sapric
S6-1-12-14	1	10 YR	4/3	sapric
S6-1-14-16	1	10 YR	4/3	sapric

Table C-2. Continued

Sample code	Pyrophosphate Index value	Munsell hue	Colour notation value/chroma	Hitosol classification
S6-1-16-18	2	10 YR	6/4	sapric
S6-1-18-20	1	10 YR	4/3	sapric
S6-1-20-22	1	10 YR	3/2	sapric
S6-1-22-24	1	10 YR	3/2	sapric
S6-1-24-26	1	10 YR	3/2	sapric
S6-1-26-28	—	—	—	—
S6-1-28-30	—	—	—	—
S7-1-0-2	4	10 YR	7/3	sapric/hemic
S7-1-2-4	3	10 YR	6/3	sapric/hemic
S7-1-4-6	4	10 YR	7/3	sapric/hemic
S7-1-6-8	2	10 YR	6/4	sapric/hemic
S7-1-8-10	2	10 YR	6/4	sapric/hemic
S7-1-10-12	2	10 YR	6/4	sapric/hemic
S7-1-12-14	3	10 YR	7/4	sapric/hemic
S7-1-14-16	2	10 YR	6/4	sapric/hemic
S7-1-16-18	2	10 YR	6/4	sapric/hemic
S7-1-18-20	2	10 YR	6/4	sapric/hemic
S7-1-20-22	2	10 YR	6/4	sapric/hemic
S7-1-22-24	2	10 YR	6/4	sapric/hemic
S7-1-24-26	2	10 YR	6/4	sapric/hemic
S7-1-26-28	2	10 YR	6/4	sapric/hemic
S7-1-28-30	2	10 YR	6/4	sapric/hemic
S8-1-0-2	1	10 YR	4/3	sapric
S8-1-2-4	1	10 YR	4/3	sapric
S8-1-4-6	2	10 YR	5/3	sapric
S8-1-6-8	2	10 YR	5/3	sapric
S8-1-8-10	—	—	—	—
S8-1-10-12	—	—	—	—
S8-1-12-14	1	10 YR	4/3	sapric
S8-1-14-16	1	10 YR	4/3	sapric
S8-1-16-18	2	10 YR	5/3	sapric
S8-1-18-20	2	10 YR	5/3	sapric
S8-1-20-22	2	10 YR	5/3	sapric
S8-1-22-24	2	10 YR	5/3	sapric
S8-1-24-26	2	10 YR	5/3	sapric
S8-1-26-28	2	10 YR	5/3	sapric
S8-1-28-30	2	10 YR	5/3	sapric

APPENDIX D

INITIAL VS. FINAL CONCENTRATION VALUES (C/C₀) FROM SEDIMENT CONTAMINATION EXPERIMENTS

LEACHATE ATTENUATION RATIO VALUES (C/C₀)

