GEOLOGICAL SURVEY OF CANADA

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ANALYSIS OF NORMAN WELLS CORE SAMPLES FINAL REPORT

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ENERGY, MINES AND RESOURCES

D.E. Patterson, D.W. Riseborough and M.W. Smith

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FOREWORD

This report documents work undertaken as part of the federal government's Permafrost and Terrain Research and Monitoring Program along the 868 km Norman Wells to Zama oil pipeline. The 324 mm diameter, shallow burial (1 m) pipeline, traverses the discontinuous permafrost zone of northwestern Canada and began operation in April 1985. A joint monitoring program with Interprovincial Pipe Lines (NW) Ltd. was established following the signing of an environmental agreement between the pipeline company and the Department of Indian and Northern Affairs (INAC) in 1983. INAC coordinates the government's monitoring program in which Energy, Mines and Resources' Geological Survey of Canada, the National Research Council's Institute for Research in Construction, and Agriculture Canada's Land Resource Research Institute participate.

A major component of this research and monitoring program involves the detailed quantification of changes in the ground thermal regime and geomorphic conditions at thirteen instrumented sites along the route. This project was developed in cooperation with the Permafrost Research Section of the Geological Survey in order to examine and quantify the effects of pipeline construction, operation and maintenance in thaw sensitive terrain. Many components of this research are contracted out.

The work undertaken in this contract report describes but one aspect of these site investigations. Interpretations contained herein are often limited to the specific data base under analysis and may thus not present an integrated or comprehensive analysis of all site observations. The opinions and views expressed by the authors are their own and do not necessarily reflect those of the Geological Survey of Canada or Indian and Northern Affairs.

Funding for the research and analyses reported herein was largely provided by INAC's Northern Affairs Program, with contributions from the Northern Oil and Gas Action Program (NOGAP).

Margo Burgess
Scientific Authority
Permafrost Research Section
Geological Survey of Canada

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Analysis of Norman Wells Core Samples

1 Introduction

During 1985, a series of soil specimens were obtained from boreholes along the right-of-way of the Norman Wells NWT to Zama Alta oil pipeline. This report summarizes the findings of a preliminary phase study to determine the physical, thermal and electrical properties of these specimens.

Table 1.1 gives the location of the boreholes where the specimens were obtained and the approximate depth of the borehole. It should be noted that core specimens were not necessarily recovered over the entire depth indicated.

Table 1.1 Borehole Locations

Site		Distance from Norman Wells (km)	Distance from Pipeline Axis (m)	Depth (m)
Table Mountain	7A	270.8	10.0 West	20.1
	7B	271.5	7.3 W	20.3
	7C	271.8	7.8 W	18.0
Manner's Creek	8A	556.9	5.3 W	20.9
	8B	557.2	5.9 W	20.9
	8C	557.4	5.55 W	20.9
Pump Station	9	582.5	7.8 W	1.4
Mackenzie Highway South	10A	587.5	10.2 E	5.6
	10B	587.9	11.0 E	5.2
Moraine South	11	596.6	8.8 E	14.2
Jean Marie Creek	12A	607.7	9.3 E	10.9
	12B	607.9	8.9 E	12.5

The coring and borehole logging was done by Hardy and

Associates (1978). A CRREL corer (see Brockett and Lawson, 1985) was generally used to recover specimens. A borehole log for the specimens was obtained during the coring operation. The specimens were shipped to Ottawa in the frozen state and are currently stored in a cold room, maintained at -10 C, at Carleton University.

The tasks undertaken by the authors included:

1. production of two copies of a photographic record of the soil specimens;

2. production of a video record of the soil specimens;

3. obtaining an initial estimate of total density for all specimens;

4. production of a core log and sample description of all samples using the NRC ice classification system, to serve as a companion to the field description;

5. analysis of the potential of non-intrusive TDR techniques to obtain a dielectric constant record of the soil specimens;

6. determination of the apparent dielectric constant by conventional intrusive TDR methods to complement other electrical properties testing and to permit phase composition determination from information obtained in task 3;

7. obtaining thermal conductivity data for the soil specimens using the needle probe technique;

8. assess the feasibility of using the EMR needle probe procedure for routine thermal conductivity measurements of frozen specimens;

9. preparation of specimens for electrical properties tests being done elsewhere;

10. examination of the feasibility of using a new core cutting device to facilitate sample preparation for electrical and acoustical properties testing and for sample preservation by the resin impregnation technique (see Frankling and Letavernier, 1986);

11. production of a database of all data using dBase III+ software. This particular database management system

was chosen since it is widely used and more flexible than convention core logging programs.

To facilitate the analysis and rapid location of particular specimens, the cores were sorted into boxes in sequential order according to borehole number and specimen number. There are nineteen boxes of specimens. The box number for all specimens in indicated in the inventory records in Appendix I so that particular cores can be retrieved for subsequent analysis.

2. Sample Preparation and Physical Properties Estimates

2.1 Sample Preparation

After the specimens were sorted, a surface was scraped smooth to remove residual material and to facilitate photography and description. The width of the scraped surface was about 5 cm wide by 1 to 1.5 cm deep along the whole length of each specimen. A drawknife was used to prepare the surfaces after trying everything from planes to furniture scrapers. The cutting edge of the drawknife was frequently resharpened using a fine-grained water stone. Occasionally, the edge was reground with a grinder when wear was substantial.

In general, the cores were very difficult to prepare. The clayey and silty materials offered substantial resistance to cutting and producing a smooth surface even with a sharp blade was time-consuming. The organic materials were generally easy to prepare if the ice content was high. Drier materials tended to crumble and gouge regardless of the technique used to smooth the surface. The sandy materials of low ice content were quite easy to prepare but necessitated frequent sharpening of the cutting blade. Other materials which contained stones, tended to rapidly ruin the cutting edge of the tools and it was difficult to keep the surface smooth with stones intact.

Every effort was made to preserve the integrity of ice lenses found in the specimen. In some cases, ice inclusions were highly fractured making this task difficult. One should, therefore, consult the specimen description when viewing the corresponding photograph.

In general, the specimens were in good physical condition, however, fracturing along ice lenses was a common occurance. It should be noted that the sum of the specimen lengths attributed to a particular depth do not necessarily correspond since it is possible that material was lost during recovery. The core depths listed in Appendix I refer to the depths during the coring procedure; the length recorded for each specimen refers to the average length of the core accounting for any oblique fractures which may be present at the ends.

2.2 Physical Properties

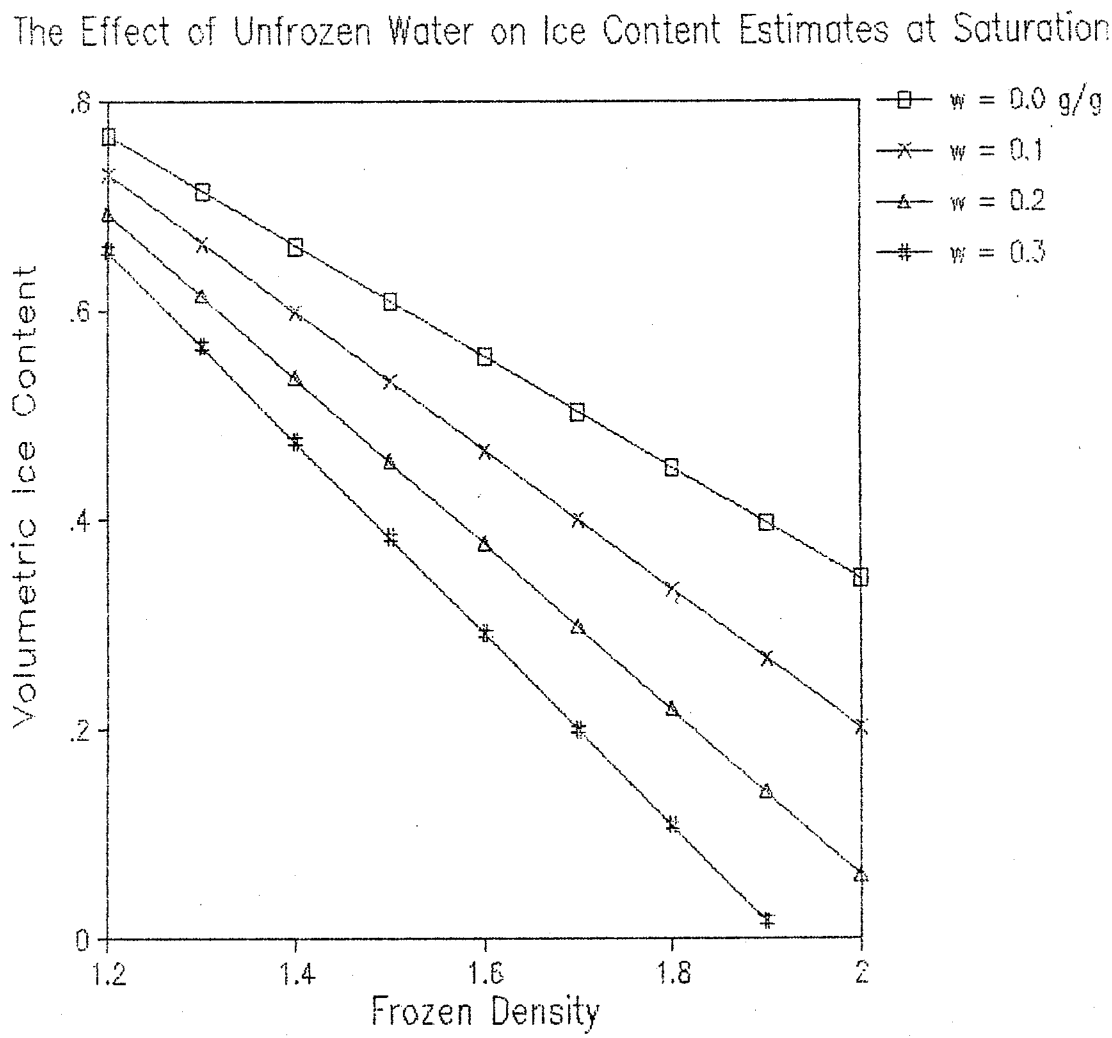
Specimen length and mass were recorded prior to preparing the smoothed surface. All specimens are 11.4 cm in diameter. The uncertainty in length is within 1 cm since the ends of the core were generally ragged or fractured at an angle across the core length. In some cases, the specimens were highly fractured resulting in greater uncertainties. Mass was obtained using a triple beam balance to within +/- 10 g.

The uncertainty in specimen length will affect volume, and hence, estimates of the total frozen density, p_t (total mass divided by total volume). It is estimated that p_t is accurate to within 6 to 8%.

Figure 2.1 shows the relationship between total density and volumetric ice content for various gravimetric unfrozen water contents. This figure assumes that the particle density, p_d, is 2.65 g cm^{-3} and that all void space is filled with either ice or water. The figure shows that as ice content increases, total density decreases.

If p_t is known and the volumetric unfrozen water content,

Figure 2.1



The Effect of Unfrozen Water on Ice Content Estimates at Saturation
Volumetric Ice Content
Frozen Density
w = 0.0 g/g
w = 0.1
w = 0.2
w = 0.3
.8
.6
.4
.2
0
1.2
1.4
1.6
1.8
2

Θ_u, can be determined (eg. via TDR) then volumetric ice contents, Θ_i, can be estimated. Figure 2.2 shows the relationship between Θ_u and Θ_i versus p_t at saturation for a soil with a gravimetric unfrozen water content, w, of 0.1 g g^{-1}. This figure shows that by using total density and unfrozen water content data it may be possible to estimate maximum ice contents.

Since p_t is a function of the particle density, total water content (water and ice) and the degree of saturation, these data must be obtained in order to interpret the preliminary data already obtained. If these data are available and the total volume is assumed to be unity, then the ice volume can be determined from equation 2.1:

$$V_i = \frac{p_d V_s + V_w - p_t(V_s + V_w + V_a)}{p_t - 0.917} \qquad (2.1)$$

where V denotes volume and the subscripts i, s, w, and a refer to ice, mineral matter, water and air respectively.

Data to completely characterize the physical properties of the specimens are to be obtained at a later date. The preliminary results of the total density determinations are shown in Figures 2.3 to 2.7. In all cases, the total density near the surface reflects the high organic content. At lower depths, high ice contents result in lower total density values.

Figure 2.2

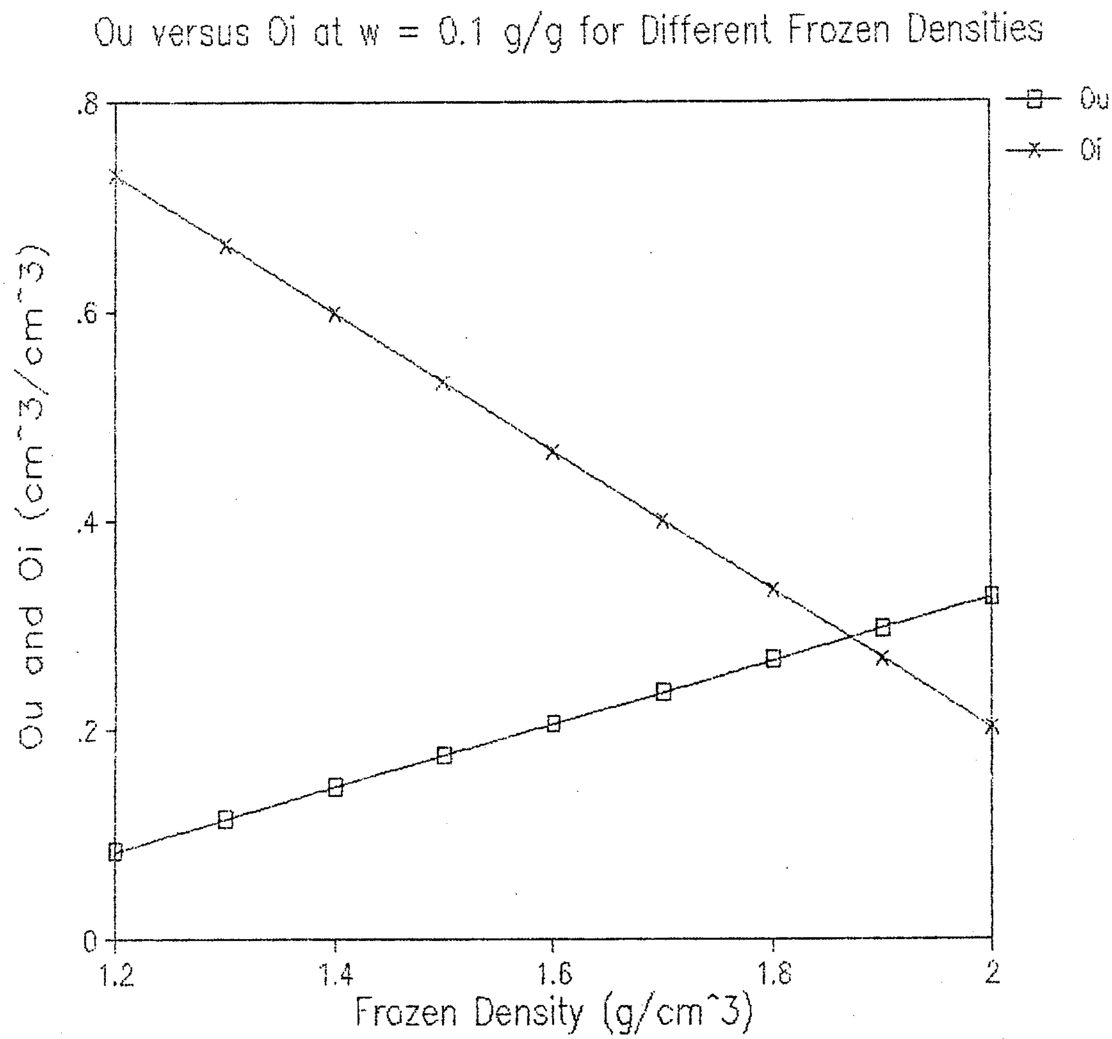

Ou versus Oi at w = 0.1 g/g for Different Frozen Densities
Ou
Oi
Ou and Oi (cm^3/cm^3)
0
.2
.4
.6
.8
1.2
1.4
1.6
1.8
2
Frozen Density (g/cm^3)