SAMPLE	HCUS	MG	NA	CA	K	FE	MN	CL	NO ₃	NH ₄	SO ₄	PO ₄
3UL125	0.10	0.00	0.00	0.00	0.00	0.20	0.00	0.18	0.00	0.00	0.00	0.02
3ULCT26	0.00	0.26	0.22	1.76	0.13	0.01	0.04	0.00	0.00	0.00	1.00	0.03
3ULCT31	0.41	0.28	0.43	1.13	0.01	0.01	0.04	0.76	0.00	0.00	0.00	1.00
3NUVU1	0.46	0.00	0.64	1.20	0.01	0.03	0.09	0.89	0.00	0.00	0.00	0.52
3NUV15	0.37	0.26	0.76	1.09	0.01	0.00	0.21	0.95	0.00	0.00	0.33	0.24
3NUV16	0.46	0.30	1.04	1.00	0.01	0.02	0.39	0.98	0.00	0.00	0.25	0.18
3NUV17	0.50	0.32	0.93	1.39	0.02	0.01	0.66	1.00	0.00	0.00	0.25	0.25
3NUV18	0.41	0.34	0.96	1.27	0.02	0.01	0.77	0.98	0.00	0.00	0.19	0.18
3NUV19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
3NUV20	0.00	0.36	1.05	1.24	0.04	0.03	0.92	1.11	0.00	0.00	0.00	0.50
3NUV25	0.00	0.35	1.10	1.13	0.06	0.10	0.35	1.00	0.00	0.00	0.00	1.00
3NUV26	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00
3NUV27	0.64	0.00	0.06	1.41	0.06	0.10	1.40	0.00	0.00	0.00	0.00	1.00
3UEC06	0.60	0.33	1.18	1.36	0.07	0.05	1.65	1.03	0.00	0.00	0.00	0.00
3UEC07	0.00	0.37	1.17	1.35	0.00	0.05	1.35	1.00	0.00	0.00	0.00	0.00
3JAN17	0.00	0.38	1.08	1.36	0.07	0.10	2.13	0.00	0.00	0.00	0.00	0.00
3JAN19	0.00	0.44	0.00	1.04	0.00	0.02	0.13	0.00	0.00	0.00	0.00	0.00
3JAN20	0.00	0.47	0.00	1.18	0.00	0.02	0.06	0.00	0.00	0.00	0.00	0.00
3JAN21	0.51	0.00	0.00	1.22	0.00	0.02	1.13	0.00	0.00	0.00	0.00	0.00
3FEB809	0.00	0.52	0.00	1.61	0.00	0.02	0.07	0.00	0.00	0.00	0.00	0.00
3FEB810	0.00	0.44	0.00	1.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
3FEB811	0.00	0.48	0.00	1.13	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
3FEB812	0.00	0.50	0.00	1.12	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
3FEB813	0.00	0.55	0.00	1.27	0.00	0.06	0.17	0.00	0.00	0.00	0.00	0.00
3FEB814	0.00	0.57	0.00	1.38	0.00	0.04	0.17	0.00	0.00	0.00	0.00	0.00
4BLCT25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4ULCT26	0.47	0.06	0.02	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
4UCU131	0.00	0.15	0.18	0.05	0.78	0.01	0.00	0.00	0.00	0.00	0.00	0.12
4NUVU1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
4NUV15	0.16	0.16	0.16	0.65	0.61	0.01	0.00	1.68	1.02	0.00	0.00	0.13
4NUV16	0.16	0.23	0.24	0.85	0.46	0.01	0.00	1.68	1.02	0.00	0.00	0.35
4NUV17	0.26	0.11	0.03	0.96	0.87	0.06	0.03	1.32	1.02	0.00	0.00	0.50
4NUV18	0.33	0.00	0.00	0.77	0.77	0.06	0.03	1.09	1.02	0.00	0.00	0.19
4NUV19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4NUV20	0.00	0.29	1.02	0.88	0.02	0.02	0.92	0.92	1.16	0.00	0.00	2.00
4NUV25	0.59	0.33	1.12	1.16	0.06	0.11	1.26	1.11	0.00	0.00	0.00	1.42
4NUV26	0.63	0.30	1.17	1.29	0.07	0.40	1.24	1.03	0.00	0.00	0.00	0.83
4NUV27	0.65	0.42	1.14	1.46	0.06	0.50	1.61	1.00	0.00	0.00	0.00	0.71
4UEC06	0.50	0.49	1.17	1.27	0.07	0.05	1.61	1.00	0.00	0.00	0.00	0.57
4UEC07	0.51	0.50	1.05	1.17	0.07	0.03	0.89	1.00	0.00	0.00	0.00	0.00
4UEC08	0.61	0.55	1.30	1.24	0.07	0.11	0.88	1.00	0.00	0.00	0.00	1.33
4JAN17	0.00	0.62	0.00	0.73	0.03	0.02	0.12	0.00	0.00	0.00	0.00	0.00
4JAN19	0.00	0.75	0.00	1.20	0.05	0.02	0.25	0.00	0.00	0.00	0.00	0.00
4JAN20	0.00	0.75	0.00	1.07	0.02	0.02	0.73	0.00	0.00	0.00	0.00	0.00
4JAN21	0.00	0.70	0.00	1.21	0.03	0.02	0.27	0.00	0.00	0.00	0.00	0.00
4FEB809	0.00	0.57	0.00	0.74	0.03	0.02	1.00	0.00	0.00	0.00	0.00	0.00
4FEB810	0.00	0.61	0.00	0.83	0.03	0.02	1.40	0.00	0.00	0.00	0.00	0.00
4FEB811	0.00	0.70	0.00	1.02	0.08	0.02	1.27	0.00	0.00	0.00	0.00	0.00
4FEB812	0.00	0.67	0.00	0.96	0.06	0.02	1.36	0.00	0.00	0.00	0.00	0.00
4FEB813	0.00	0.71	0.00	1.10	0.06	0.02	1.67	0.00	0.00	0.00	0.00	0.00
5ULCT25	0.04	0.37	0.08	0.87	0.09	0.05	0.00	0.00	0.05	0.00	0.00	0.36
5ULCT26	0.57	0.43	0.17	1.71	0.06	0.01	0.15	0.55	0.00	0.00	0.00	0.21
5ULCT31	0.64	0.58	0.30	1.43	0.07	0.03	1.38	0.54	0.00	0.00	0.00	2.27
5NUVU1	0.64	2.17	0.43	1.59	0.07	0.02	1.25	0.75	0.00	0.00	0.00	0.57
5NUV15	0.82	0.74	0.50	1.87	0.10	0.02	3.04	0.81	0.00	0.00	0.00	0.94
5NUV16	0.78	0.66	0.61	1.05	0.12	0.06	0.64	0.93	0.00	0.00	0.00	0.65
5NUV17	0.74	0.80	0.70	0.80	0.17	0.05	0.00	0.00	0.00	0.00	0.00	0.88
5NUV18	0.68	0.28	0.72	1.38	0.18	0.03	0.10	0.98	0.00	0.00	0.00	0.00
5NUV19	0.76	0.63	0.81	1.67	0.13	0.47	0.25	1.05	0.00	0.00	0.00	0.50
5NUV20	0.75	0.64	0.86	1.48	0.21	0.27	1.91	1.06	0.00	0.00	0.00	3.25
5NUV25	0.71	0.57	0.84	1.52	0.23	0.13	1.91	1.06	0.00	0.00	0.00	3.00
5NUV26	0.82	0.52	0.96	1.82	0.27	1.60	3.38	1.05	0.00	0.00	0.00	2.33
5NUV27	0.79	0.58	0.91	1.67	0.29	1.45	0.30	1.00	0.00	0.00	0.00	1.71
5UEC06	0.82	0.60	1.02	1.61	0.40	0.70	1.17	1.05	0.00	0.00	0.00	0.00
5UEC07	0.80	0.57	0.97	1.39	0.40	0.03	1.22	1.00	0.00	0.00	0.00	0.00
5UEC08	0.83	0.59	1.00	1.45	0.43	0.23	1.76	1.00	0.00	0.00	0.00	0.00
5JAN17	0.00	0.97	0.00	1.76	0.52	0.09	0.13	0.00	0.00	0.00	0.00	0.00
5JAN19	0.00	0.96	0.00	1.84	0.63	0.03	2.38	0.00	0.00	0.00	0.00	0.00
5JAN20	0.00	0.90	0.00	1.53	0.68	0.02	1.88	0.00	0.00	0.00	0.00	0.00
5JAN21	0.00	0.85	0.00	1.87	0.66	0.02	1.61	0.00	0.00	0.00	0.00	0.00
5FEB09	0.00	0.90	0.00	1.70	0.66	0.10	2.13	0.00	0.00	0.00	0.00	0.00
5FEB10	0.00	0.86	0.00	1.66	0.67	0.06	2.25	0.00	0.00	0.00	0.00	0.00
5FEB11	0.00	0.79	0.00	1.62	0.68	0.03	1.94	0.00	0.00	0.00	0.00	0.00
5FEB12	0.00	0.74	0.00	1.39	0.67	0.09	2.00	0.00	0.00	0.00	0.00	0.00
5FEB13	0.00	0.73	0.00	1.48	0.69	0.06	2.25	0.00	0.00	0.00	0.00	0.00