Figure 2.3

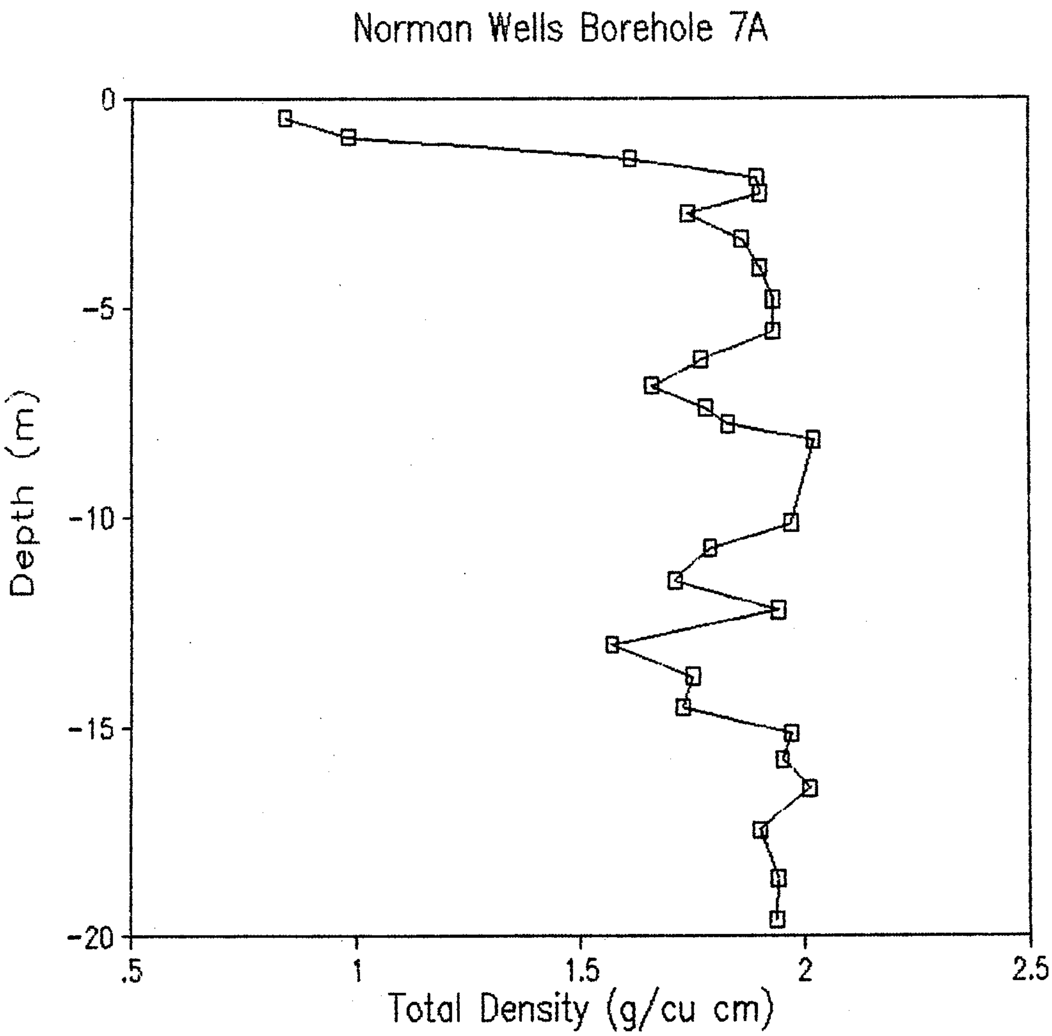
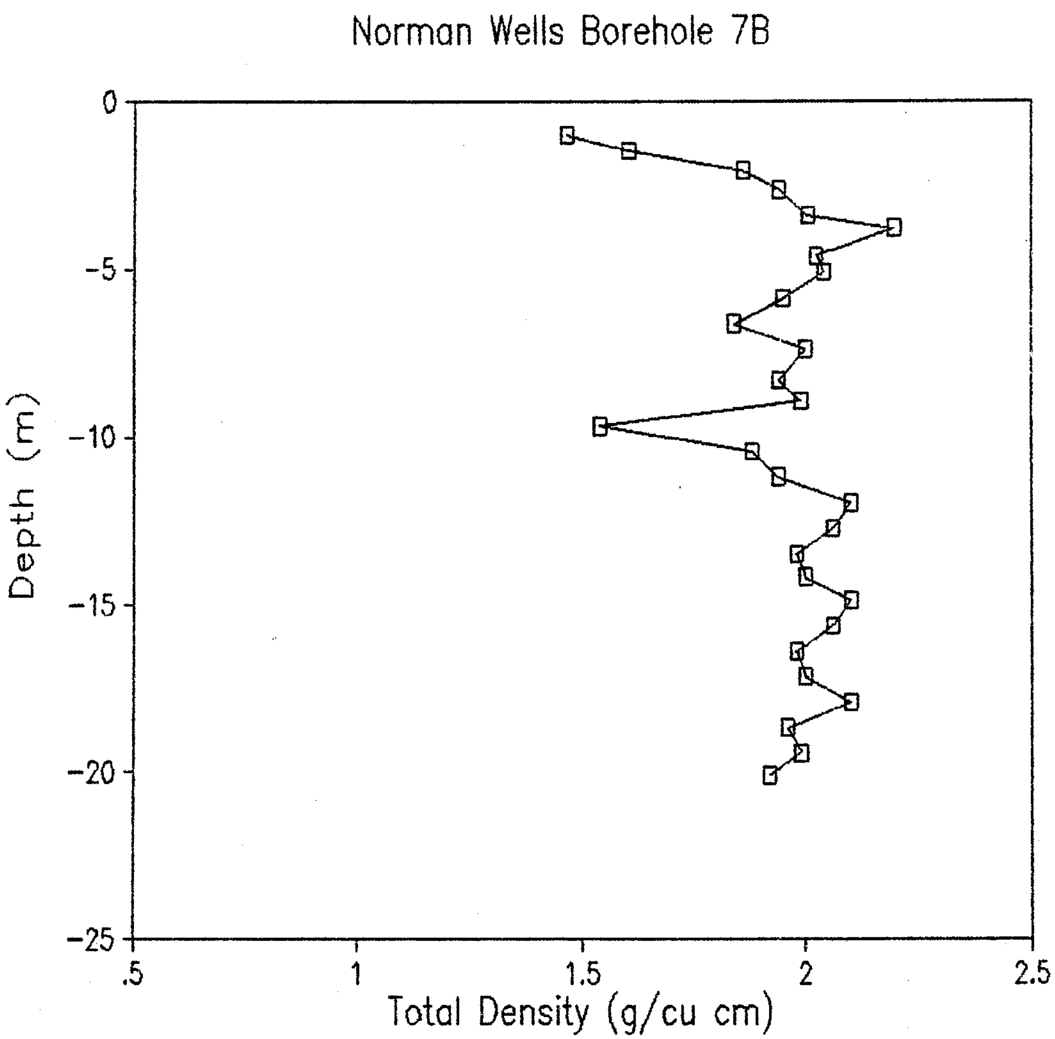

Norman Wells Borehole 7A
0
-5
-10
-15
-20
Depth (m)
.5
1
1.5
2
2.5
Total Density (g/cu cm)

Figure 2.4



Norman Wells Borehole 7B
0
-5
-10
-15
-20
-25
Depth (m)
.5
1
1.5
2
2.5
Total Density (g/cu cm)

Figure 2.5

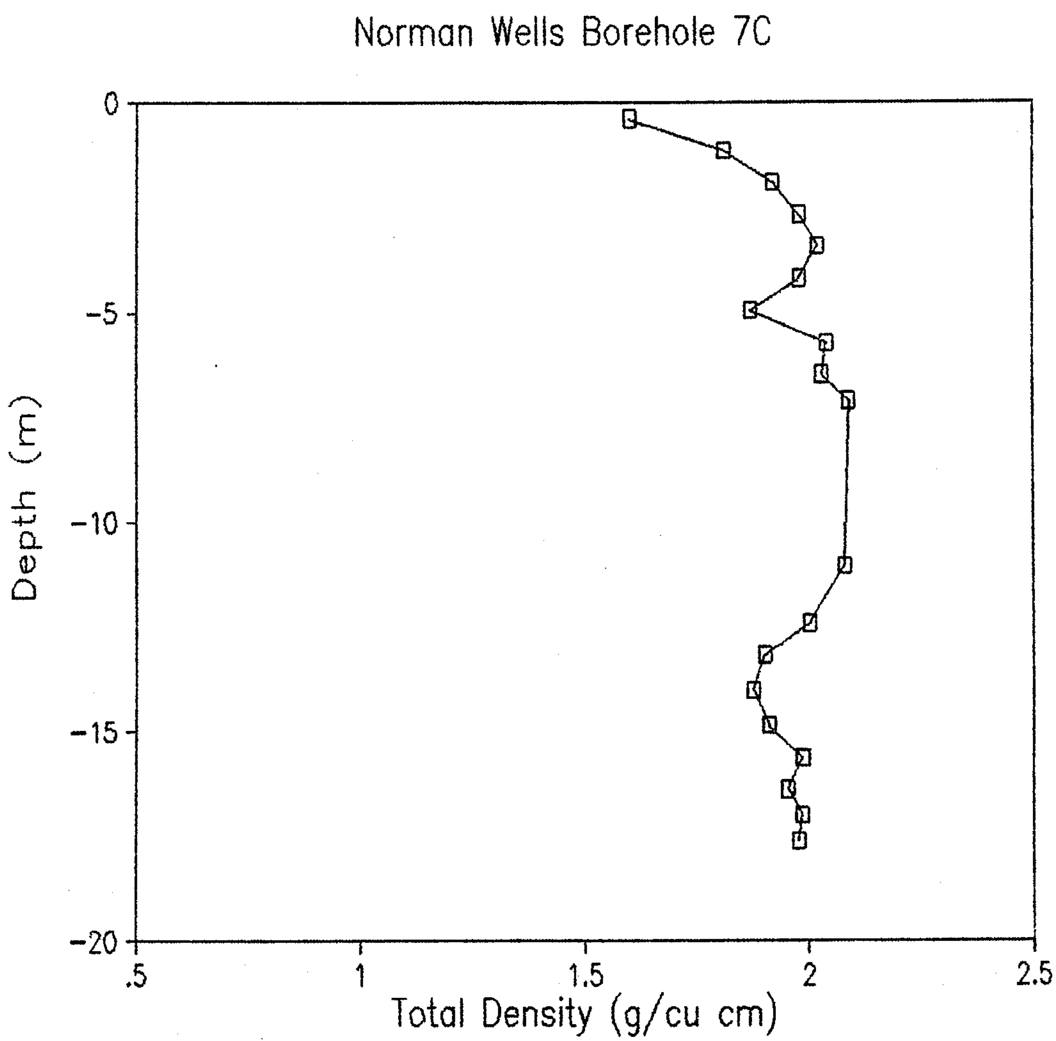
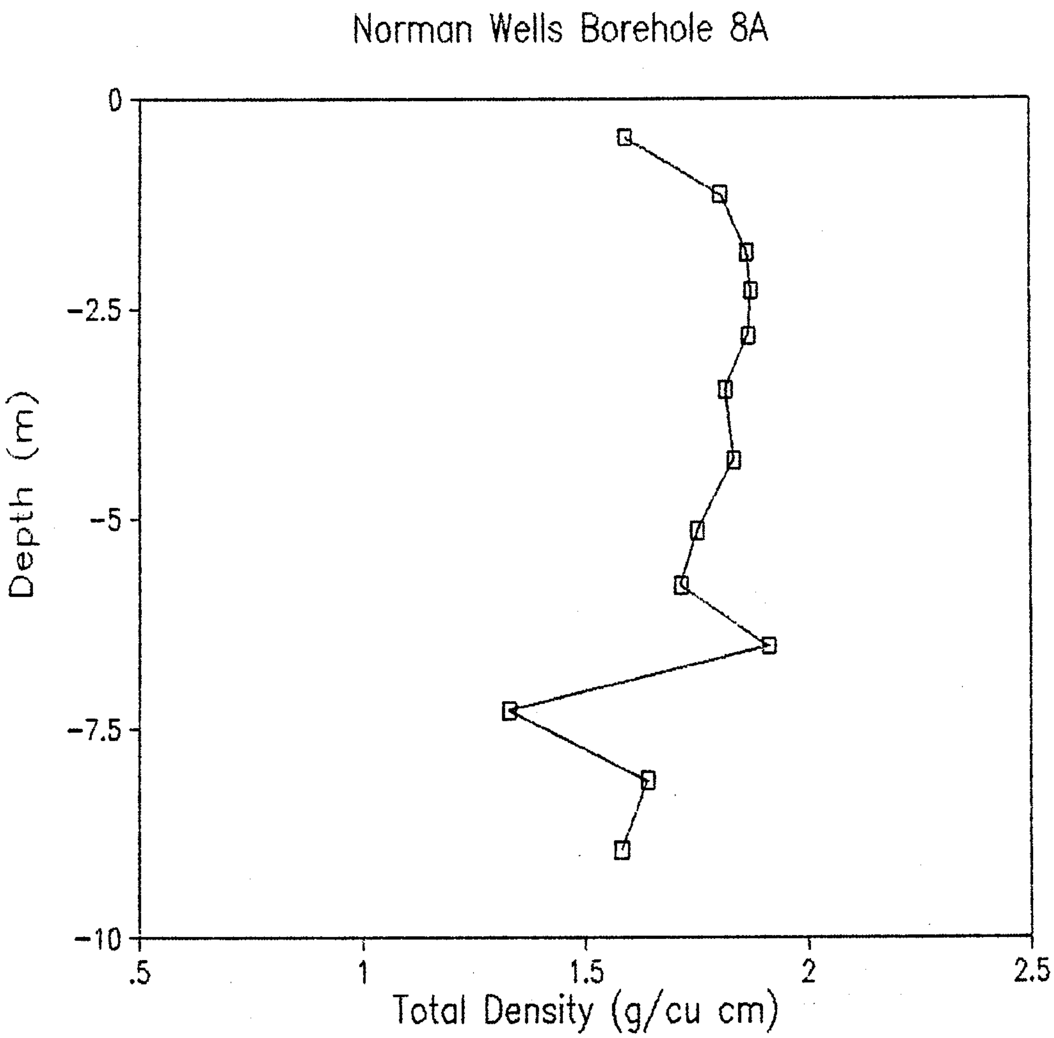
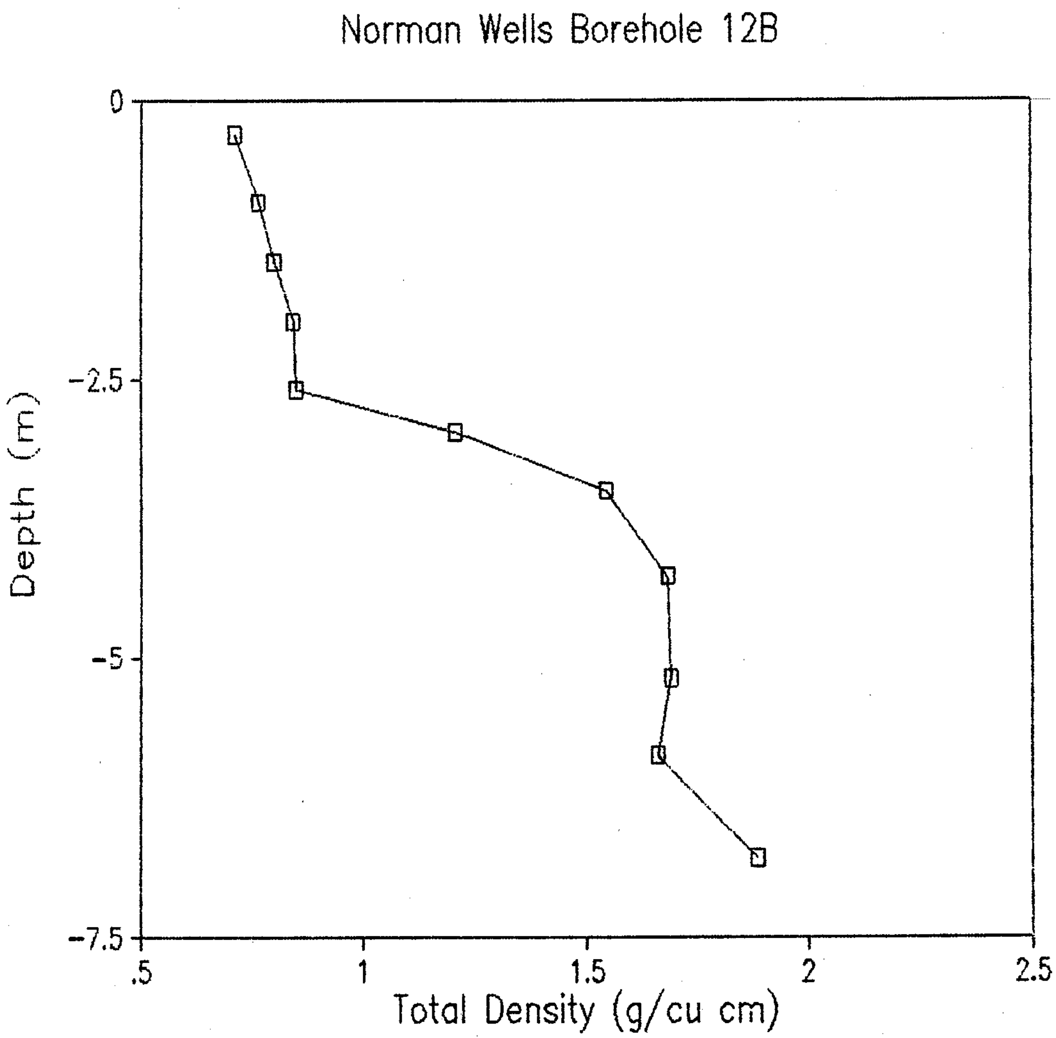

Norman Wells Borehole 7C
0
-5
-10
-15
-20
Depth (m)
.5
1
1.5
2
2.5
Total Density (g/cu cm)

Figure 2.6



Norman Wells Borehole 8A
Depth (m)
0
-2.5
-5
-7.5
-10
.5
1
1.5
2
2.5
Total Density (g/cu cm)

Figure 2.7



Norman Wells Borehole 12B
0
-2.5
-5
-7.5
Depth (m)
.5
1
1.5
2
2.5
Total Density (g/cu cm)

3. Analysis of Specimens by Time-domain Reflectometry

3.1 Introduction

Time-domain reflectometry (TDR) is a high frequency electromagnetic method used to obtain measurements of the apparent dielectric constant, K_a, of soil materials which can be used to obtain estimates of the volumetric unfrozen water content, O_u. The intent in this study was to examine the use of TDR as a routine borehole monitoring tool such that estimates of K_a (hence O_u) could be obtained immediately upon core recovery. Rather than doing the assessment in the field, it was felt that much could be gained by using TDR techniques on the cores recovered during the 1985 sampling season.

Two approaches to using TDR were examined in this preliminary phase: non-intrusive TDR and intrusive TDR. The terms used to denote these approaches refer to the placement of the balanced parallel rod transmission lines during K_a determination. In conventional (instrusive) TDR, a balanced parallel rod line is installed in a soil specimen. For non-intrusive TDR, the parallel rod lines are placed outside of the specimen but within the electric field of the transmission line.

The disadvantage of using intrusive TDR during a borehole recovery and logging procedure is that time is required to drill pilot holes to install the balanced parallel rod lines. The ambient conditions during logging may either be hostile to the operator and equipment (temperatures below 0 C) or hostile towards the specimen (eg. sample is frozen but ambient temperature is above 0 C). In either case, it is desirable to obtain estimates of K_a in as short a time as possible. A first attempt at non-intrusive TDR is discussed in section 3.3 while section 3.4 discusses aspects of intrusive TDR. The next section provides a brief review of pertinent information on the use of TDR in earth materials.

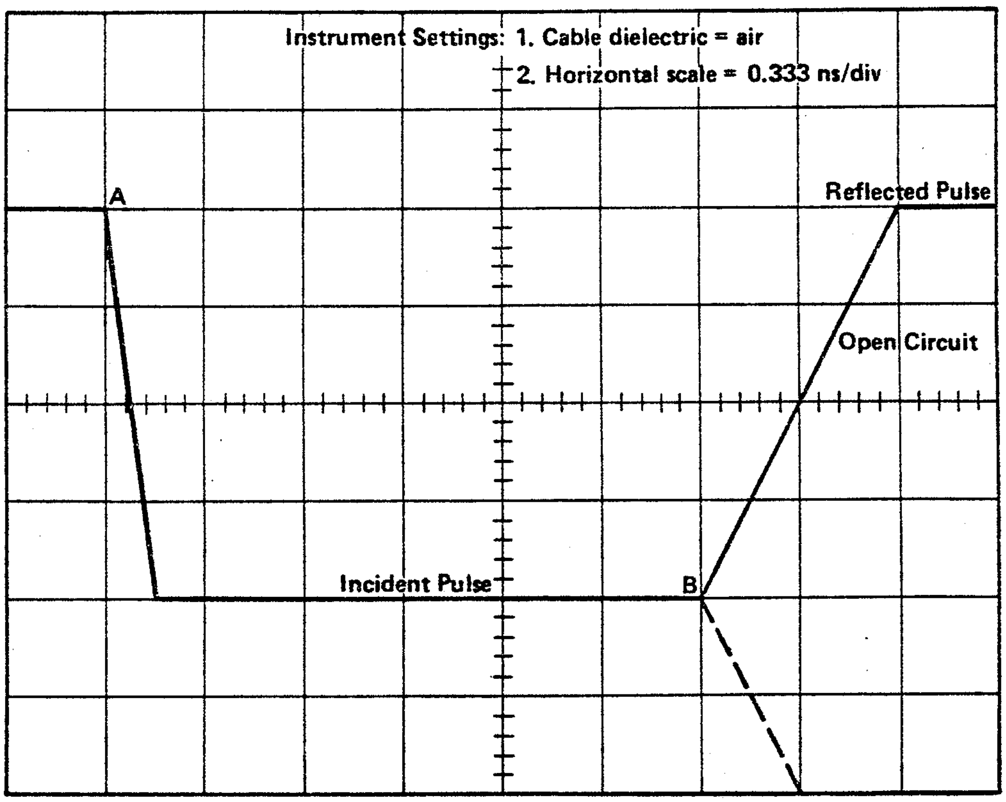
3.2 Time-domain Reflectometry

Time-domain reflectometry is used to obtain estimates of the apparent dielectric constant, K_a, of earth materials from measurements of the travel time of a step-voltage along a transmission line embedded (balanced parallel rod line) or containing (coaxial) a soil specimen. The authors use a Tektronics 1502 TDR since it is battery operated and field portable.