LEACHATE ATTENUATION RATIO VALUES (%/L)

SAMPLE	HCO3	Mg	Na	Ca	K	Fe	Mn	Cl	NO3	NH4	SO4	Po4
6UC125	0.54	0.11	0.34	0.66	0.06	0.04	0.00	0.38	0.00	0.00	0.00	0.58
6UC130	0.38	0.15	0.09	1.55	0.04	0.02	0.44	0.00	0.00	0.00	0.00	0.28
6UC131	0.41	0.19	0.24	1.09	0.04	0.03	0.43	0.00	0.00	0.00	1.00	2.73
6NUV01	0.41	0.20	0.35	1.32	0.07	0.11	0.64	0.00	0.00	0.00	0.00	0.53
6NUV15	0.41	0.20	0.52	1.43	0.12	0.02	0.93	0.00	0.00	0.00	1.38	1.76
6NUV19	0.39	0.24	0.51	1.26	0.33	0.04	1.00	0.00	0.00	0.00	1.00	1.18
6NUV18	0.38	0.20	0.59	1.04	0.24	0.01	1.10	0.00	0.00	0.00	1.19	0.91
6NUV19	0.38	0.20	0.67	1.33	0.31	0.12	1.11	0.00	0.00	0.00	1.25	6.50
6NUV20	0.39	0.21	0.71	1.08	0.32	0.04	1.11	0.00	0.00	0.00	1.75	3.00
6NUV22	0.38	0.18	0.75	1.26	0.34	0.11	1.10	0.00	0.00	0.00	1.50	3.00
6NUV26	0.44	0.14	0.89	1.26	0.39	0.48	1.03	0.00	0.00	0.00	1.00	2.57
6NUV27	0.46	0.17	0.88	1.28	0.45	0.56	1.03	0.00	0.00	0.00	0.00	0.00
6DEC06	0.45	0.18	1.01	1.11	0.64	0.02	1.14	0.00	0.00	0.00	0.00	0.00
6DEC07	0.47	0.21	1.06	1.19	0.64	0.11	1.12	0.00	0.00	0.00	0.00	0.57
6DEC08	0.42	0.29	1.00	1.07	0.89	0.12	1.00	0.00	0.00	0.00	0.00	0.00
6JAN17	0.00	0.30	0.00	1.11	0.98	0.22	1.19	0.00	0.00	0.00	0.00	0.00
6JAN19	0.00	0.26	0.00	1.04	1.02	0.02	1.06	0.00	0.00	0.00	0.00	0.00
6JAN20	0.00	0.29	0.00	1.04	1.02	0.02	1.06	0.00	0.00	0.00	0.00	0.00
6JAN21	0.00	0.29	0.00	1.29	1.12	0.02	1.19	0.00	0.00	0.00	0.00	0.00
6FEB09	0.00	0.28	0.00	1.06	1.11	0.02	1.06	0.00	0.00	0.00	0.00	0.00
6FEB10	0.00	0.28	0.00	1.18	1.16	0.02	1.14	0.00	0.00	0.00	0.00	0.00
6FEB11	0.00	0.28	0.00	1.18	1.16	0.02	1.14	0.00	0.00	0.00	0.00	0.00
6FEB12	0.00	0.31	0.00	1.26	1.19	0.04	1.25	0.00	0.00	0.00	0.00	0.00
6FEB13	0.00	0.31	0.00	1.26	1.19	0.04	1.14	0.00	0.00	0.00	0.00	0.00
7UC125	0.57	0.31	0.03	0.81	0.16	0.01	0.00	0.14	0.00	0.00	0.00	0.20
7UC126	0.58	0.36	0.11	1.80	0.07	0.01	0.96	0.00	0.00	0.00	0.00	0.64
7UC131	0.67	0.42	0.14	1.30	0.04	0.02	1.96	0.00	0.00	0.00	0.00	1.25
7NUV01	0.65	0.51	0.27	1.73	0.06	0.13	1.54	0.00	0.00	0.00	0.00	0.77
7NUV15	0.69	0.69	0.40	2.26	0.12	0.01	1.72	0.00	0.00	0.00	0.00	1.60
7NUV17	0.79	0.59	0.54	1.78	0.08	0.11	1.95	0.00	0.00	0.00	0.00	0.71
7NUV18	0.69	0.63	0.59	1.50	0.00	0.03	1.71	0.00	0.00	0.00	0.00	0.55
7NUV19	0.78	0.76	0.79	1.86	0.00	0.23	1.58	0.00	0.00	0.00	0.00	2.67
7NUV20	0.75	0.72	0.81	1.64	0.00	0.08	1.08	0.00	0.00	0.00	0.00	4.00
7NUV25	0.83	0.46	1.05	1.77	0.00	0.50	0.05	0.00	0.00	0.00	0.00	3.25
7NUV27	0.77	0.51	1.02	1.66	0.00	0.54	1.63	0.00	0.00	0.00	0.00	1.71
7DEC06	0.80	0.50	1.32	1.48	0.00	0.11	1.91	0.00	0.00	0.00	0.00	0.42
7DEC07	0.78	0.49	0.99	1.52	0.00	0.08	1.91	0.00	0.00	0.00	0.00	1.33
7DEC08	0.80	0.84	0.00	1.80	0.00	0.02	1.90	0.00	0.00	0.00	0.00	0.00
7JAN17	0.00	0.85	0.00	1.76	0.00	0.02	1.90	0.00	0.00	0.00	0.00	0.00
7JAN19	0.00	0.81	0.00	1.95	0.00	0.02	1.90	0.00	0.00	0.00	0.00	0.00
7JAN20	0.00	0.74	0.00	1.64	0.00	0.06	1.90	0.00	0.00	0.00	0.00	0.00
7JAN21	0.00	0.78	0.00	1.68	0.00	0.04	1.38	0.00	0.00	0.00	0.00	0.00
7FEB10	0.00	0.75	0.00	1.68	0.00	0.11	1.63	0.00	0.00	0.00	0.00	0.00
7FEB11	0.00	0.70	0.00	1.67	0.66	0.05	1.63	0.00	0.00	0.00	0.00	0.00
7FEB12	0.00	0.64	0.00	1.41	0.70	0.09	1.94	0.00	0.00	0.00	0.00	0.00
7FEB13	0.00	0.63	0.05	0.82	0.09	0.04	1.45	0.00	0.00	0.00	0.00	0.48
8UCT25	0.57	0.25	0.08	1.71	0.10	0.01	0.96	0.00	0.00	0.00	0.00	0.32
8UCT26	0.54	0.02	0.11	1.39	0.03	0.05	0.60	0.00	0.00	0.00	0.00	0.86
8UCT31	0.57	0.42	0.19	1.73	0.06	0.05	0.60	0.00	0.00	0.00	0.00	2.38
8NUV01	0.67	0.50	0.27	2.00	0.06	0.02	0.48	0.00	0.00	0.00	0.00	0.71
8NUV15	0.69	0.50	0.37	1.15	0.09	0.04	0.48	0.00	0.00	0.00	0.00	0.65
8NUV16	0.66	0.48	0.48	1.78	0.10	0.02	0.50	0.00	0.00	0.00	0.00	0.69
8NUV17	0.66	0.48	0.57	1.42	0.12	0.01	0.85	0.00	0.00	0.00	0.00	0.55
8NUV18	0.58	0.19	0.67	1.71	0.15	0.13	1.58	0.00	0.00	0.00	0.00	4.33
8NUV19	0.66	0.83	0.71	1.44	0.18	0.13	1.11	0.00	0.00	0.00	0.00	4.50
8NUV20	0.65	0.42	0.71	1.44	0.18	0.13	1.11	0.00	0.00	0.00	0.00	2.00
8NUV25	0.61	0.37	0.69	1.52	0.19	0.11	1.69	0.00	0.00	0.00	0.00	1.80
8NUV26	0.69	0.35	0.88	1.74	0.25	0.56	1.95	0.00	0.00	0.00	0.00	2.33
8NUV27	0.67	0.35	0.93	1.61	0.28	0.70	1.00	0.00	0.00	0.00	0.00	2.14
8UEL06	0.68	0.35	0.99	1.43	0.40	0.05	1.78	0.00	0.00	0.00	0.00	1.71
8UEL07	0.66	0.34	0.95	1.26	0.43	0.03	0.97	0.00	0.00	0.00	0.00	1.33
8UEL08	0.68	0.34	0.92	1.36	0.46	0.11	1.48	0.00	0.00	0.00	0.00	0.00
8JAN17	0.00	0.68	0.00	1.82	0.54	0.09	1.68	0.00	0.00	0.00	0.00	0.00
8JAN19	0.00	0.68	0.00	1.78	0.75	0.07	2.00	0.00	0.00	0.00	0.00	0.00
8JAN20	0.00	0.64	0.00	1.71	0.88	0.05	1.75	0.00	0.00	0.00	0.00	0.00
8JAN21	0.00	0.53	0.00	1.74	0.76	0.03	1.44	0.00	0.00	0.00	0.00	0.00
8FEB09	0.00	0.61	0.00	1.66	0.80	0.12	1.75	0.00	0.00	0.00	0.00	0.00
8FEB10	0.00	0.60	0.00	1.68	0.92	0.11	1.94	0.00	0.00	0.00	0.00	0.00
8FEB11	0.00	0.55	0.00	1.64	0.90	0.05	1.63	0.00	0.00	0.00	0.00	0.00
8FEB12	0.00	0.47	0.00	1.24	0.90	0.19	1.50	0.00	0.00	0.00	0.00	0.00
8FEB13	0.00	0.44	0.00	1.31	0.89	0.08	1.38	0.00	0.00	0.00	0.00	0.00

APPENDIX E

RESULTS FROM CONTAMINANT REMOBILIZATION EXPERIMENTS USING SIMULATED RAINWATER

The following table contains the analytical results for all of the samples collected during the remobilization experiments.