The cathode ray tube (crt) display of the TDR shows reflection coefficient, ρ, on the y-axis and distance along the x-axis. The y-axis is essentially an impedance axis and the x-axis can be converted to travel time. Figure 3.1 shows a stylized crt display of an open-circuited balanced parallel rod line embedded in a material. The A point on the trace denotes the point where the TDR pulse enters the specimen and the B point denotes the response at the open circuit. The one-way travel time within the material is determined from the A to B distance as measured along the x-axis and the value of K_a is determined from equation 3.1:

$$K_a = (c \times tt / L)^2 \qquad (3.1)$$

Figure 3.1



Travel time in soil = no. of divisions x time/div

No. of divisions = Distance AB

$$K_a = \left[\frac{30 \text{ cm/ns} \times \text{travel time}}{\text{line length (cm)}}\right]^2$$

DETERMINING K_a FROM TDR TRACE.

where c is the free space velocity (30 cm/nanosecond); tt is the travel time (determined from the A-B distance and the x-axis setting on the TDR) and L is the line length in cm.

The value of K_a can be used to determine the volumetric water content of frozen or unfrozen soils by equation 3.2 (Topp et al. 1980 and Patterson and Smith 1980, 1985):

$$K_a = 3.03 + 9.6\,O_v + 146\,O_v^2 - 76.7\,O_v^3 \qquad (3.2)$$

where O_v can be substituted with O_u, the volumetric unfrozen water content, if one is dealing with freezing soils. This relationship is generally applicable to within about +/- 2.5% in O_v for mineral based soils. An individual calibration of K_a and O_v for a particular soil is preferable if one wishes greater accuracy. Patterson and Smith (1985) found that equation 3.3 expressed the K_a - O_u for a variety of soils obtained from combined TDR-dilatometer experiments:

$$K_a = 3.63 + 8.54\,O_u + 165.3\,O_u^2 - 136.3\,O_u^3 \qquad (3.3)$$

The test data were obtained using saturated soils which, when frozen, consist of mineral matter, unfrozen water and ice. Equation 3.2, however, is based on two possible components, mineral matter and water. It is not surprising then that, for a given water content, the specimen containing ice should have a higher K_a since ice (K_a = 3.2) has replaced air (K_a = 1).

Equation 3.3 should be considered a tentative substitute to equation 3.2 until further data are obtained. The differences between the relationships are minor but seem to account for the replacement of air by ice as a dielectric medium at low values of O_u (generally cold temperatures in fine-grained materials). Table 3.1 summarizes the differences assuming equations 3.2 and 3.3 represent the exact relationships between K_a and O_v and K_a and O_u respectively. The data shown more than covers the range of expected K_a values at the test temperature of -10 C in this study.

Table 3.1 Possible Differences in Water Content Estimates for Frozen and Unfrozen Soils Based Upon Equation 3.2 and Equation 3.3

K_a	O_v [1] (cm^3 cm^{-3}, %)	O_u [2] (cm^3 cm^{-3}, %)	Difference (cm^3 cm^{-3}, %)
3.5	3.3	0	3.3
4.0	5.6	2.8	2.8
4.5	7.5	5.2	2.3
5.0	9.0	7.1	2.1
6.0	11.7	10.0	1.7
8.0	16.2	14.7	1.5
10.0	19.8	18.5	1.3
12.5	23.8	22.7	1.1
15.0	27.4	26.6	0.8
17.5	30.8	30.2	0.6
20.0	34.0	33.6	0.4

[1] from equation 3.2 [2] from equation 3.3

3.3 Non-intrusive TDR techniques

As mentioned earlier, it was hoped that non-intrusive TDR could be used to obtain indications of the variability of K_a during borehole logging. The intent of the application was not to obtain estimates of O_u necessarily but to denote areas of differing dielectric properties when cores are recovered. To this end, it was decided to examine the feasibility of using balanced parallel rod lines on the outside of the soil core running parallel to the core length. Since the balanced parallel rods are not installed in the specimen, part of the "sensing" field extends into the soil and part into the surrounding air. This results in a reduction of the measured dielectric property compared to that which would be obtained if the lines were installed within the specimen.

Initial studies suggested that this reduction in K_a could be in the order of 35-40%. Unfortunately, this was based upon good contact between the parallel rod lines and the soil specimen. The specimens to be examined are not ideal in this regard since small fractures, protrusions and a generally uneven surface make perfect contact between the probes and the soil impossible.

To test the effects of this uneven surface on K_a estimates, a saturated clay and a sand were frozen in plastic bags at about -12 C. The diameter of the specimens were about 10 cm and the length was about 25 cm. A 20 cm balanced parallel rod line (line spacing, 2.5 cm) was installed in the middle of each sample and a balanced parallel line with 10 cm spacing was taped to the outside of the bag so that each line was on the axis of the specimen diameter. No effort was made to ensure perfect contact between the probes and the soil materials.

A K_a value of 6.5 (O_u approximately 11.3 %) was obtained from the parallel rod line installed within the clay while one of about 2.9 was obtained from the parallel rod line on the outside.

For the sand, values of 3.5 and 1.7 were obtained respectively for the "within" and "without" parallel rod lines. Since the possible error in K_a is about 0.4 (given the TDR scale setting used and the crt trace length) it is apparent that the non-intrusive TDR lines do not produce an acceptable range in K_a with changes in unfrozen water content. Attempts to smooth out the surfaces produced somewhat better estimates, however, the long preparation time negates the utility of non-intrusive TDR techniques. Work is currently underway to investigate other forms of transmission lines which may suffer less from the contact problem. The interim recommendation is to use intrusive TDR.

3.4 Intrusive TDR Techniques

Balanced parallel rod lines can generally be installed in unfrozen soils with relative ease. Short lines, generally up to about 25 cm in length can be pushed in, hammered in, or if necessary, pilot holes can be drilled to accommodate the lines. In frozen soils, the only option is to drill pilot holes.

Tests were carried out on several of the specimens to determine any difficulties in installing the balanced parallel rod lines. The materials range from peat materials to stiff clays and should reflect varying degrees of difficulty in probe installation. It was decided that TDR probe installation should be across the core diameter (a maximum of about 11.4 cm).

The TDR probe consisted of two parallel stainless rods 0.32 cm in diameter (1/8 inch), 20 cm long spaced about 2 cm apart. Two parallel holes the same diameter and spacing as the lines were drilled about 10.5 cm deep into the specimen along the length axis. After the holes were drilled, they were reamed using a slightly undersized rod to ensure they were free of debris. The specimens were allowed to equilibrate to ambient temperatures since the drilling would warm (or melt) the material around the holes. A TDR probe was then pushed into the pilot holes to a depth of 10 cm and a trace of the TDR's crt was recorded on an x-y recorder housed outside the coldroom.

In principle the above procedure should work quite well, however, the finer-grained materials offered significant resistance to probe insertion unlike similar unfrozen soils. As a result, probe insertion was difficult or they would get stuck before the desired 10 cm installation depth. In some instances it was impossible to remove them without bending the lines or damaging the core. If the hole was reamed out slightly oversized with the electric drill then probe insertion was much easier.

The use of an oversized pilot hole to ease probe insertion leads to concerns about whether the measured value of K_a is the "true" value since the air gap is unlike the soil material electrically. Annan (1977) discussed the air gap problem around parallel rod transmission lines. In brief, the measured dielectric constant of a material will be less than its true value if an air gap is present. The reduction in value depends upon the size of the gap, the dielectric constant of the material in the gap, the dielectric constant of the material being tested and the probe configuration (line diameter and spacing). More details are presented in Appendix II.

The calculated deviation of K_a from "true" value is shown in

Figure 3.2 and in Table 3.2. The data are for the probe configuration used in the experiments (0.766" line spacing; 0.125" line diameter and a 0.141" (9/64") pilot hole). The cases of an air filled gap (K = 1) and an oil filled gap (Dow Corning silicon oil K = 2.8) are shown. Further discussion is also provided in Appendix II.

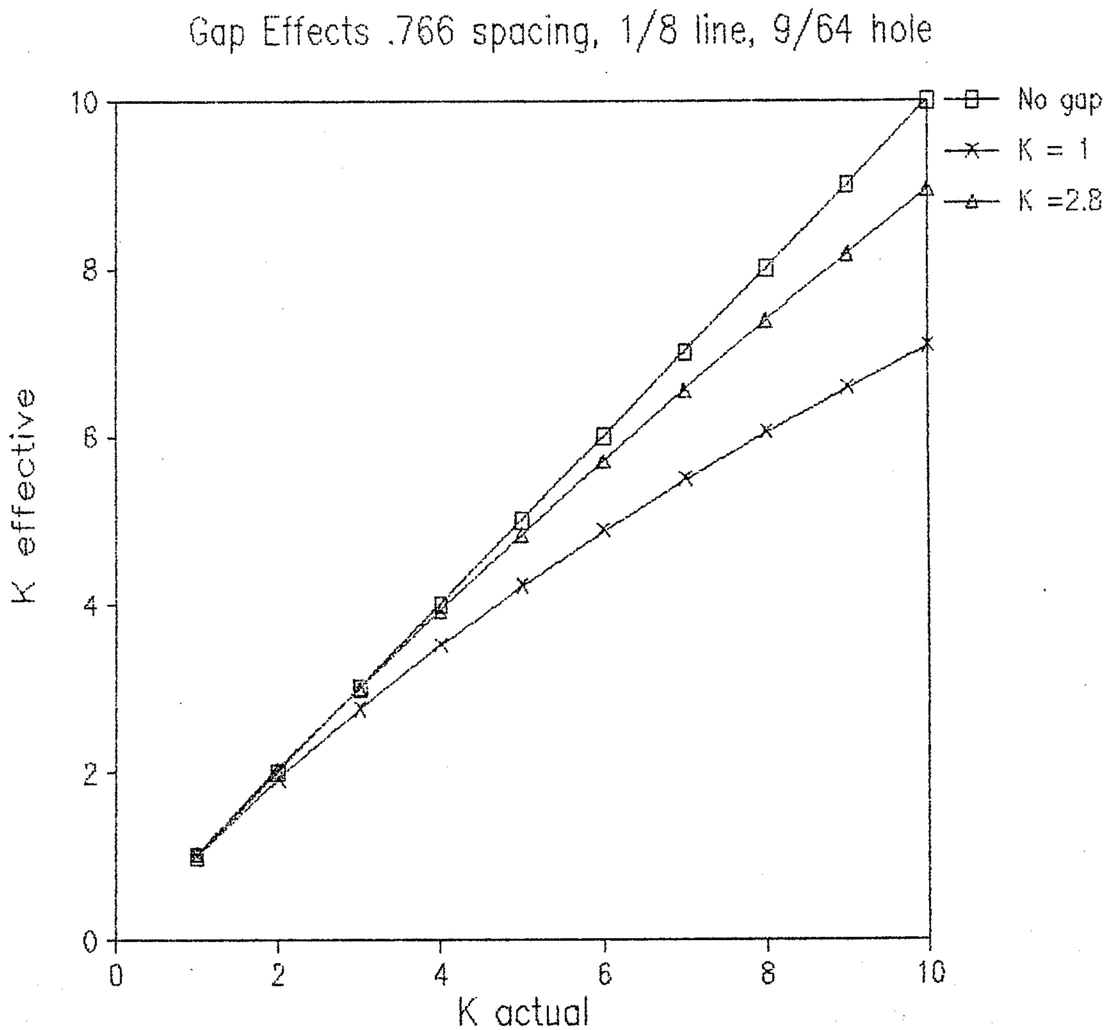
The probe configuration and the size of the pilot hole was chosen because parallel rods of this size are fairly rugged; long drill bits are available in 9/64" size and fairly small stratigraphic features (approximately 4 cm) could be examined. Any variation in the line spacing, diameter or pilot hole size can be used but must be analysed separately.

Table 3.2 Reduction in Dielectric Constant Due to Gaps Around Parallel Rod Lines

K actual	K for air filled gap	% of actual	K for oil filled gap	% of actual
20	10.7	53.5	15.6	78.1
18	10.1	56.2	14.4	80.0
16	9.5	59.3	13.2	82.2
14	8.8	62.6	11.8	84.5
12	8.0	66.5	10.4	86.9
10	7.1	70.8	9.0	89.5
8	6.1	75.8	7.4	92.1
6	4.9	81.3	5.7	95.0
4	3.5	88.0	3.9	98.0
3	2.8	91.2	3.0	99.7

This table applies for one parallel rod line configuration and gap size, see text.

Figure 3.2


Gap Effects .766 spacing, 1/8 line, 9/64 hole
K effective
K actual
No gap
K = 1
K =2.8
0
2
4
6
8
10

In general, the oil filled gap is the better alternative particularily since the K_a is not expected to exceed 10 (O_u = 0.20 cm^3 cm^{-3}) for these materials and at the ambient temperature of -10 C.

If determining O_u is of importance then the presence of an air gap will affect estimates. Table 3.3 shows possible errors in O_u using the data in Table 3.2 and assuming equation 3.3 describes the relationship between dielectric constant and volumetric unfrozen water content.

Table 3.3 Reduction in Unfrozen Water Content Estimates Due to Gaps Around Parallel Rod Lines

K actual	O_u (cm^3 cm^{-3})	O_u for air filled gap	O_u for oil filled gap
20	.336	.197	.275
18	.309	.187	.257
16	.280	.175	.238
14	.250	.162	.216
12	.219	.146	.193
10	.185	.127	.166
8	.146	.102	.133
6	.100	.066	.092
5	.071	.040	.065
4	.028	0	.024

This table applies for one parallel rod line configuration and gap size, see text.

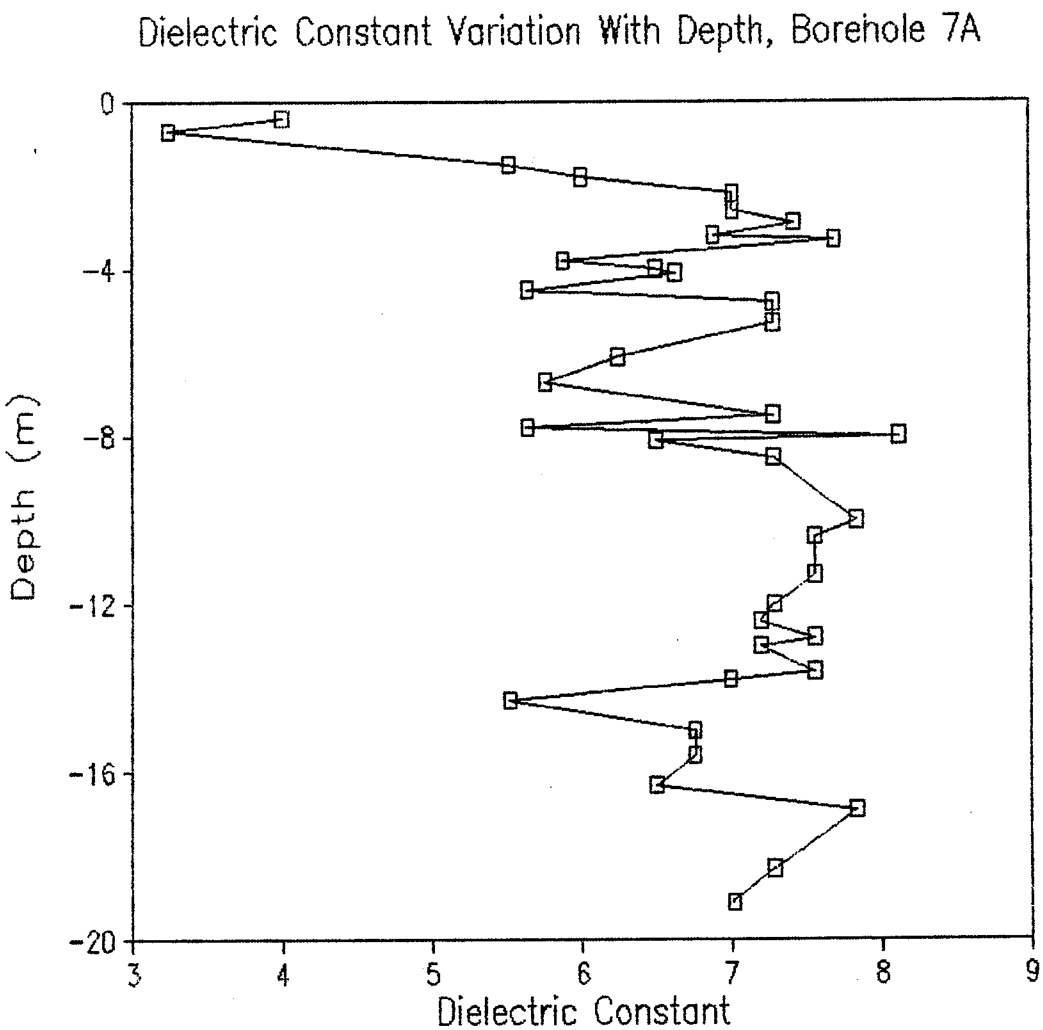
Table 3.2 shows that if the real dielectric constant is less than 12, then an oil filled gap (given the configuration discussed previously), will give an estimate of O_u to within 2.6 % of "actual".

Tests were performed on a variety of specimens to confirm the above analysis. Pilot holes of 1/8" diameter were drilled and the probes were forced into the specimen. After a K_a determination was made, the probes were removed and the pilct holes were drilled oversized; filled with silicon oil; the probes inserted and a K_a determination made. In no instance did the measured K_a data differ by more than 0.3 from the calculated relationship for an oil-filled gap. This procedure was used to analyse subsequent specimens.