RAINWATER REMOBILIZATION EXPERIMENT DATA

SAMPLE CODE	LITRE SAMPLE	TIME MINUTES	EH PROBE 1 MV	EH PROBE 2 MV	EH PROBE 3 MV	PH PROBE 1	PH PROBE 2	CA	MG	NA	K
								-----	MG/LITRE	-----	-----
\$5-000		0.08	220	220		5.7	6.0				
\$5-001	00	0.00	220	220		5.8	6.1	14.0	0.1	1.0	0.5
\$5-002		0.50	220	220		5.8	6.0				
\$5-003		0.80	220	220		5.9	6.0				
\$5-004		1.00	220	220		6.1	6.0				
\$5-005		1.25	220	220		6.2	6.0				
\$5-006		1.42	220	220		6.3	6.1				
\$5-007		1.50	220	220		6.3	6.1				
\$5-008		1.67	220	220		6.3	6.1				
\$5-009		1.75	220	220		6.3	6.1				
\$5-010		1.92	220	220		6.4	6.1				
\$5-011		2.17	220	220		6.4	6.1				
\$5-012		2.42	220	220		6.4	6.1				
\$5-013		2.58	220	220		6.4	6.1				
\$5-014		2.75	220	220		6.4	6.1				
\$5-015	01	3.17	220	220		6.2	6.2	70.0	10.2	70.0	17.5
\$5-016		3.67	225	225		6.0	6.2				
\$5-017		4.33	230	225		5.9	6.2				
\$5-018		4.83	232	225		5.9	6.3				
\$5-019		5.50	232	225		5.9	6.3				
\$5-020		6.17	237	217		5.9	6.4				
\$5-021	02	6.50	237	217		5.9	6.4	10.0	18.0	10.0	25.7
\$5-022		6.83	237	217		5.9	6.4				
\$5-023		7.58	240	215		5.9	6.5				
\$5-024		8.33	240	215		5.9	6.5				
\$5-025		9.00	240	215		5.9	6.5				
\$5-026		9.50	240	210		5.9	6.5				
\$5-027	03	9.83				5.9	6.6	90.0	14.5	92.0	24.5
\$5-028		10.00	242	212		5.9	6.6				
\$5-029		12.00	245	215		5.9	6.6				
\$5-030	04	13.42				5.8	6.7	65.0	9.9	79.0	20.0
\$5-031		14.00	250	215		5.8	6.7				
\$5-032	05	16.00	255	217		5.8	6.8	48.0	7.6	65.0	17.7
\$5-033		16.92				5.7	6.8				
\$5-034		18.00	257	217		5.8	6.8				
\$5-035		20.00	260	220		5.7	6.8				
\$5-036	06	20.83				5.7	6.8	40.0	6.3	57.0	16.0
\$5-037		22.00	260	220		5.7	6.8				
\$5-038		24.00	260	220		5.7	6.8				
\$5-039	07	24.55				5.7	6.8	33.5	5.1	49.0	14.2
\$5-040		26.00	260	220		5.7	6.8				
\$5-041		28.00	260	220		5.8	6.8				
\$5-042	08	28.75				5.8	6.8	28.5	4.4	42.0	13.4
\$5-043		30.00	260	220		5.9	6.8				
\$5-044		32.00	262	220		5.9	6.9				
\$5-045	09	32.50				5.9	6.9	25.0	3.7	38.0	11.8
\$5-046		34.00	265	220		5.8	6.9				
\$5-047		36.00	262	220		5.7	6.9				
\$5-048	10	36.33				5.9	6.9	23.5	3.3	36.0	11.2
\$5-049		38.00	262	220		5.7	6.9				
\$5-050		40.00	262	222		5.7	7.0	21.0	2.9	32.0	10.4
\$5-051	11	40.08				5.7	7.0				
\$5-052		42.00	262	222							

RAINWATER REMOBILIZATION EXPERIMENT DATA

SAMPLE CODE	LITRE SAMPLE	TIME MINUTES	EH PROBE MV	EH PROBE MV	EH PROBE MV	PH PROBE 1	PH PROBE 2	CA ----- MG MG/LITRE-----	MG NA ----- K-----
SS-U23	12	43.83						20.0	2.7
SS-U54		44.00	262	222		5.7	7.0	30.0	9.7
SS-U55		46.00	262	225		5.7	7.0	29.0	9.5
SS-U56	13	47.92				5.7	7.0	19.0	2.5
SS-U57		48.00	262	227		5.7	7.0	27.0	9.3
SS-U58		50.00	262	230		5.7	7.0	25.0	9.3
SS-U59	14	51.83				5.7	7.0	13.0	2.3
SS-U60		52.00	262	230		5.7	7.0	16.5	2.2
SS-U61		54.00	262	230		5.7	7.0	24.0	9.3
SS-U62	15	55.92				5.7	7.0	16.0	2.1
SS-U63		56.00	262	230		5.7	7.0	23.0	7.9
SS-U64		58.00	265	230		5.7	7.0	15.0	2.0
SS-U65		60.00	265	230		5.7	7.0	15.0	1.9
SS-U66	16	60.67				5.7	7.0	21.0	8.7
SS-U67		62.00	265	230		5.7	7.0	20.0	7.4
SS-U68		64.00	265	300		5.7	7.0	14.5	1.8
SS-U69	17	64.45				5.8	7.0	20.0	7.4
SS-U70		66.00	265	228		5.7	7.0	15.0	2.0
SS-U71		68.00	265	225		5.7	7.0	22.0	8.8
SS-U72	18	68.92				5.7	7.0	15.0	1.9
SS-U73		70.00	265	225		5.7	7.1	21.0	8.7
SS-U74		72.00	265	222		5.7	7.0	20.0	7.4
SS-U75	19	73.25				5.7	7.0	14.5	1.8
SS-U76		74.00	265	222		5.7	7.0	20.0	7.4
SS-U77		76.00	265	225		5.7	7.0	14.5	1.8
SS-U78	20	77.58				5.7	7.0	20.0	7.4
SS-U79		78.00	265	225		5.7	7.0	14.5	1.8
SS-U80		80.00	268	225		5.7	7.0	20.0	7.4
SS-U81		81.00				5.7	7.0	14.5	1.8
SS-U82		82.00	270	225		5.7	7.0	20.0	7.4
SS-U83	21	82.33	260	225		5.7	7.0	14.5	1.8
SS-U84		83.20	260	225		5.7	7.0	20.0	7.4
SS-U85		84.00	260	230		5.9	7.1		
SS-U86		86.00	262	222		6.1	7.1		
SS-U87		86.20				6.3			
SS-U88		86.33				6.4			
SS-U89		86.42				6.5			
SS-U90		86.75				6.7			
SS-U91		86.92				6.8			
SS-U92		87.00				6.9			
SS-U93		87.42	262	238		6.9	7.1		
SS-U94		88.00	260	238		6.6	7.1		
SS-U95		88.50				6.7	7.0		
SS-U96		88.58	260	240		6.8	7.1		
SS-U97		88.92				6.9			
SS-U98		89.50	260	240		6.6	7.1		
SS-U99	22	90.00	260	240		6.7	7.1	14.5	1.9
S6-U00	00	0.00	270	240		6.8	6.7	14.0	0.7
S6-U01		0.50	260	240		6.9	6.7	10.0	4.7
S6-U02		0.67	260	240		6.9	6.7	10.0	2.5
S6-U03		1.00	260	240		6.9	6.7	9.8.0	3.4.5
S6-U04	02	1.50	265	240		6.9	6.7	05.0	8.8
S6-U05		1.75	272	240		6.8	6.7		
S6-U06		2.00	280	237		6.8	6.7		
S6-U07		2.50	280	235		6.7	6.7		
S6-U08	03	2.67						08.0	9.6
S6-U09		3.00	277	235		6.7	6.8	09.0	09.0
S6-U10		3.50	298	230		6.6	6.8	90.0	7.3
S6-U11	04	4.00	300	230		6.6	6.8	91.0	35.0
S6-U12		4.50	305	230		6.6	6.9		

RAINWATER REMOBILIZATION EXPERIMENT DATA

SAMPLE CODE	LITRE SAMPLE	TIME MINUTES	FH MV	EH PROBE 1 MV	EH PROBE 2 MV	EH PROBE 3 MV	PH PROBE 1	PH PROBE 2	CA	MG MG/LITRE	NA	K
S6-U13	05	5.50	300	223			6.5	6.9	65.0	5.4	77.0	29.0
S6-U14		6.00	310	225			6.5	6.9	47.5	4.2	63.0	24.5
S6-U15	06	6.15					6.5	6.9				
S6-U16		7.00	320	225			6.5	6.9				
S6-U17	07	7.17					6.4	7.0	39.5	3.5	56.0	22.5
S6-U18		8.00	320	222			6.4	7.0	36.0	3.0	49.0	21.0
S6-U19	08	8.33					6.4	7.0				
S6-U20		9.00	320	220			6.4	7.0	31.0	2.6	45.0	18.0
S6-U21	09	9.33					6.3	7.0				
S6-U22		10.00	320	220			6.4	7.0				
S6-U23		11.00	310	220			6.5	6.9	26.5	2.2	41.0	16.5
S6-U24	10	11.17					6.5	6.9	28.5	2.4	41.0	16.5
S6-U25		12.00	320	220			6.5	6.9	24.0	2.0	37.0	15.0
S6-U26	11	12.33					6.4	6.9	21.5	1.7	33.0	13.5
S6-U27		13.00	320	220			6.3	6.9	19.5	1.5	30.0	12.5
S6-U28	12	13.50					6.2	7.0	17.0	1.3	26.0	10.8
S6-U29		14.00	337	220			6.1	6.9	16.0	1.2	25.0	10.3
S6-U30	13	14.67					6.1	6.9	15.5	1.2	23.0	9.5
S6-U31		15.00	340	220			6.0	6.9	17.0	1.2	22.0	9.3
S6-U32	14	15.83					6.0	6.9	17.0	1.1	20.0	8.7
S6-U33		16.00	342	220			6.0	6.9	16.5	1.0	20.0	8.7
S6-U34	15	17.00	345	220			6.0	6.9	16.5	1.0	20.0	8.7
S6-U35		18.00	345	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U36	16	18.17					6.0	6.9	16.5	1.0	20.0	8.7
S6-U37		19.00	345	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U38	17	19.33					6.0	6.9	16.5	1.0	20.0	8.7
S6-U39		20.00	350	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U40	18	20.50					6.0	6.9	16.5	1.0	20.0	8.7
S6-U41		21.00	350	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U42	19	21.67					6.0	6.9	16.5	1.0	20.0	8.7
S6-U43		22.00	350	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U44	20	22.83					6.0	6.9	16.5	1.0	20.0	8.7
S6-U45		23.00	355	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U46	21	24.00	355	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U47		25.00	355	215			6.0	6.9	16.5	1.0	20.0	8.7
S6-U48		25.50	355	212			6.0	6.9	16.5	1.0	20.0	8.7
S6-U49		25.75	340	210			6.0	6.9	16.5	1.0	20.0	8.7
S6-U50		26.00	345	210			6.0	6.9	16.5	1.0	20.0	8.7
S6-U51	22	26.50	350	215			6.0	7.1	16.0	1.0	20.0	8.3
S6-U52		27.00	360	215			6.1	7.1				
S6-U53		27.50	360	215			6.1	7.2				
S6-U54		28.00	355	215			6.1	7.2				
S6-U55		28.50	355	215			6.1	7.2				
S6-U56		29.00	355	215			6.1	7.3				
S6-U57		29.50	355	215			6.2	7.3				
S6-U58		30.00	355	215			6.2	7.4				