3.5 Dielectric Constant Variation For Selected Boreholes

The variation in K_a for two boreholes was examined to see what variations existed with depth. Figure 3.3 and 3.4 show the variations in K_a for boreholes 7A and 8A respectively. The patterns shown are inconsistent although the low value of K_a in the near surface zone can be accounted for by the organic layer present. The variation in K_a at other depths correspond to differences in unfrozen water content and ice content. It is impossible to completely analyse the variations exhibited since complete information on the phase composition is not available at this stage. Once the total water content, dry density and particle size analyses are completed at a later date then the record can be examined with respect to phase composition. In general, low values for K_a were obtained in high ice content materials or sandy materials. The higher values for K_a were found in specimens of silty clay with seemingly low ice contents. The pattern shown in Figure 3.5 suggests a weak relationship between dielectric constant and total density. These data though

Figure 3.3



Dielectric Constant Variation With Depth, Borehole 7A
0
-4
-8
-12
-16
-20
Depth (m)
3
4
5
6
7
8
9
Dielectric Constant

Figure 3.4

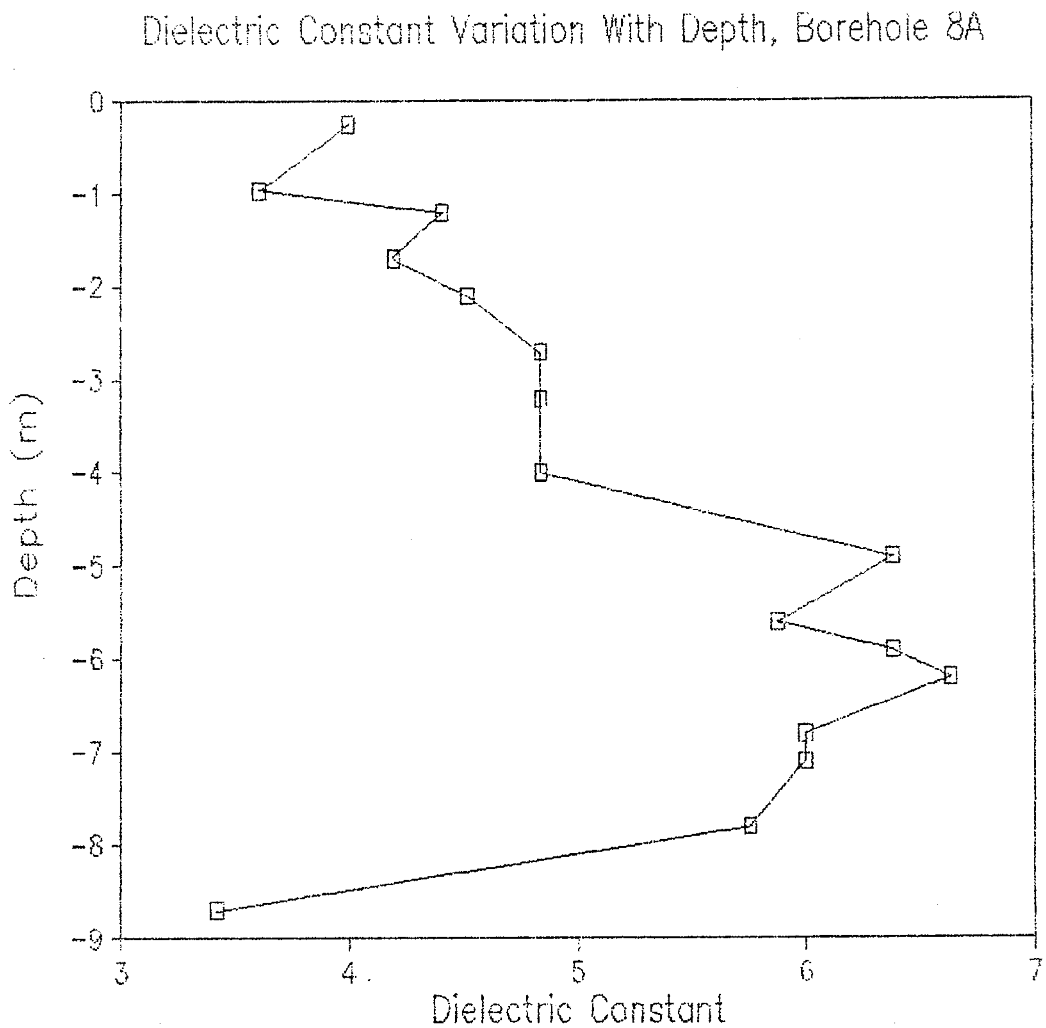
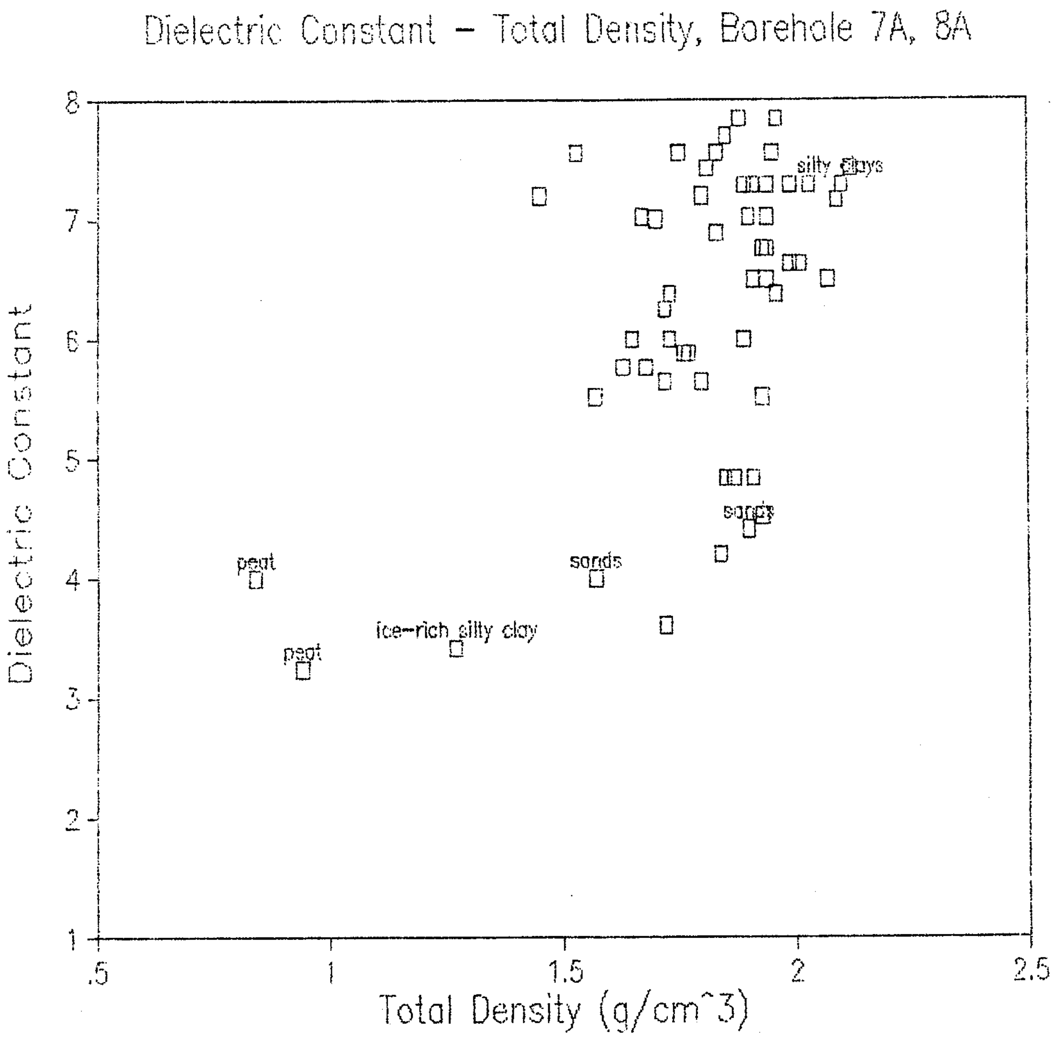

Dielectric Constant Variation With Depth, Borehole 8A
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
3
4
5
6
7
Dielectric Constant

Figure 3.5



Dielectric Constant - Total Density, Borehole 7A, 8A
Dielectric Constant
Total Density (g/cm^3)
8
7
6
5
4
3
2
1
.5
1
1.5
2
2.5
silty clays
sands
peat
sands
ice-rich silty clay
peat

do not account for variations in grain-size and mineralogy etcetera which will affect the phase composition relationship. It is suggested that K_a data be obtained again during subsampling to determine total water content (water and ice) and dry bulk density. The use of TDR in such situations will prove invaluable to determining phase composition of frozen core specimens.

4. The Photographic Record of the Soil Specimens

4.1 Still Photographic Record

The core specimens were photographed after a surface was scraped smooth as discussed in section 2.1. The photographs serve as a basis for examining changes in stratigraphy and to aid in identifying ice types and form in future studies.

To aid in photographing the specimens, a wooden frame was constructed which would support the specimens, support the necessary lighting and provide a flat non-glare surface. The frame could be tilted to ensure that the specimen was normal to the film plane. A PVC trough about 40 cm long and 12 cm in diameter was installed in the centre of the frame and light stands were attached at either end of the trough. Photoflood lamps were used for illumination since surface glare could be eliminated more readily by changing the angle of the lamps or by re-orienting the specimen.

The photos of the specimens were produced to about two thirds life-size so that ice features could be easily detected. The contrast in the negatives and on the prints was enhanced to accentuate these features. Two copies of the photographic record are housed with the scientific authority.

4.2 Video Record

A video record was prepared of all of the frozen cores delivered to the coldroom. This record of the core materials provides a quick overview which complements the detailed information in the photographic and database records.

A video camera was placed on a tripod inside the coldroom, connected by cable to the video-recorder unit in the anteroom. A frame was constructed to hold core material in three tiers, permitting simultaneous viewing of up to 3 metres of core.

Cores were removed from their plastic storage bags and placed on the frame with the scraped surfaces exposed. Recording proceeded sequentially by borehole and depth, with core fragments having the same core number (eg. c7a, c7b, c7c) sharing each tier. A wide-angle view of the entire frame was recorded, followed by a slow close-up pan of each core. The audio channel was used to provide a running commentary on the stratigraphy of each borehole, and to point out changes in soil texture and ice conditions.

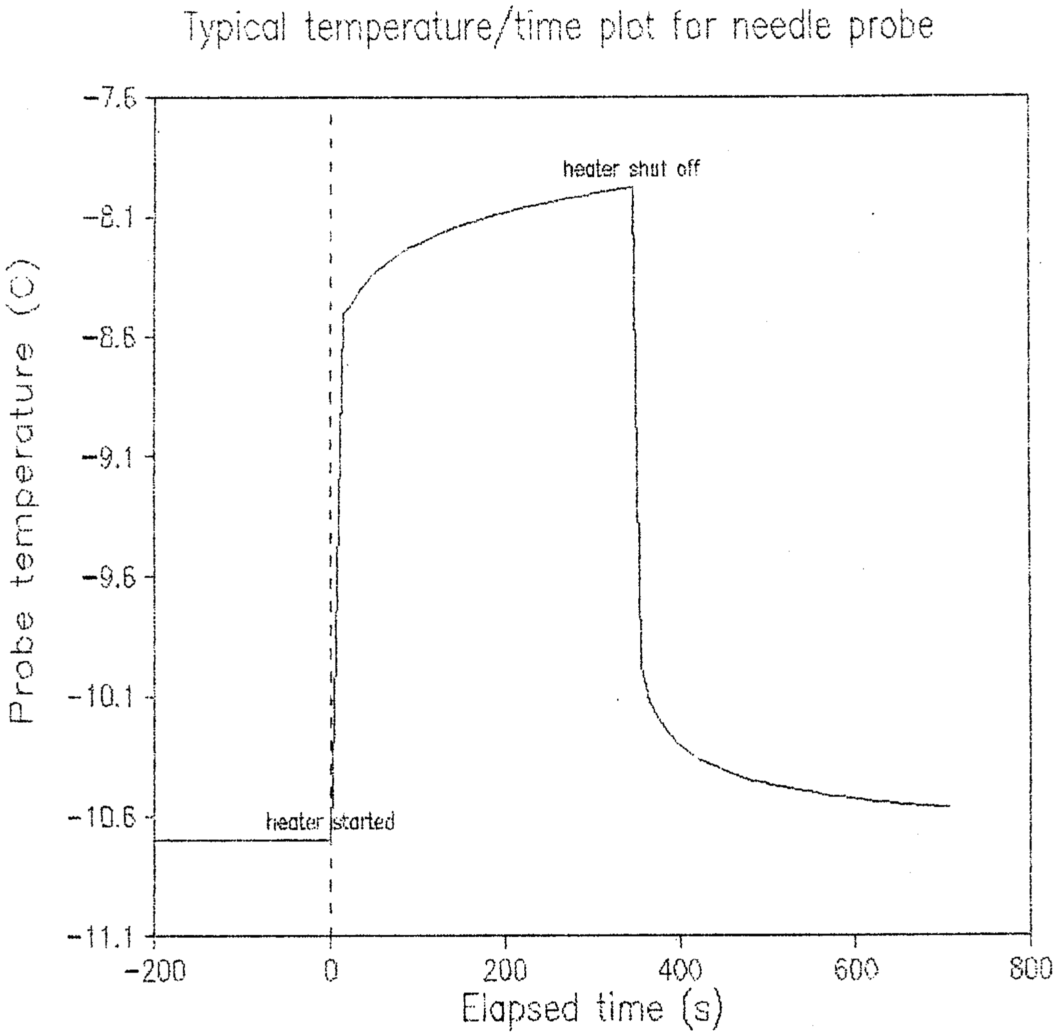
5. Thermal Conductivity Analysis by the Needle Probe Technique

The thermal conductivity of the core specimens was determined by the needle probe method, using apparatus supplied by the scientific authority. This apparatus permits simultaneous thermal conductivity tests on up to nine separate specimens. References to the limitations and applicability of the technique are found in the literature (Weschler, 1966; Slusarchuck and Watson, 1975)

5.1 Principle of Operation

A needle probe consists of a long thin metal tube containing a temperature sensor and a wire heater element running along its length. The probe is placed in a test specimen and heated at a known constant rate. The temperature at the midpoint of the probe is monitored, and the thermal conductivity of the test material is determined by analysis of the temperature-time relationship obtained during the test. A typical temperature-time plot is shown in Figure 5.1. The method is based upon an analytical equation describing the temperature rise during constant heating of a heat source of infinite length embedded in an initially isothermal medium having uniform and constant thermal properties. The method is only an approximation of the analytical solution describing it, although the errors resulting from these approximations can be kept small by appropriate design of the test apparatus and the testing procedure. If the probe is considered to be a line heat source, with zero cross section and heat capacity, then the temperature rise is expressed by equation 5.1 (Carslaw and Jaeger 1959) :

Figure 5.1


Typical temperature/time plot for needle probe
heater shut off
heater started
Probe temperature (C)
Elapsed time (s)
-7.6
-8.1
-8.6
-9.1
-9.6
-10.1
-10.6
-11.1
-200
0
200
400
600
800

$$T = - \frac{q}{4 \pi k} . Ei \left(- \frac{r^2}{4 \alpha t} \right) \qquad (5.1)$$

where

$$-Ei(-x) = \int_x^{\infty} \frac{e^{-u}}{u} du$$

is the exponential integral; k is the specimen thermal conductivity; q, is heat input per unit length; r, is radial distance from probe; t, is the time from start of test; T, is the temperature rise above initial temperaure and α , is specimen thermal diffusivity.

The analytical model may be simplified if tests are run for an extended period. During the initial period of heating, the diffusivity of the specimen and the properties of the probe dominate the temperature rise. Once the criterion in equation 5.2 is satisfied, temperature rises linearly with the logarithm of time as shown in equation 5.3:

$$\frac{4 \alpha t}{a^2} \gg 1 \qquad (5.2)$$

where $\bar{a}$ is the probe radius

$$T = \frac{q}{4 \pi k} . \ln(t) + B \qquad (5.3)$$

$$T = - \frac{q}{4 \pi k} \cdot Ei \left(- \frac{r^2}{4 \alpha t} \right) \qquad (5.1)$$

where

$$-Ei(-x) = \int_{x}^{\infty} \frac{e^{-u}}{u} du$$

is the exponential integral; k is the specimen thermal conductivity; q, is heat input per unit length; r, is radial distance from probe; t, is the time from start of test; T, is the temperature rise above initial temperaure and α , is specimen thermal diffusivity.

The analytical model may be simplified if tests are run for an extended period. During the initial period of heating, the diffusivity of the specimen and the properties of the probe dominant the temperature rise. Once the criterion in equation 5.2 is satisfied, temperature rises linearly with the logarithm of time as shown in equation 5.3:

$$\frac{4 \alpha t}{a^2} \gg 1 \qquad (5.2)$$

where a is the probe radius

$$T = \frac{q}{4 \pi k} \cdot \ln(t) + B \qquad (5.3)$$

where B is a constant.

This fomulation eliminates parameters related to the properties of the probe, as well as the effect of contact resistance. This is not valid indefinitely, as axial heat flow and edge heat loss become increasingly significant. Thermal conductivity is determined by evaluating the slope of the T vs. ln(t) plot using equation 5.3.

5.2 Test Setup

The system used for the thermal conductivity tests included:

1. 9 Geotherm needle probes (1mm diameter, 60 mm length, heater wire resistances between 24 and 35 ohms),
2. current source (Hewlett Packard model 6181C) (to supply heat to the needle probes)
3. voltmeter (Hewlett Packard model 3456A) (to record the thermistor resistance in each probe and the voltage drop across the probe heater wire)
4. multimeter (to monitor current supplied to the probes, this was not connected to the data aquisition system)

An automatic data acquisition and control unit (Hewlett Packard model 3497A) and microcomputer (Hewlett Packard model 85) were used to control timing, current supply, and data storage during a run. The computer is used in subsequent analysis of the data, including conversion of thermistor resistance data to temperature and the calculation of thermal conductivities.

5.3 Experimental Details

Since the experimental apparatus and operation procedures were provided, the authors were required to develop procedures for use in frozen specimens. The following aspects were examined:

1. temperature stability during tests;
2. methods of probe insertion;
3. selection of suitable contact materials.

A conductivity test manual was prepared by the contractor, to standardize test procedures when different operators were involved. A copy of the test manual is supplied in an appendix.

5.3.1 Data analysis

The computer analysed the heating data after an initial time lag of approximately 200 seconds. This satisfies the initial time lag criterion in equation 5.2, which, for a specimen having a diffusivity of 1×10^{-6} m^2s^{-1} (typical for a frozen clay), yields a value of 3200 for the left hand side. In practice, the linearity of the temperature rise was evaluated by checking the correlation coefficient generated by least squares analysis of the temperature data. For most tests this value exceeded 0.9999, and tests were rejected if the this fell below 0.999 (very few fell below this value).

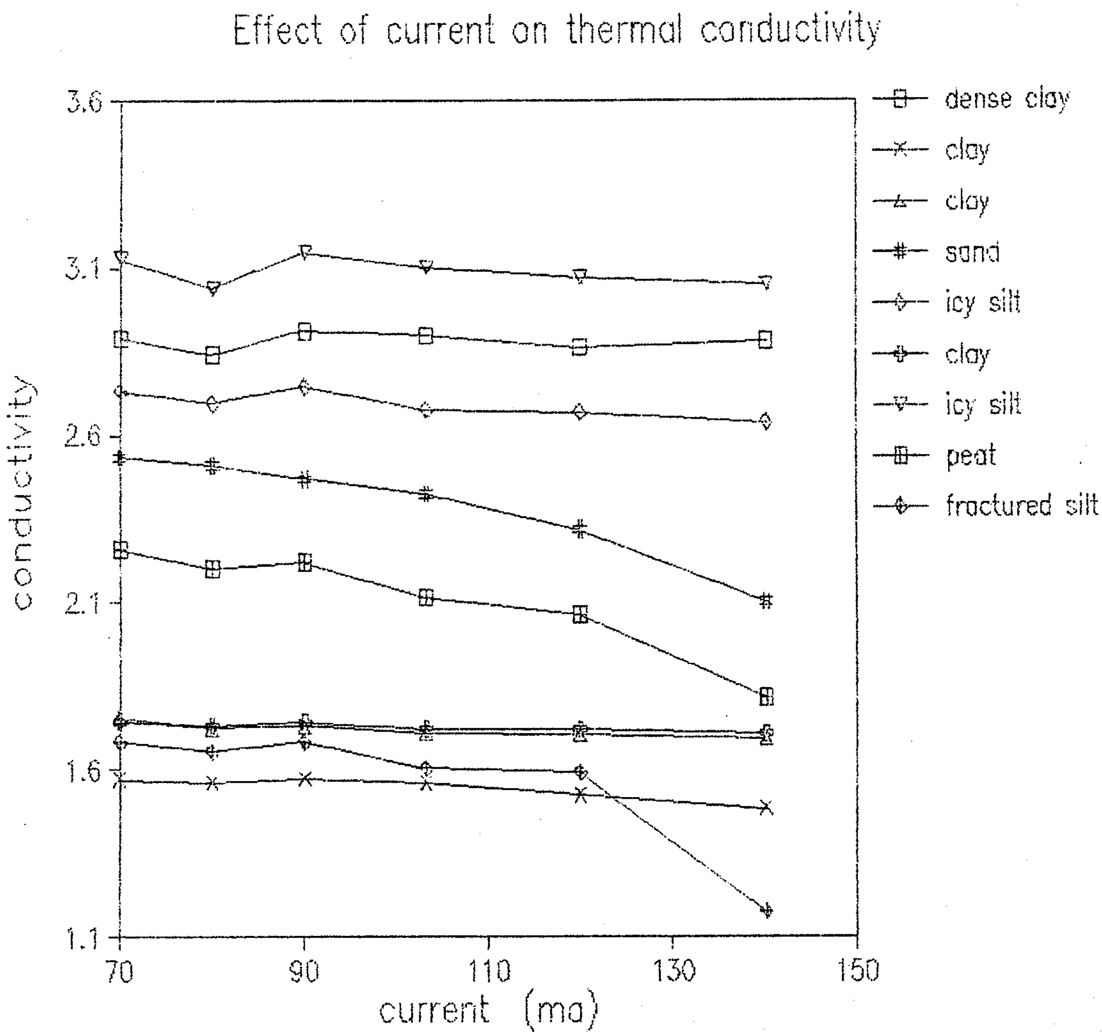
5.3.2 Current Supply

During tests, approximately 100 milliamperes of current was supplied to each probe for 6 minutes. The probe heater wire resistance was between 24.3 and 34.6 ohms, so that the temperature rise in the specimens resulting from this combination ranged from approximately 2.6 celsius degrees in sandy materials to 6 celsius degrees in peat materials. Since the specimens were maintained at about -10 C, this temperature rise would not result in significant interferences to the thermal conductivity measurements since phase change would be small in most instances.

Judgement must be exercised in determining the current supplied to the probes. A higher current will result in higher temperatures as well as steeper temperature gradients within the specimen, which may induce moisture migration and phase change in the specimens. Lower current will alleviate these problems, but will increase the error in measurement due to temperature drift and limitations on temperature measurement accuracy.

The scientific authority recommended that the current be set at 100 ma. This recommendation was followed, although tests of the effect of current on conductivity results were also carried out. Repeated thermal conductivity tests were performed on a variety of soils, with the current supply ranging from 70 to 140 ma, resulting in a fourfold variation in the heat supplied to the probes (since $Q = I^2R$). The results of these tests are shown in Figure 5.2. In all but three of the specimens, the effect of varations in the current supply was negligible. Of the three specimens whose conductivity exhibited a dependence on heat input, two (the peat and the icy silt specimens) were known to contain voids or cracks, while the sandy specimen gave indirect evidence that it may also have contained these (since the test thermal conductivity was uncharacteristically low). This suggests that variations in current will only influence tests in which this is a problem. The effect is probably due to the influence of contact resistance, which would be high for these materials if the contact fluid drained out through the cracks. The high

Figure 5.2



Effect of current on thermal conductivity
3.6
3.1
2.6
2.1
1.6
1.1
conductivity
70
90
110
130
150
current (ma)
dense clay
clay
clay
sand
icy silt
clay
icy silt
peat
fractured silt

contact resistance would increase the test temperature, inducing phase change and thereby lowering the specimen thermal conductivity as well as extending the initial time lag for the test (from equation 5.2).

5.3.3 <u>Temperature Stabalization</u>

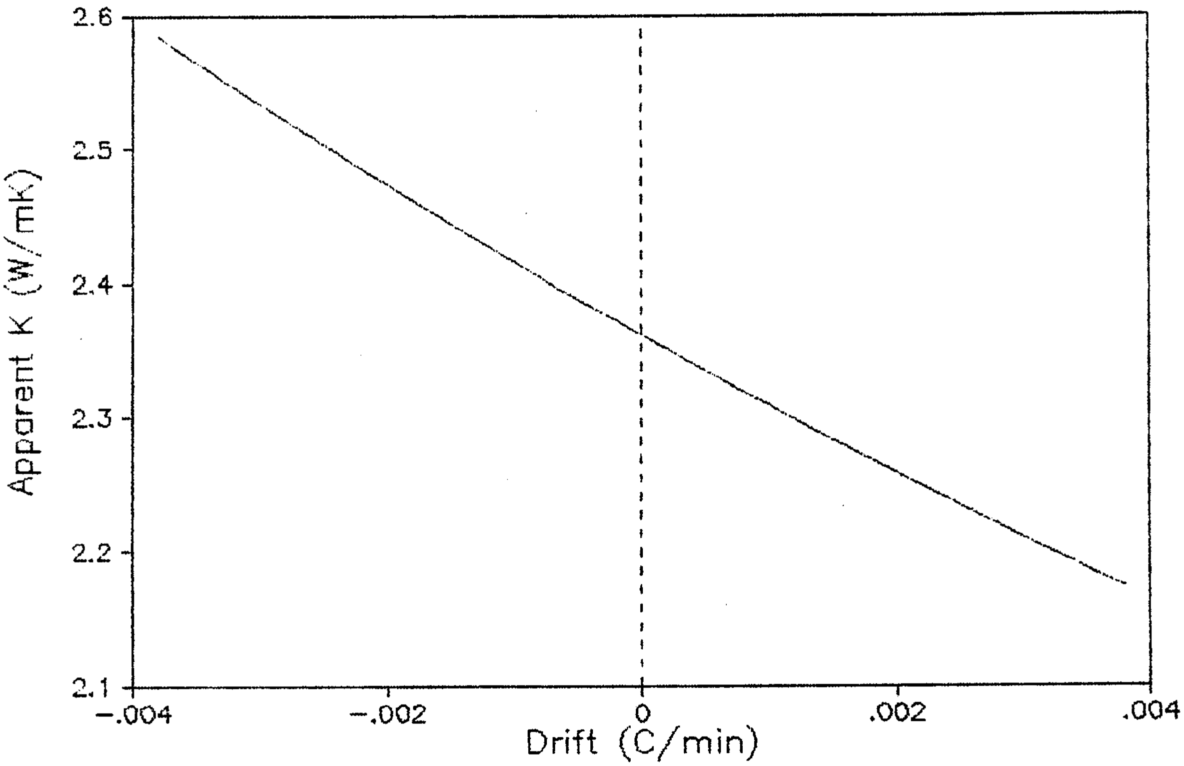
Two insulated boxes were constructed to contain the core specimens during the tests in order to reduce ambient temperature drift. The boxes were lined with 5 cm of foam insulation and included a tight-fitting lid to minimize cyclical or random temperature changes. Using these boxes, temperature drift could be kept below 0.0002 degrees per minute, which was considered to be the acceptable maximum drift allowable before tests could proceed (see Figures 5.3 and 5.4).

Even though the temperature stability in the cold room is quite good, variations in the ambient temperature conditions were of some concern. The chamber goes through defrost cycles on a regular basis, during which the ambient temperature rises to -1 C for approximately 10 minutes. This is not sufficient to change the temperature of the specimens substantially but possibly sufficient to affect the thermal conductivity tests.

To assess the effect of ambient temperature conditions, seven specimens were placed in the insulated test boxes and thermal conductivity was determined during a defrost cycle, and again 4 hours later at ambient (-10 C). The test values differed by less than 1 percent, so that it was not considered necessary to schedule tests around defrost cycles.

Figure 5.3

Temperature Drift Effects on K Estimates for Frozen Clay



Values are for Standard Conditions / Apparatus

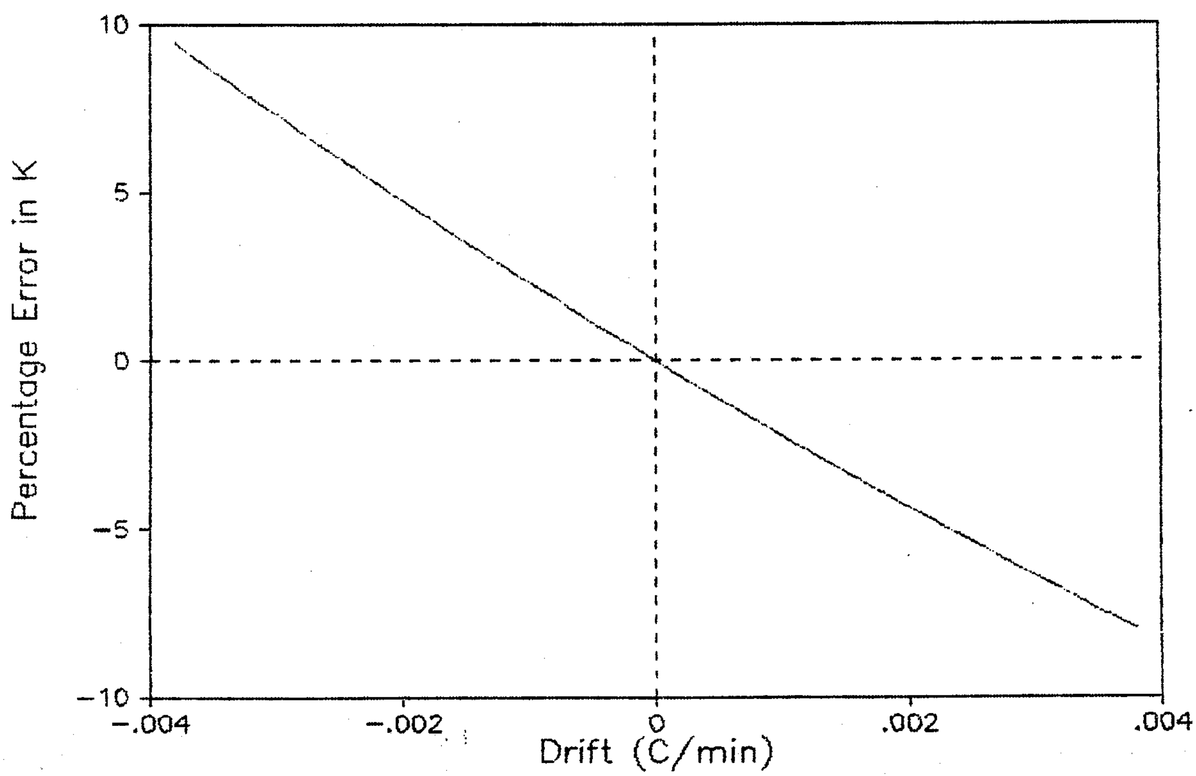
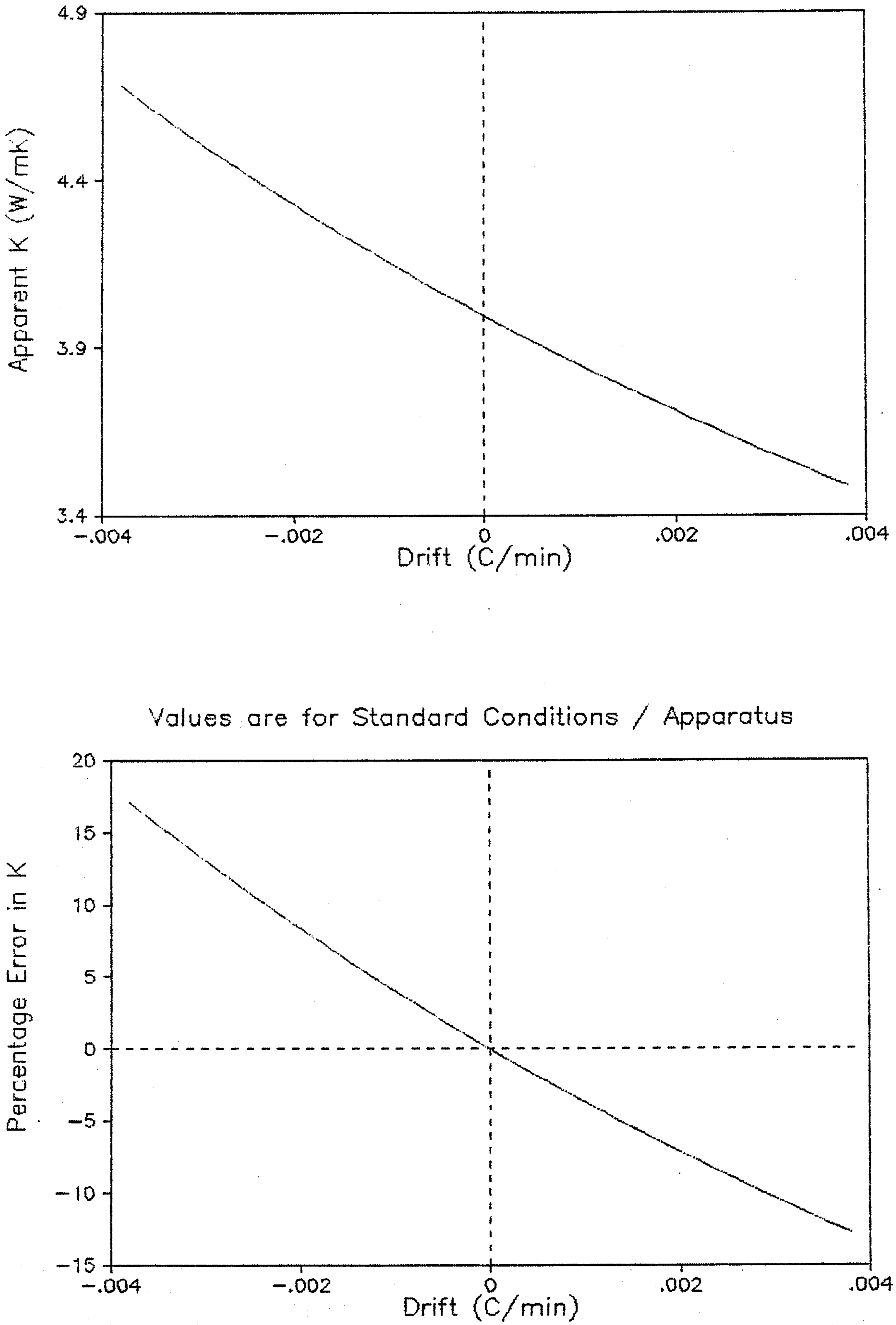


Figure 5.4

Temperature Drift Effects on K Estimates for Frozen Sand



5.3.4 Probe Insertion

The primary concern when inserting the probe in the core is that there be good, uniform contact between the probe and the specimen. For undisturbed, unfrozen materials, the usual procedure for ensuring good contact is to insert the probe directly into the core, or to insert the probe into an undersized hole and then mould the material around the probe. Sincethe core materials were frozen, such procedures could not be followed.

The needle probes were inserted into pre-drilled holes in the cores. The holes had to be drilled slightly oversized (1.5 mm diameter), since smaller diameter bits could not be obtained in the appropriate length. The gap was filled with a highly conductive material to minimize contact resistance.

5.3.5 Contact Medium

A syringe with a large diameter needle was used to introduce the contact medium into the pre-drilled holes. In practice, the needle was inserted into the hole and the contact material released as the needle was extracted. Initially, a high thermal conductivity silicon grease (containing metallic oxides) was tried, unfortunately, this material became quite viscous at the low ambient temperatures. Dow Corning 200 cs silicon oil was substituted since it has a high thermal conductivity and remains fluid.

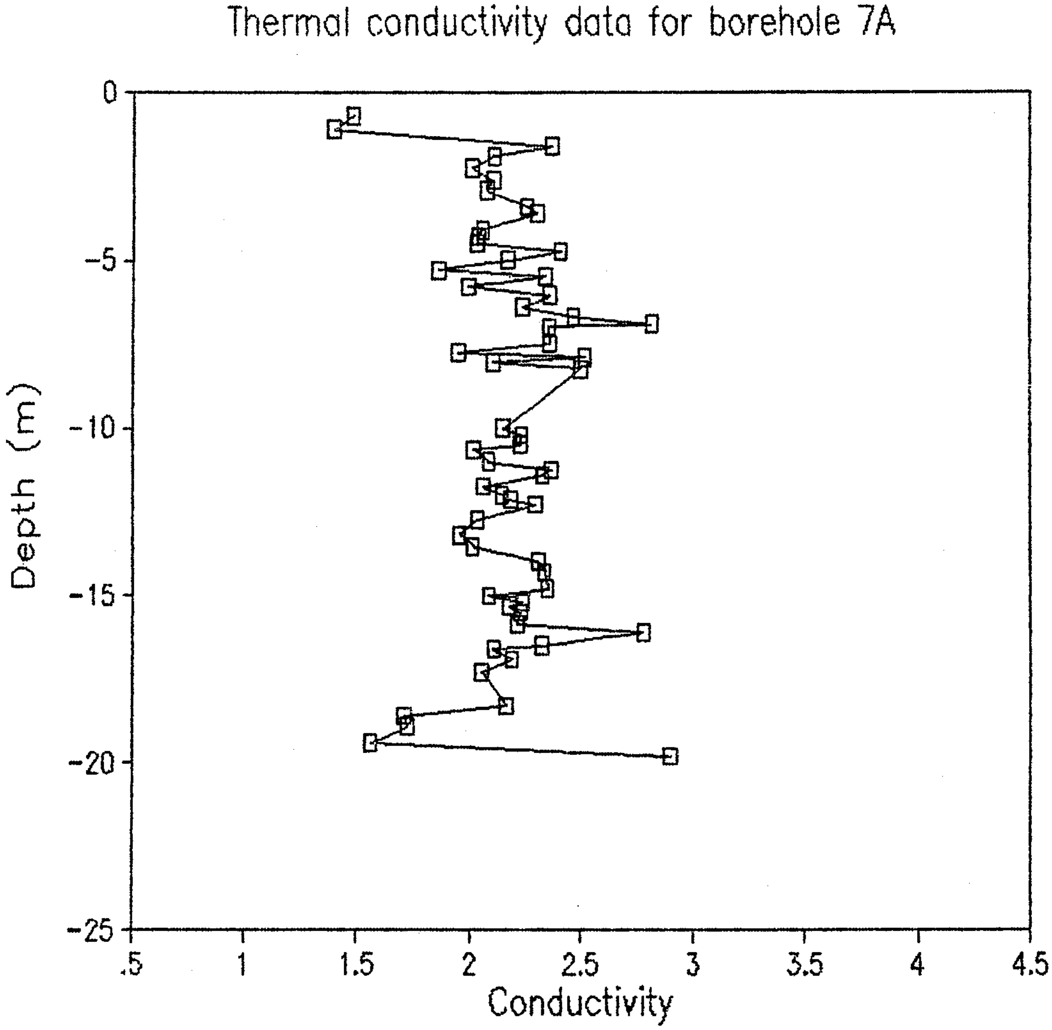
The use of silicon oil rather than silicon grease as a contact medium for thermal conductivity tests was assessed before the thermal properties inventory was started. Three cores were selected and thermal conductivity was determined using silicon grease as the contact medium. The experiment was repeated with silicon oil as the contact medium (reusing the same holes, with the grease purged). Differences in thermal conductivity values between tests were less than 1 percent in all cases, so that the silicon oil was considered to be an acceptable substitute.

5.4 Results

Thermal conductivity data for selected boreholes are shown in Figures 5.5 to 5.9. The data are stored in the database record. A printed output of the conductivity data, together with other pertinent information from the database, is included with this report.

Thermal conductivity values for all sites fall within the normal range for frozen soil materials, indicating that no unusual minerals predomiant. In general, materials identified as being predominantly clay tend to have thermal conductivities in the range between 2 and 3 $W\,m^{-1}K^{-1}$; sandy materials tend to have thermal conductivities between 3 and 4.5 $W\,m^{-1}K^{-1}$; and materials identified as silty tend to have thermal conductivities covering the ranges of the previous soil types. This variability can be attributed to the greater variation in excess ice content in the silty material, and possibly to a more variable mineralogy for the silty material. Organic materials tend to have thermal conductivities between 0.8 and 2.2, with significant variations due to ice content.