RAINWATER REMOBILIZATION EXPERIMENT DATA

SAMPLE CODE	LITRE SAMPLE	TIME MINUTES	EH	PROBE 1	EH	PROBE 2	EH	PROBE 3	PH	PROBE 1	PH	PROBE 2	CA	MG	NA	K
			MV	MV	----- MG/MG/LITRE-----	14.0	0.1	1.0								
S8-000	00	0.00														
S8-001		0.50														
S8-002		1.00	240		270		180		6.7		6.7					
S8-003		1.50														
S8-004		2.00	250		270		180		6.7		6.7					
S8-005		2.50														
S8-006		3.00	240		270				6.7		6.7					
S8-007		3.50														
S8-008		4.00	240		270		180		6.7		6.7					
S8-009		4.50														
S8-010		5.00	240		265		180		6.7		6.7					
S8-011	01	6.00	240		260		180		6.8		6.7		47.0	4.0	57.0	18.5
S8-012		7.00	240		260		185		6.8		6.7					
S8-013		8.00	235		255		185		6.9		6.7					
S8-014		9.00	235		255		180		6.9		6.7					
S8-015	02	10.00	235		255		182		6.9		6.7		79.0	6.5	82.0	27.5
S8-016		11.00	230		255		180		6.9		6.7					
S8-017		12.00	230		252		180		6.9		6.7					
S8-C18		13.00	230		250		180		6.9		6.7					
S8-C19		14.00	230		250		180		6.9		6.7					
S8-020		15.00	230		250		180		6.9		6.7					
S8-021		16.00	230		250		180		6.9		6.8					
S8-022	03	16.10											89.0	7.4	91.0	31.0
S8-023		17.00	230		250		180		6.9		6.8					
S8-024		18.00	230		250		180		6.9		6.8					
S8-025		19.00	232		250		178		6.9		6.9					
S8-026		20.00	232		258		178		6.9		6.9					
S8-027	04	21.33											70.0	6.1	81.0	28.5
S8-028		22.00	235		258		178		6.9		6.9					
S8-029		24.00	240		258		178		6.9		6.9					
S8-030		26.00	240		260		178		6.9		6.9					
S8-C31	05	26.83											52.0	4.5	71.0	25.0
S8-C32		28.00	240		260		178		6.9		7.0					
S8-C33		30.00	240		260		178		6.8		7.0					
S8-034		32.00	240		260		178		6.8		7.0					
S8-035	06	32.17											39.0	3.3	59.0	21.0
S8-036		34.00	240		260		178		6.8		7.0					
S8-037		36.00	240		260		178		6.8		7.0					
S8-038	07	37.50											30.0	2.5	50.0	17.5
S8-039		38.00	242		260		178		6.8		7.0					
S8-040		40.00	245		260		178		6.8		7.1					
S8-041		42.00	250		260		178		6.8		7.1					
S8-042	08	43.00											5.0	2.0	43.0	16.0
S8-043		44.00	250		262		178		6.8		7.1					
S8-044		46.00	250		262		178		6.8		7.1					
S8-045		48.00	250		262		180		6.8		7.1					
S8-C46	09	48.50											1.0	1.6	37.0	14.0
S8-C47		50.00	250		262		178		6.8		7.2					
S8-C48		52.00	260		270		178		6.8		7.2					
S8-C49	10	53.50											8.0	1.5	34.0	12.5
S8-050		54.00	260		270		180		6.8		7.4					
S8-051		56.00	260		270		180		6.8		7.4					
S8-052		58.00	262		275		180		6.8		7.5					