Figure 5.5



Thermal conductivity data for borehole 7A
0
-5
-10
-15
-20
-25
Depth (m)
.5
1
1.5
2
2.5
3
3.5
4
4.5
Conductivity

Figure 5.6

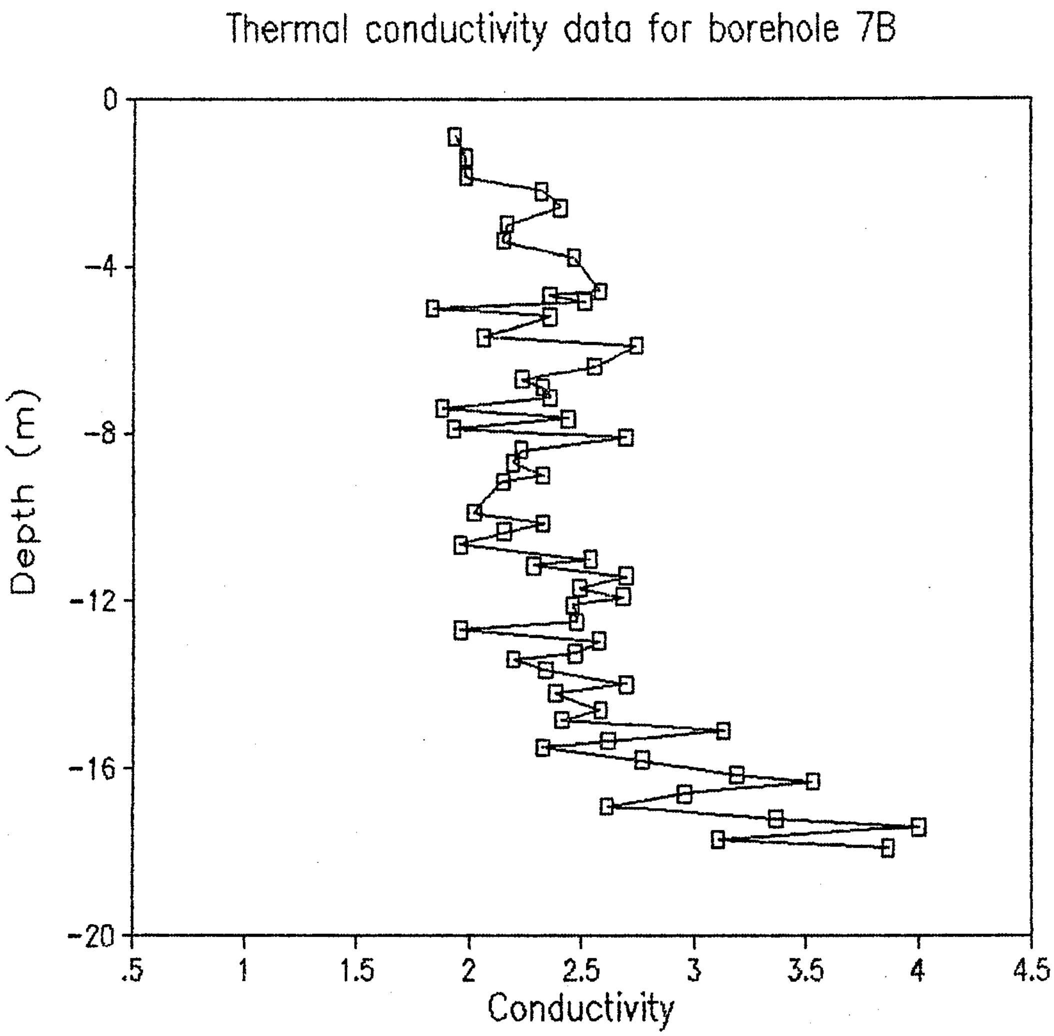

Thermal conductivity data for borehole 7B
0
-4
-8
-12
-16
-20
Depth (m)
.5
1
1.5
2
2.5
3
3.5
4
4.5
Conductivity

Figure 5.7

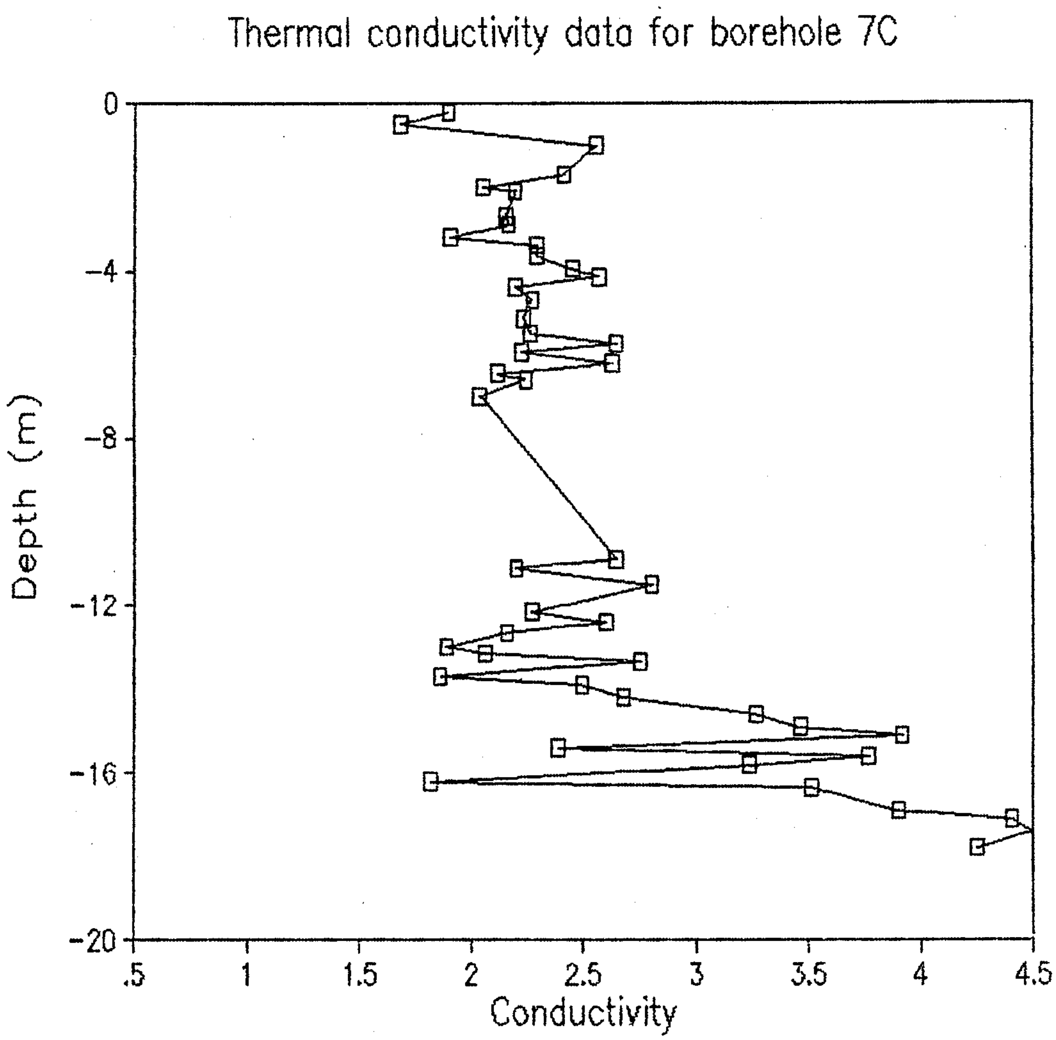

Thermal conductivity data for borehole 7C
Depth (m)
0
-4
-8
-12
-16
-20
.5
1
1.5
2
2.5
3
3.5
4
4.5
Conductivity

Figure 5.8

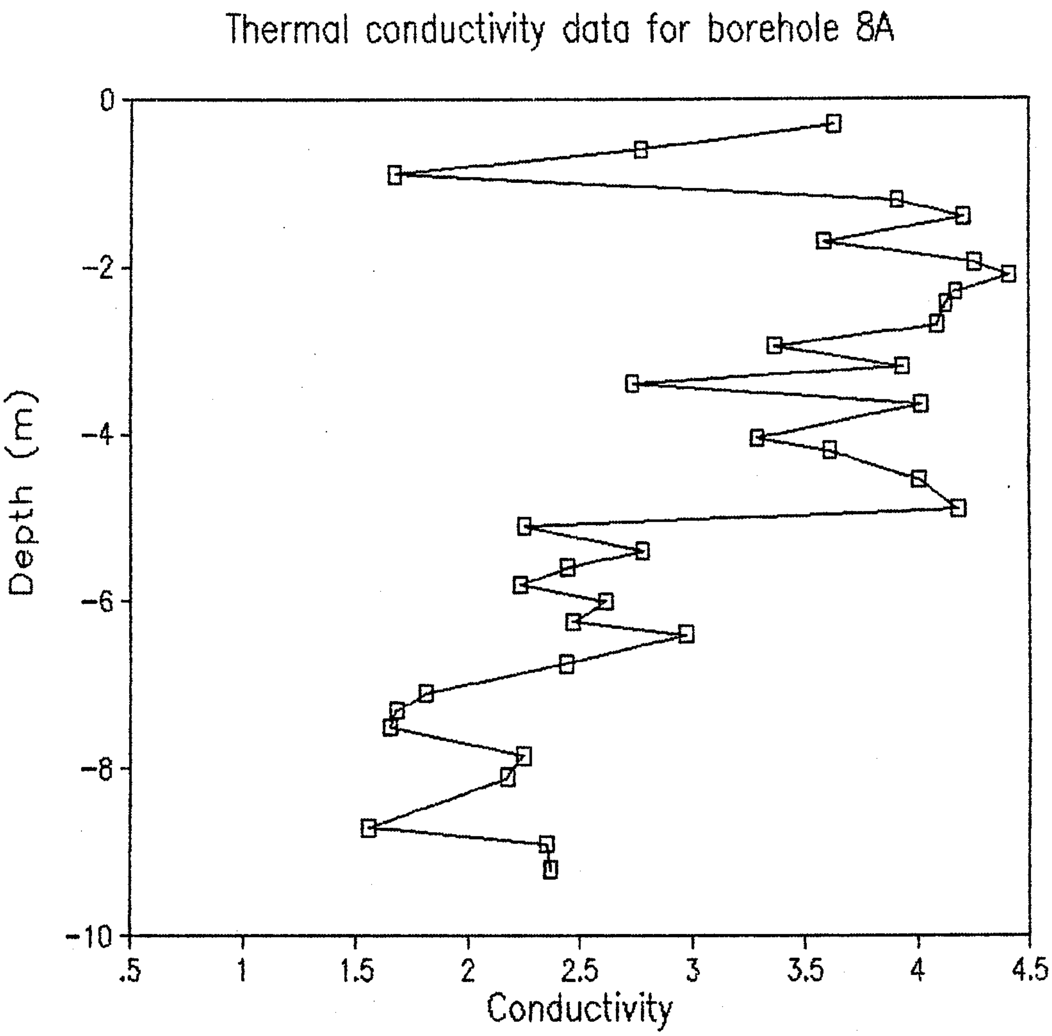
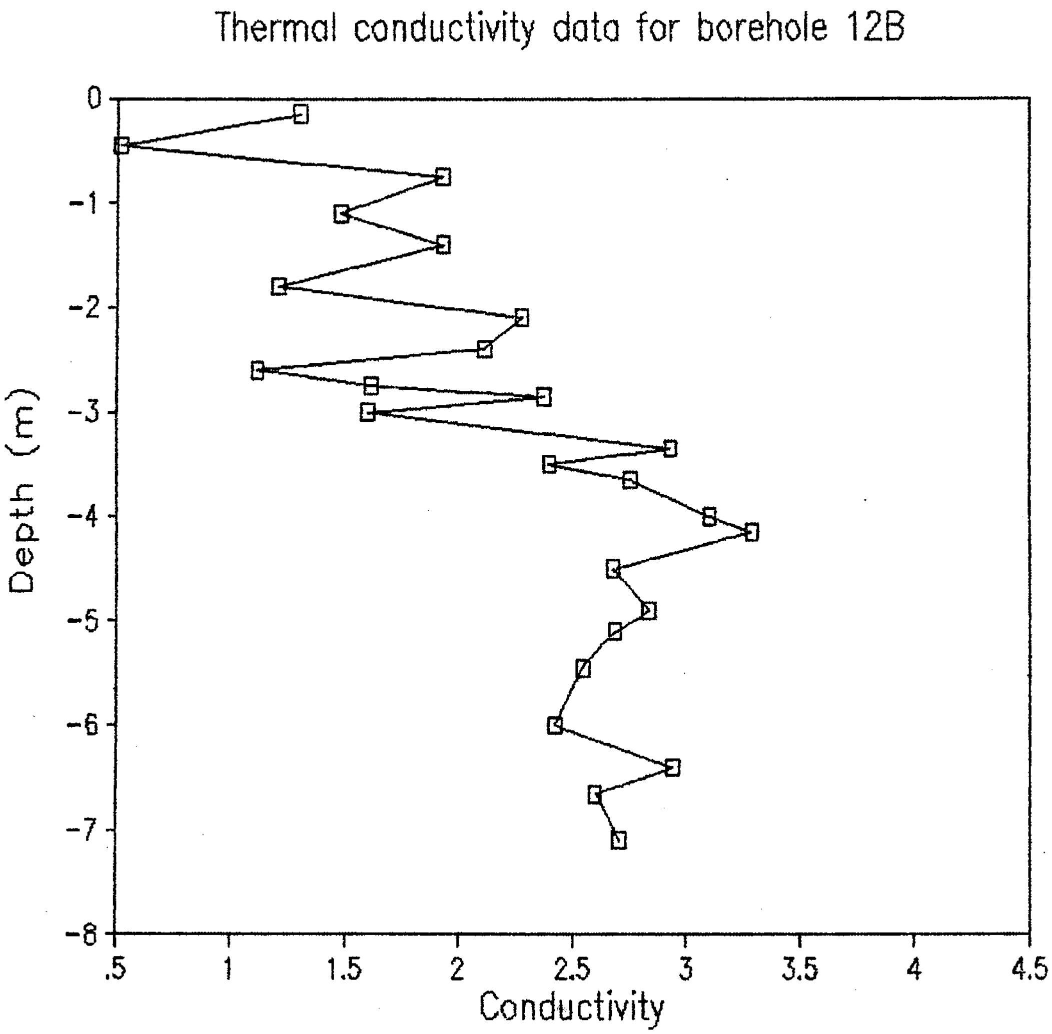

Thermal conductivity data for borehole 8A
Depth (m)
0
-2
-4
-6
-8
-10
.5
1
1.5
2
2.5
3
3.5
4
4.5
Conductivity

Figure 5.9


Thermal conductivity data for borehole 12B
Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
.5
1
1.5
2
2.5
3
3.5
4
4.5
Conductivity

The variability in thermal conductivity values may be due to natural variation in thermal conductivity, or may be artifacts of the test situation. Factors contributing to the natural variation of thermal properties include stratigraphic variation in mineralogy, density, and ice content. The factors which relate to test procedure include placement of the probe adjacent to anomalies such as gravel inclusions and fractures. The silty clay with gravel inclusions present in the upper layer at sites 7A, 7B, and 7C has a fairly consistent thermal conductivity, with a mean value of approximately 2.3 W $m^{-1}K^{-1}$. Scatter in hole 7A is approximately +/- 0.2 (with a few outside this range), compared to +/- 0.4 for 7B and 7C. The difference in scatter may indicate a more uniform material at site 7A. Alternately, there may be more gravel in the material at the other two sites, which would tend to increase the scatter.

5.5 <u>Thermal Diffusivity by the Dual Needle Probe Technique</u>

Drury (1985) has investigated the use of thermal conductivity probes for the determination of thermal diffusivity. In his method, two thermal conductivity probes are inserted side by side into a specimen. One probe is used as a line heat source, the other to measure temperature. Thermal diffusivity is then determined by an iterative procedure in which the measured temperature rise in the unheated probe is compared to its predicted temperature rise (using Equation 5.1) with a range of diffusivity values. According to Drury (1985), the principle source of error in this method is in the evaluation of the spacing of the probes. To date this technique has been used on unfrozen material. The present work examines the feasibility of extending this technique to frozen materials.

5.5.1 Test Setup

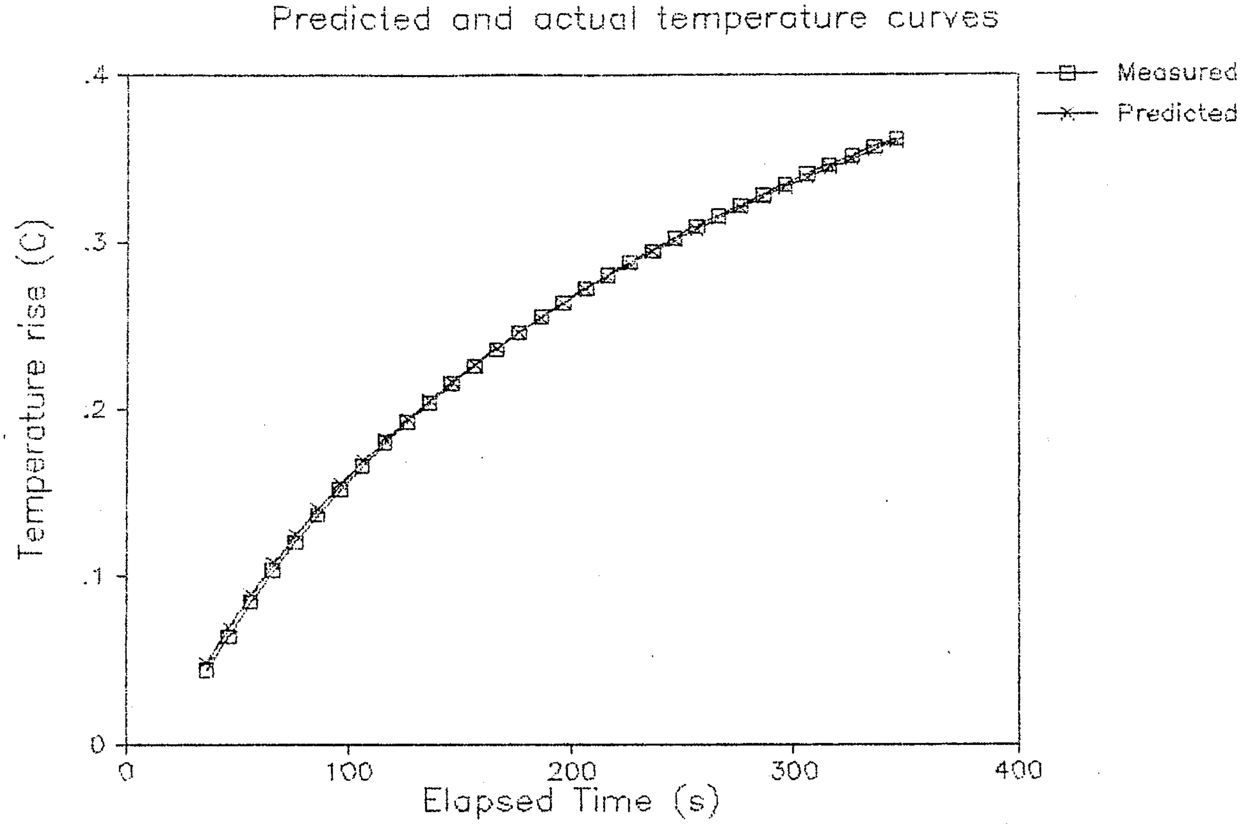
Data for thermal diffusivity evaluation was obtained during routine thermal conductivity determinations by employing the monitor probe as the heat sensor and one of the heated probes as the heat source. Probe insertion was the same as previously described but a second hole for the monitor probe was drilled adjacent to the hole for one of the thermal conductivity determinations. Probe spacing was measured at the specimen surface using a steel rule graduated in mm. An iterative procedure was used to obtain the thermal diffusivity value which best fit the temperature data.

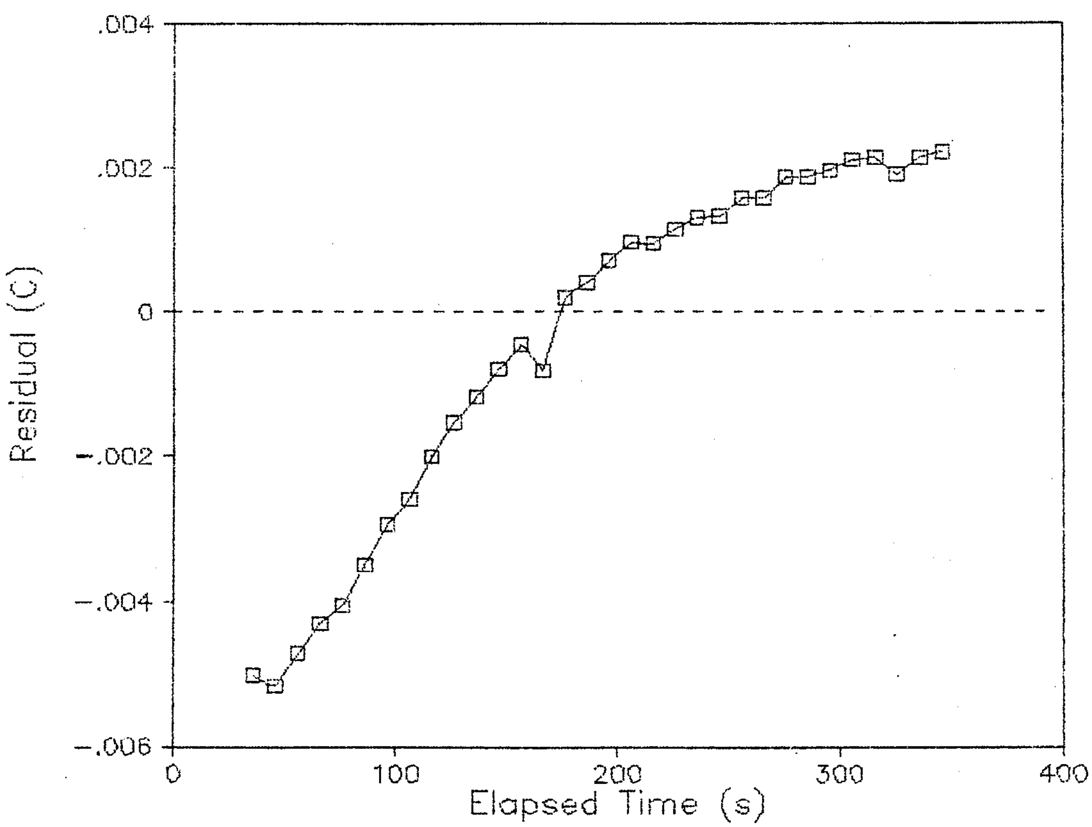
5.5.2 Results and Discussion

Data for a silty clay soil and a sandy soil were obtained. Data for the silty clay specimen only are considered. Figure 5.10 shows the measured and predicted temperature/time plots for the silty clay material. The technique gives a diffusivity value of 1.376×10^{-6} $M^2 s^{-1}$.

While the fit is good, the residuals from this fit are not randomly distributed, indicating that the test situation is not adequately modelled by equation 5.1 alone. Possible sources of deviation from the simple analytical model include temperature drift, temperature dependent thermal properties, and contact resistance. The pattern of residuals suggests that temperature drift could not be the sole source of error, since such drift

Figure 5.10


Predicted and actual temperature curves
Measured
Predicted
Temperature rise (C)
.4
.3
.2
.1
0
0
100
200
300
400
Elapsed Time (s)


Residual (C)
.004
.002
0
-.002
-.004
-.006
0
100
200
300
400
Elapsed Time (s)

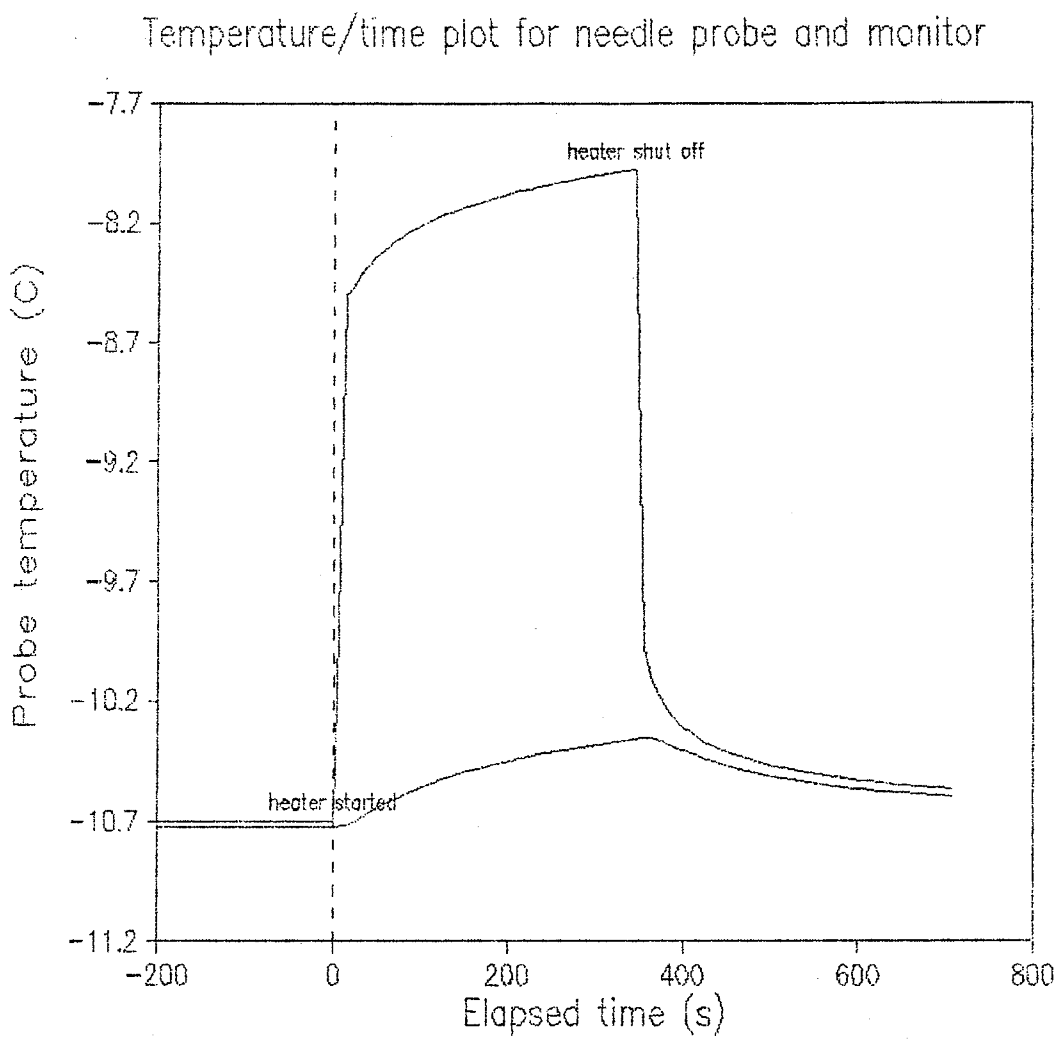
would be expected to be linear, and would therfore produce linear residuals.

If the diffusivity of the specimen varies significantly over the temperature range covered during the test, the analytical model will not represent the test situation. While the temperature range experienced in the monitor probe was small (less than 0.4 C), the temperature range at the heat source was almost 2.8 degrees. The typically high correlation coefficient for the thermal conductivity value obtained during this run suggests that the thermal properties were not significantly variable in this range, since the thermal conductivity test would also be influenced by this effect. The large temperature rise at the heat source (Figure 5.11) does suggest, however, that applicability of this approach will be subject to an upper temperature limit. The limit will be similar to that for thermal conductivity tests (approximately -2 C in clay materials).

The difference between frozen and unfrozen materials suggests that contact resistance may be the source of error in this situation (while the thermal conductivity determination is sensitive to an uneven or changing contact resistance, test results are not affected by a uniform and constant contact resistance, although this influences the test duration).

For tests in unfrozen materials, the probe can be inserted into an undersized hole, minimizing the contact resistance. Undersized holes cannot be used for probe installation in frozen core materials, and in fact they were drilled slightly oversized. Although the gap was filled with a highly conductive material to minimize contact resistance, the properties of this

Figure 5.11


Temperature/time plot for needle probe and monitor
heater shut off
heater started
Probe temperature (C)
-7.7
-8.2
-8.7
-9.2
-9.7
-10.2
-10.7
-11.2
-200
0
200
400
600
800
Elapsed time (s)

space were different from the soil material.

Further work is required to determine the source of the small residual error in the predicted temperature rise, as well as the magnitude of the error in the diffusivity value due to it. This is not possible with the limited data available from the present investigation, since no independent diffusivity measurement is available.

Future work should also investigate the potential for error due to the uncertainty of probe spacing. While Drury (1985) indicates that 20 mm should be considered an upper limit on probe spacing in unfrozen materials (because of the decreasing temperature rise with increasing distance from the heat source), a greater spacing may be possible in frozen materials because of their higher diffusivity. Increasing the distance between the probes will decrease the relative uncertainty in probe spacing. This potential advantage may be offset by the need to reduce the temperature rise at the heat source.

Assuming that satisfactory answers can be found to these questions, our preliminary finding is that this technique is feasible for use in frozen materials.

6. A Guide to the Database for the Borehole Sites

All information collected about the core materials was summarized in a computer database using the dBASE III program. This progam permits updating, indexing and sorting of the data, data manipulation, and the preparation of printed data summaries.

At present, the database contains 313 records, one for each bagged fragment of core material in the coldroom. Records are subdivided into fields representing individual pieces of information. The field labels and contents are summarized below. (In the descriptions below, "fragment" refers to the contents of individual storage bags, while "pieces" are groups of one to three fragments with the same number designation.)

Norman Wells Database
Field Labels and Description of Contents

HOLE_NUM	Borehole identification number
CORE_NUM	Core piece number (from core label)
CORE_ABC	Core fragment letter deignation - A,B, or C (from core label)
BOX_NUM	Number designation of box in which core is stored
CORE_TOP	Depth of the top of the core piece (feet/inches) (from core label)
CORE_BOTTM	Depth of the bottom of the core piece (feet/inches) (from core label)
CORE_LENTH	Length of core fragment (cm) measured in coldroom
CORE_MASS	Mass of core fragment (kg) measured in coldroom
SOIL_TYPE	Visual soil type of fragment, determined in coldroom after scraping
INCLUSIONS	Inclusions in core soil matrix (other than ice)
ICE_CLASS	NRC ground ice classification for fragment

ICE_ORIENT	spatial orientation of ice bodies in fragment
HARDNESS	hardness of ice bodies in fragment
STRUCTURE	structure of ice within ice bodies
ICE_COLOUR	colour of ice in ice bodies
ICE_SHAPE	shapes of ice bodies
LENS_THICK	thickness of ice lenses or ice veins in fragment
GRAIN_DIAM	diameter of ice grains in fragment
COMMENTS	comments
CONDY	thermal conductivity test result (W $m^{-1}K^{-1}$)

Several database reports were created using these data. Because the information in each record was too extensive to fit completely into column format, the information in each report was selected to present the information which would be useful for particular purposes. Separate reports were developed which:

1. describe the contents of each storage box;
2. describe the core from each borehole in a general way;
3. describe the core from each borehole with an emphasis on the properties of the soil material;
4. describe the core from each borehole with an emphasis on the properties of the ice inclusions;
5. give the thermal conductivity data for each borehole, including potentially pertinent physical data;
6. give the dielectric property data for each borehole, including potentially pertinent physical data.

Copies of these database reports are included with this document. They serve as examples only: reports can be modified or updated, and new reports can be created by the scientific authority using the dBASE program.

7. Core Cutting of Frozen Specimens for Sample Preparation and Sample Preservation

7.1 Introduction

The feasibility of using a diamond wire saw (provided by the scientific authority) to obtain sections of frozen core with minimal damage to the cut surface was invesigated. Cutting frozen specimens to length is usually accomplished by means of a sawblade of some form. For most work this is adequate, however, blades can induce fracturing in ice structures and the cut is rarely clean enough for detailed analysis of ice inclusions or other features.

7.2 Description of the Core Cutting Device

The scientific authority provided a diamond wire saw with the capability to control cut thickness, cutting rate and the pressure on the cutting surface. The apparatus was originally developed for cutting seniconductor materials, and has been used on frozen soil materials by Osterkamp (1977).

The saw consists of a diamond coated cutting wire and associated hardware (pulleys, capstan and motor) to control wire speed, a stage with a micrometer adjustment to control the thickness of the specimen cut, a balance system to control the force exerted on the cutting surface, and a system to supply slurry or lubricant to the cutting surface. Osterkamp (1977) suggests that the cutting speed be less than 30 cm s^{-1} and that the pressure on the diamond wire be less than 100 g.

The apparatus as supplied could not be used for the work involved in this contract (cutting 3-5 cm sections of frozen core from larger core fragments). The stage supplied with the apparatus was designed to support materials weighing a few grams, and to permit cuts in thin materials. In contrast, the frozen core materials weighed up to 5 kg, and a cutting depth of 11 cm was required. As a result, the stage was removed from the apparatus, and a new stage was designed and built.

While similar in concept to the original stage, it supports the core on one side of the cutting wire (the original stage was supported on both sides of the wire). This change was necessary to give sufficient cutting depth between the diamond wire and the body of the apparatus, and to provide support for the core nearer to its centre of mass (to prevent twisting). In addition, the new stage is less precise and has no micrometer adjustment.

An addition difficulty with the saw (as delivered) was that the motor driving the cutting wire was packed with a lubricant which isunsuitable for use in the coldroom. When the saw was allowed to cool down to the ambient temperature of the coldroom, the motor could not overcome the greater viscosity of the lubricant. The apparatus was warmed up in the anteroom, and then returned to the coldroom and switched on immediatly, to determine whether it could maintain its temperature by keeping it running. After running for a few minutes, the apparatus slowed down and behaved as it had when started cold.

Time constraints did not permit completion of all nessesary modifications to the saw before specimen cutting could be performed on a routine basis. Specimens were cut for acoustical and electrical properties (carried out elsewhere) using the traditional cutting method (a hacksaw).

If this saw is to be used in the coldroom in the future, some method of lowering the viscosity of the motor lubricant must be devised. Osterkamp (1977) utilized a low temperature lubricant, however, using a battery blanket around the motor may be an acceptable alternative.

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Appendix I

Inventory of Norman Wells Core Samples

	Depth (ft)		Depth (m)		Mass	Length	Total Density
Box 19							
7A C1	1.00	2.00	.30	.61	2.32	27.00	.84
7A C2a	2.00	4.00	.61	1.22	3.00	31.00	.94
7A C2b					2.69	26.00	1.01
7A C3a	4.00	5.50	1.22	1.68	3.88	23.00	1.64
7A C3b					3.14	19.50	1.57
7A C4	5.50	7.00	1.68	2.13	6.22	32.00	1.89
7A C5	7.00	8.00	2.13	2.44	4.88	25.00	1.90
7A C6a	8.00	10.00	2.44	3.05	5.39	31.50	1.67
7A C6b					5.57	30.00	1.81
7A C7a	10.00	12.00	3.05	3.66	4.98	26.50	1.83
7A C7b					3.51	18.50	1.85
7A C7c					4.57	23.50	1.90
7A C8a	12.00	14.50	3.66	4.42	5.16	28.50	1.76
7A C8b					4.77	24.00	1.94
7A C8c					5.41	26.50	1.99
7A C9a	14.50	17.00	4.42	5.18	4.52	24.50	1.80
7A C9b					4.96	23.00	2.10
Box 18							
7A C9c					5.23	27.00	1.89
7A C10a	17.00	19.50	5.18	5.94	3.53	18.00	1.91
7A C10b					4.94	25.00	1.93
7A C10c					4.41	22.00	1.95
7A C11a	19.50	21.50	5.94	6.55	4.76	27.00	1.72
7A C11b					5.56	30.00	1.81
7A C12a	21.50	23.50	6.55	7.16	4.01	24.00	1.63
7A C12b					4.34	25.00	1.69
7A C12c					4.42	26.00	1.66
7A C13a	23.50	25.00	7.16	7.62	3.95	24.50	1.57
7A C13b					4.70	23.00	1.99
7A C14a	25.00	26.00	7.62	7.92	4.68	26.50	1.72
7A C14b					4.45	22.50	1.93
7A C15a	26.00	27.50	7.92	8.38	4.78	22.00	2.12
7A C15b					4.31	22.00	1.91
7A C16	27.50	28.00	8.38	8.53	2.86	-	-
7A C17a	32.50	34.00	9.91	10.36	5.52	27.50	1.96

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 17							
7A C17b					5.48	27.00	1.98
7A C18a	34.00	36.50	10.36	11.13	4.23	22.50	1.83
7A C18b					4.55	25.00	1.77
7A C18c					4.89	27.00	1.77
7A C19a	36.50	39.00	11.13	11.89	4.68	26.00	1.75
7A C19b					5.33	29.00	1.79
7A C19c					4.18	25.50	1.60
7A C20a	39.00	41.00	11.89	12.50	5.72	27.50	2.03
7A C20b					6.57	32.00	2.00
7A C20c					3.69	20.00	1.80
7A C21a	41.50	44.00	12.65	13.41	3.45	22.00	1.53
7A C21b					4.30	29.00	1.45
7A C21c					4.82	27.00	1.74
7A C22a	44.00	46.50	13.41	14.17	5.19	26.00	1.95
7A C22b					4.71	27.00	1.70
7A C22c					4.09	25.00	1.59
7A C23a	46.50	48.75	14.17	14.86	5.55	28.00	1.93
7A C23b					4.04	26.00	1.51
7A C23c					4.29	24.00	1.74
7A C24a	48.75	50.50	14.86	15.39	4.78	24.00	1.94
7A C24b					4.00	20.00	1.95
7A C24c					4.98	24.00	2.02
7A C25a	50.50	53.00	15.39	16.15	5.75	29.00	1.93
7A C25b					4.80	23.00	2.03
7A C25c					5.07	26.00	1.90
7A C26a	53.00	55.00	16.15	16.76	4.03	19.00	2.07
Box 16							
7A C26b					6.09	30.00	1.98
7A C26c					4.40	21.50	1.99
7A C27a	55.00	59.50	16.76	18.14	5.41	28.00	1.88
7A C27b					5.17	27.50	1.83
7A C27c					5.22	25.50	1.99
7A C28a	59.50	62.50	18.14	19.05	4.98	25.00	1.94
7A C28b					6.35	31.50	1.96
7A C28c					5.76	29.00	1.94
7A C29a	62.50	66.00	19.05	20.12	4.87	24.50	1.94
7A C29b					4.66	23.70	1.92
7A C29c					6.27	31.50	1.94
7B C1a	2.50	4.00	.76	1.22	6.69	44.50	1.47
7B C2	4.00	5.50	1.22	1.68	6.25	38.00	1.60
7B C3a	5.50	8.00	1.68	2.44	7.87	41.00	1.87