RAINFALL REMOBILIZATION EXPERIMENT DATA

SAMPLE CODE	LITRE SAMPLE	TIME MINUTES	EH PROBE 1 MV	EH PROBE 2 MV	EH PROBE 3 MV	PH PROFILE 1	PH PROFILE 2	CA -----MG/LITRE-----	MG	NA	K
S8-053	11	60.00	262	275	180	6.8	7.5	13.0	1.4	32.0	11.3
S8-054	12	63.00	260	272	180	6.8	7.5	12.0	1.0	28.0	10.5
S8-055		64.00	260	273	180	6.8	7.5				
S8-056		66.00	260	275	180	6.8	7.5				
S8-058	13	67.50	260	275	180	6.8	7.5	11.0	0.9	26.0	10.0
S8-059		68.00	260	275	180	6.8	7.5				
S8-060	14	70.00	260	275	180	6.8	7.5	10.0	0.8	25.0	9.5
S8-061		71.50	260	275	180	6.8	7.5				
S8-062		72.00	260	275	180	6.8	7.5				
S8-063		74.00	260	275	180	6.8	7.5				
S8-064		76.00	260	275	180	6.8	7.5				
S8-065	15	76.33	262	278	180	6.8	7.4	9.0	0.8	23.0	9.0
S8-066		78.00	262	277	182	6.8	7.4				
S8-067		80.00	265	277	182	6.8	7.4				
S8-068	16	80.83	265	280	185	6.8	7.4	9.0	0.7	23.0	8.5
S8-069		82.00	265	280	185	6.8	7.4				
S8-070		84.00	265	280	185	6.8	7.4				
S8-071	17	85.42	270	280	185	6.8	7.4	9.0	0.7	22.0	8.5
S8-072		86.00	270	280	185	6.8	7.4				
S8-073		88.00	270	280	185	6.8	7.4				
S8-074		90.00	270	280	187	6.8	7.4				
S8-075	18	90.42	270	280	187	6.8	7.4	8.0	0.7	21.0	8.0
S8-076		92.00	270	280	187	6.8	7.4				
S8-077		94.00	270	280	190	6.8	7.4				
S8-078	19	94.92	270	280	190	6.8	7.4	8.0	0.7	22.0	8.0
S8-079		96.00	270	280	190	6.8	7.4				
S8-080		98.00	275	280	190	6.8	7.4				
S8-081	20	99.22			190	6.8	7.4	8.0	0.6	20.0	8.0
S8-082		100.00	275	280	190	6.8	7.4				
S8-083		102.00	277	280	190	6.8	7.4				
S8-084		104.00	277	280	190	6.8	7.4				
S8-085	21	104.83			190	6.8	7.4	8.0	0.6	20.0	8.0
S8-086		106.00	277	280	195	6.8	7.4				
S8-087		108.00	277	280	195	6.8	7.4				
S8-088	22	109.83			195	6.8	7.4	8.0	0.6	19.0	7.5
S8-089		110.00	277	280	197	6.8	7.4				
S8-090		112.00	280	280	197	6.8	7.4				
S8-091	23	114.00	280	280	197	6.8	7.4	7.0	0.6	19.0	7.5
S8-092		115.33			197	6.8	7.4				
S8-093		116.00	280	280	200	6.8	7.4				
S8-094		118.00	280	280	200	6.8	7.4				
S8-095		120.00	280	280	200	6.8	7.4				
S8-096	24	120.17			200	6.8	7.4	7.0	0.6	17.0	7.5
S8-097		122.00	280	285	200	6.8	7.4				
S8-098		124.00	280	285	200	6.8	7.4	7.0	0.6	17.0	7.5
S8-099	25	125.67			200	6.8	7.4	7.0	0.6	17.0	7.5
S8-100		126.00	282	285	200	6.8	7.4				
S8-101		128.00	282	285	200	6.9	7.4				
S8-102		130.00	282	285	200	6.9	7.4				
S8-103	26	130.25			200	6.9	7.4	7.0	0.5	15.0	7.0
S8-104		132.00	282	287	200	6.9	7.4				
S8-105		134.00	282	287	200	6.9	7.4				
S8-106	27	135.00			200	6.9	7.4	7.0	0.5	15.0	7.0
S8-107		136.00	282	287	200	6.9	7.4				
S8-108		138.00	282	287	200	6.9	7.4				
S8-109	28	138.83			200	6.9	7.4	8.0	0.5	15.0	7.0
S8-110		140.00	285	290	200	6.9	7.4				
S8-111		142.00	282	290	200	6.9	7.4				
S8-112		144.00	287	292	205	6.9	7.4				

RAINWATER REMOBILIZATION EXPERIMENT DATA

SAMPLE CODE	LITRE SAMPLE	TIME MINUTES	EH PROBE 1 MV	EH PROBE 2 MV	EH PROBE 3 MV	PH PROBE 1 MV	PH PROBE 2 MV	CA ----- MG/LITRE-----	MG NA ----- K-----
88-113	29	144.33	287	292	295	6.9	7.4	7.0	0.5 14.0 7.0
88-115	30	148.00	287	292	295	6.9	7.4	7.0	0.5 14.0 7.0
88-116		150.00	287	292	295	6.9	7.4	7.0	0.5 14.0 7.0
88-117	31	155.00	287	292	295	6.9	7.4	7.0	0.5 14.0 7.0
88-118		160.00	287	292	297	6.9	7.3	7.0	0.5 14.0 7.5
88-119	32	160.87							
88-120		165.00	287	295	297	6.9	7.3	7.0	0.5 13.0 7.0
88-121	33	166.00							
88-122		170.00	287	295	297	6.9	7.3	7.0	0.5 13.0 7.0
88-123	34	171.00							
88-124		175.00	290	295	297	6.9	7.2	7.0	0.6 13.0 7.0
88-125	35	176.08							
88-126		180.00	290	295	297	7.0	7.3	7.0	0.5 12.0 7.0
88-127	36	180.92							
88-128		185.00	290	295	297	7.0	7.3	7.0	0.6 12.0 7.0
88-129	37	185.83							
88-130		190.00	290	295	297	7.0	7.3	7.0	0.6 12.0 7.0
88-132	38	190.67							
88-133		195.00	290	295	297	7.0	7.3	7.0	0.5 12.0 7.0
88-134	39	195.33							
88-135	40	200.00	292	295	297	7.0	7.3	7.0	0.5 11.0 7.0
88-136	41	205.17							
88-137	42	210.50	295	297	297	7.0	7.3	7.0	0.5 10.0 7.0
88-138	43	216.33							
88-139	44	221.33	295	297	297	7.0	7.2	7.0	0.6 10.0 6.5
88-140	45	226.92							
88-141	46	231.75	297	297	297	7.0	7.2	7.0	0.6 10.0 7.0
88-142	47	236.42							
88-143	48	241.08	297	297	297	7.0	7.2	8.0	0.6 9.0 6.5
88-144	49	245.33							
88-145	50		297	297	300	7.0	7.2	8.0	0.6 8.0 6.5
88-146	51	255.17						8.0	0.7 8.0 6.5
88-147		252.00	300	320	320	7.1	7.3		
88-148		257.00	295	310	320	7.3	7.5		
88-149		257.50	300	315	320	7.3	7.5		
88-150		258.50	300	315	320	7.2	7.4		
88-151		259.50	300	320	320	7.2	7.3		
88-152		260.50	300	320	320	7.2	7.4		
88-153		261.50	300	325	320	7.2	7.4		
88-154		262.50	300	325	320	7.2	7.4		
88-155		263.50	300	325	320	7.2	7.5		
88-156		264.50	295	320	320	7.3	7.4		
88-157		266.00							
88-158		267.00							
88-159		268.00							
88-160		269.00							
88-161		270.00							
88-162		271.00							
88-163		272.00							
88-164		273.00							
88-165		274.00							
88-166		275.00							

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