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 15							
7B C3b					5.89	31.00	1.85
7B C4a	8.00	9.25	2.44	2.82	8.76	46.00	1.86
7B C4b	9.25	10.50	2.82	3.20	6.61	32.00	2.01
7B C5a	10.50	11.75	3.20	3.58	7.82	38.00	2.01
7B C5b	11.75	13.00	3.58	3.96	7.89	35.00	2.20
7B C6a	14.75	15.50	4.50	4.72	8.31	40.00	2.02
7B C6b					7.72	37.00	2.03
7B C7a	15.50	18.00	4.72	5.49	6.51	29.00	2.19
7B C7b					5.03	25.00	1.96
7B C7c					5.08	25.00	1.98
7B C8a	18.00	10.50	5.49	3.20	4.94	28.00	1.72
7B C8b					6.12	30.00	1.99
7B C8c					4.64	21.00	2.15
7B C9a	20.50	23.00	6.25	7.01	5.71	28.00	1.99
7B C9b					5.23	35.00	1.46
Box 14							
7B C9c					5.98	28.00	2.08
7B C10a	23.00	25.50	7.01	7.77	5.75	30.00	1.87
7B C10b					4.39	22.00	1.94
7B C10c					3.38	15.00	2.20
7B C11a	25.50	28.00	7.77	8.53	5.30	26.00	1.99
7B C11b					5.47	27.00	1.97
7B C11c					5.74	30.00	1.86
7B C12a	28.00	30.50	8.53	9.30	5.53	28.00	1.92
7B C12b					5.24	24.00	2.13
7B C12c					4.39	22.00	1.94
7B C13a	30.50	33.00	9.30	10.06	4.49	26.00	1.68
7B C13b					3.35	26.00	1.26
7B C13c					3.28	19.00	1.68
7B C14a	33.00	35.50	10.06	10.82	3.51	20.00	1.71
7B C14b					5.60	28.00	1.95
7B C14c					5.67	28.00	1.97

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 13							
7B C15a	35.50	38.00	10.82	11.58	5.81	28.50	1.99
7B C15b					5.21	26.50	1.92
7B C15c					3.85	19.50	1.92
7B C16a	38.00	40.50	11.58	12.34	6.08	28.00	2.12
7B C16b					6.37	30.00	2.07
7B C16c					4.68	21.50	2.12
7B C17a	40.50	43.00	12.34	13.11	5.43	24.50	2.16
7B C17b					4.75	23.50	1.97
7B C17c					6.17	29.50	2.04
7B C18a	43.00	45.50	13.11	13.87	3.58	18.50	1.89
7B C18b					5.73	29.50	1.89
7B C18c					4.97	22.50	2.15
7B C19a	45.50	47.50	13.87	14.48	5.98	29.50	1.98
7B C19b					5.93	28.50	2.03
7B C20a	47.50	50.00	14.48	15.24	5.65	26.50	2.08
7B C20b					5.69	26.50	2.09
7B C20c					5.80	26.50	2.13
Box 12							
7B C21a	50.00	52.50	15.24	16.00	5.43	28.00	1.89
7B C21b					4.61	23.00	1.95
7B C21c					5.04	24.00	2.05
7B C22a	52.50	55.00	16.00	16.76	4.78	24.00	1.94
7B C22b					4.72	23.00	2.00
7B C22c					5.53	26.50	2.03
7B C23a	55.00	57.50	16.76	17.53	4.90	25.00	1.91
7B C23b					5.22	26.00	1.96
7B C23c					4.46	23.00	1.89
7B C24a	57.50	60.00	17.53	18.29	5.94	26.00	2.23
7B C24b					4.62	21.00	2.14
7B C24c					5.55	27.50	1.97
7B C25a	60.00	62.50	18.29	19.05	5.93	30.00	1.93
7B C25b					6.19	30.00	2.01
7B C26a	62.50	65.00	19.05	19.81	5.25	26.00	1.97
7B C26b					4.53	22.00	2.01
7B C26c					4.98	20.50	2.37

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 11							
7B C27a	65.00	66.80	19.81	20.36	5.98	30.00	1.94
7B C27b					4.16	26.00	1.56
7C C1a	.00	2.50	.00	.76	5.53	29.00	1.86
7C C1b					4.09	30.00	1.33
7C C2a	2.50	5.00	.76	1.52	2.75	-	-
7C C2b					3.45	18.00	1.87
7C C2c					5.01	28.00	1.74
7C C3a	5.00	7.50	1.52	2.29	5.35	28.00	1.86
7C C3b					5.35	27.00	1.93
7C C3c					5.47	27.00	1.97
7C C4a	7.50	10.00	2.29	3.05	5.36	26.00	2.01
7C C4b					6.09	30.00	1.98
7C C4c					4.37	22.00	1.94
7C C5a	10.00	12.50	3.05	3.81	6.01	30.00	1.95
7C C5b					5.37	25.00	2.09
7C C5c					5.78	28.00	2.01
Box 10							
7C C6a	12.50	15.00	3.81	4.57	4.49	22.00	1.99
7C C6b					5.97	30.00	1.94
7C C6c					5.91	28.50	2.02
7C C7a	15.00	17.50	4.57	5.33	4.94	26.00	1.85
7C C7b					4.77	24.00	1.94
7C C7c					5.22	28.00	1.82
7C C8a	17.50	20.00	5.33	6.10	5.75	28.00	2.00
7C C8b					4.31	20.00	2.10
7C C8c					6.05	29.00	2.03
7C C9a	20.00	22.50	6.10	6.86	5.96	29.00	2.00
7C C9b					5.93	28.50	2.03
7C C9c					5.91	28.00	2.06
7C C10	22.50	24.00	6.86	7.32	6.54	30.50	2.09
7C C11a	35.00	37.50	10.67	11.43	5.88	26.00	2.20
7C C11b					5.43	27.00	1.96

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 9							
7C C11c					5.00	23.50	2.07
7C C12a	39.50	42.00	12.04	12.80	5.32	27.00	1.92
7C C12b					6.46	30.00	2.10
7C C12c					5.71	28.00	1.99
7C C13a	42.00	44.50	12.80	13.56	5.71	30.00	1.85
7C C13b					4.65	23.00	1.97
7C C13c					6.07	31.50	1.88
7C C14a	44.50	47.50	13.56	14.48	5.59	28.00	1.95
7C C14b					2.84	15.50	1.79
7C C14c					5.64	29.00	1.90
7C C15a	47.50	50.00	14.48	15.24	5.50	28.00	1.91
7C C15b					4.35	22.00	1.93
7C C15c					4.85	25.00	1.89
7C C16a	50.00	52.50	15.24	16.00	4.57	22.00	2.02
7C C16b					5.54	26.00	2.08
7C C16c					5.15	27.00	1.86
7C C17a	52.50	55.00	16.00	16.76	3.54	17.00	2.03
Box 8							
7C C17b					4.39	22.50	1.90
7C C17c					5.74	29.00	1.93
7C C18a	55.00	56.50	16.76	17.22	4.87	24.00	1.98
7C C18b					4.50	22.00	1.99
7C C19a	56.50	59.00	17.22	17.98	5.00	25.00	1.95
7C C19b					4.53	21.00	2.10
7C C19c					6.18	32.00	1.88
8A C1a	.50	2.50	.15	.76	3.55	22.00	1.57
8A C1b					3.80	23.00	1.61
8A C2a	2.50	5.00	.76	1.52	4.60	26.00	1.72
8A C2b					5.75	29.50	1.90
8A C2c					3.77	20.50	1.79
8A C3a	5.00	7.00	1.52	2.13	4.72	25.00	1.84
8A C3b					5.14	26.50	1.89
8A C4a	6.50	8.50	1.98	2.59	3.56	18.00	1.93
8A C4b					4.86	26.00	1.82
8A C4c					4.90	25.50	1.87

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 7							
8A C5a	8.50	10.00	2.59	3.05	5.31	28.00	1.85
8A C5b					4.07	21.00	1.89
8A C6a	10.00	12.75	3.05	3.89	5.46	28.50	1.87
8A C6b					5.52	31.00	1.74
8A C6c					4.93	26.00	1.85
8A C7a	12.75	15.50	3.89	4.72	5.99	30.50	1.91
8A C7b					5.49	29.00	1.84
8A C7c					4.84	27.00	1.75
8A C8a	15.50	18.25	4.72	5.56	5.30	30.00	1.72
8a C8b					4.17	25.50	1.59
8a C8c					5.78	29.00	1.94
8a C9a	18.00	20.00	5.49	6.10	5.28	29.00	1.77
8a C9b					4.62	23.00	1.96
8a C9c					3.99	27.50	1.41
8a C10a	20.00	22.75	6.10	6.93	5.55	27.00	2.00
8a C10b					6.18	30.00	2.01
Box 6							
8A C10c					6.20	35.00	1.73
8A C11a	22.75	25.00	6.93	7.62	4.90	29.00	1.65
8A C11b					3.85	29.00	1.29
8A C11c					2.90	27.00	1.05
8A C12a	25.25	28.00	7.70	8.53	4.49	26.00	1.68
8A C12b					4.66	27.00	1.68
8A C12c					4.95	31.00	1.56
8A C13a	28.00	30.75	8.53	2.60	3.26	25.00	1.27
8A C13b					4.75	26.00	1.78
8A C13c					5.57	32.00	1.70
8C C1a	.50	3.00	.15	.91	1.33	14.00	.93
8C C1b					2.16	22.00	.96
8C C1c					3.27	33.00	.97
8C C2a	3.00	5.00	.91	1.52	2.46	29.00	.83

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 5							
8C C2b					1.75	27.00	.63
8C C2c					2.69	30.00	.87
8A C3a	5.00	6.50	1.52	1.98	2.65	23.50	1.10
8A C3b					3.59	24.50	1.43
8A C3c					3.96	25.00	1.54
8C C4a	6.50	8.50	1.98	2.59	4.53	29.00	1.52
8C C4b					2.72	19.00	1.40
8C C4c					2.60	21.50	1.18
8C C5a	8.50	10.50	2.59	3.20	2.39	16.00	1.46
8C C5b					3.17	20.00	1.54
8C C5c					3.39	28.00	1.18
9 C1a	.50	2.50	.15	.76	3.88	29.00	1.30
9 C1b					5.24	34.00	1.50
9 C2a	2.50	4.50	.76	1.37	5.01	25.00	1.95
9 C2b					4.83	23.00	2.05
Box 4							
10A C1a	.50	2.50	.15	.76	3.10	39.00	.77
10A C1b					4.04	35.00	1.12
10B C1a	.50	3.00	.15	.91	2.11	30.00	.69
10B C1b					2.18	25.00	.85
10B C1c					2.94	34.00	.84
10B C2a	3.00	5.00	.91	1.52	1.94	23.50	.80
10B C2b					2.08	26.50	.76
10B C2c					2.65	30.50	.85
10B C3a	5.50	8.50	1.68	2.59	2.76	34.00	.79
10B C3b					2.23	29.00	.75
10B C3c					2.53	29.00	.85
11 C1a	.50	2.50	.15	.76	3.38	38.00	.87
Box 3							
11 C1b					3.73	23.00	1.58
11 C1c					3.78	23.50	1.57
11 C2a	2.50	5.00	.76	1.52	4.17	22.50	1.81
11 C2b					4.01	21.50	1.82
11 C2c					6.90	35.00	1.92
11 C3a	5.00	7.50	1.52	2.29	4.23	22.00	1.87
11 C3b					5.94	30.00	1.93
11 C3c					5.98	31.00	1.88
11 C4	7.50	8.50	2.29	2.59	5.75	28.50	1.97
12A C1a	.50	3.00	.15	.91	2.82	30.00	.92
12A C1b					3.81	22.50	1.65
12A C1c					5.15	27.00	1.86
12A C2a	3.00	5.50	.91	1.68	5.19	27.00	1.87
12A C2b					6.70	34.00	1.92
12A C2c					4.92	25.00	1.92

	Depth (ft)		Depth (m)		Mass	Length	Wet Density
Box 2							
12A C3a	5.50	8.00	1.68	2.44	5.02	25.00	1.96
12A C3b					5.66	28.50	1.94
12A C3c					6.59	31.50	2.04
12B C1a	.00	2.00	.00	.61	2.10	30.00	.68
12B C1b					1.97	28.00	.69
12B C1c					1.92	24.50	.76
12B C2a	2.00	4.00	.61	1.22	1.77	20.50	.84
12B C2b					2.14	30.00	.70
12B C2c					2.25	29.00	.76
12B C3a	4.00	5.50	1.22	1.68	2.06	27.00	.74
12B C3b					2.11	24.00	.86
12B C4a	5.50	7.50	1.68	2.29	2.60	33.00	.77
12B C4b					2.01	21.00	.93
12B C4c					1.79	21.00	.83
Box 1							
12B C5a	7.50	9.50	2.29	2.90	2.35	28.50	.80
12B C5b					1.90	24.00	.77
12B C5c					2.55	25.50	.97
12B C6a	9.00	10.50	2.74	3.20	2.91	23.00	1.23
12B C6b					4.49	37.00	1.18
12B C7a	10.50	12.50	3.20	3.81	2.95	19.00	1.51
12B C7b					4.70	30.00	1.53
12B C7c					4.75	29.00	1.60
12B C8a	12.50	15.50	3.81	4.72	5.34	30.00	1.73
12B C8b					5.40	30.00	1.75
12B C8c					4.80	30.00	1.56
12B C9a	15.50	18.50	4.72	5.64	5.33	33.50	1.55
12B C9b					5.31	29.00	1.78
12B C9c					5.16	29.00	1.73
12B C10a	18.00	20.50	5.49	6.25	3.87	26.00	1.45
12B C10b					4.45	26.00	1.67
12B C10c					5.07	26.50	1.86
12B C11a	20.50	24.00	6.25	7.32	4.75	23.70	1.95
12B C11b					7.11	35.00	1.98
12B C11c					6.20	35.00	1.73

Appendix II

Determining the Effect of Gaps Around Parallel Rod Transmission Lines

The dielectric constant of a parallel rod line installed in a soil in an oversized pilot hole can be determined if one knows the physical dimensions of the transmission and the size of the pilot hole. The resultant dielectric constant, K, will be different than the actual dielectric constant, K_{real}, by some factor, F, which depends upon the configuration of the line, the size of the gap and material in the gap:

$$K = K_{real} \times F \qquad (1)$$

The F factor is found from equation (2):

$$F = \frac{k_1 e_o}{k_2 (e_0 - e_1) + k_1 e_1} \qquad (2)$$

where k_1 is the dielectric constant of the material in the gap and k_2 is the dielectric constant of the soil material and

$$e_1 = \cosh^{-1}(c/d) \qquad (3)$$

$$e_0 = \cosh^{-1}(a/b) \qquad (4)$$

where :

$$c/d = \frac{((a/b)^2 + 2n + n^2)^{1/2}}{1 + n} \qquad (5)$$

where a is one-half the line spacing, b is the line radius and

$$n = \text{average gap size} / b \qquad (6)$$

In practice the average gap size is determined from the difference in transmission line diameter and pilot hole size and the equations are solved in reverse order than presented. The analysis can easily be set up on commercial spreadsheet programs to permit rapid analysis of changing conditions. One should be cautioned that one may find an optimum pilot hole size for a given line configuration only to find that drill bits are not available in the desired diameter or necessary length.

Appendix III

Procedure for Thermal Conductivity Tests in Frozen Soils Using the EMR Needle Probe and Data Acquisition System

1. Installing the Needle Probe into Frozen Soil Specimens

1.1 Materials Required

The materials described here are for the Geotherm needle probes. These probes have a length of 60 mm and a diameter of 1. mm. The following equipment is required for proper installation of the needle probe into frozen soil specimens:

1. the appropriate number of Geotherm needle probes;
2. insulated specimen box(es) to contain specimens during tests;
3. electric drill and an extra long 1.5 x 70 mm drill bit;
4. a syringe equiped with a large diameter needle filled with silicon grease or silicon oil (eg. Dow Corning 200 cs)
5. a beaker full of warm water to remove residue from the drill bit (replace water after probes are inserted);
6. a small diameter wire to clean the hypodermic needle;
7. a wire to clean the hole drilled in the soil specimen;
8. data sheets thermal conductivity test;

1.2 Procedure

Since the data acquisition system and associated hardware are located outside the coldroom ensure that the specimen box is appropriately located so that the needle probe's wire leads reach outside the coldroom and that there is no tension on the leads after insertion in the specimens.

1.2.1 <u>Probe Insertion</u>

There are several general guidelines regarding the installation of the needle probes and the location within a specimen where tests will be made:

1. The needle probes should be at least 5 cm from the end of the core and spacing between probes should be at least 10 cm. It follows then that only one test can be made if the specimen length is less than 20 and two is if it is 30 cm. If increased spatial resolution is required then the tests will have to be done at different times.

2. The needle probes should be inserted into reasonable homgenous soil and ice units within the specimen. Treat fractures and obvious voids in the core as if they were core ends. These act as barriers to heat flow which can invalidate results.

3. The needle probes are usually inserted normal to the core length and not in the ends. It is preferable to the drill on the previously scraped surface since one has a better idea of the underlying material.

4. The specimen does not have to be removed from its bag for the thermal conductivity test and holes are drilled through the bag.

The recommended installation procedure is as follows:

1. assemble materials and test specimens in the coldroom;

2. drill a hole perpendicular to the specimen length using light pressure.

   a. never allow the bit to stop moving while it is still in the hole since it will freeze in place;

   b. void spaces or changes in soil texture or structure beneath the surface can be detected by variations in the penetration rate of the drill bit. These changes should be recorded on the test data sheet in the comments column beside the appropriate probe #.

3. Withdraw the drill bit with the drill still turning to prevent freeze-up and insert the cleaner wire into the drilled hole (since the cuttings tend to melt, they must be removed or packed to the bottom of the access hole before they refreeze). Ensure that the hole is of the appropriate depth;

4. Clean the drill bit by immersing it in a beaker of warm

water while the bit is still turning. Residue should be removed in this way after every hole is drilled. Dry off any excess water on the bit to prevent ice formation.

4. Squeeze some silicon grease/oil out of the hypodermic needle to make sure that it is clear of blockage. Insert the needle into the hole and squeeze in the grease/oil as the needle is slowly withdrawn. If the procedure has been properly carried out the grease/oil should be evident at the surface of the hole. If no compound is evident, then check the hypodermic needle for blockage. If the needle is not the problem, then there may be large voids in the specimen.

5. Insert a probe in the hole. If there is sufficient heat sink compound in the hole, the probe should slide into the hole easily until it is almost fully inserted. Push the probe firmly in the hole the rest of the way to ensure that it is fully seated in the hole and to expel any excess heat sink compound.

6. record the core number and core depth beside the appropriate probe number on the thermal conductivity test data sheet. Indicate the position along the specimen where the needle probe(s) is installed using the end of the specimen closest to the soil surface as the reference. A probe placed 10 cm from near-surface end would be recorded as "+ 10 cm ". Any relevant comments about apparent voids or inhomogeneities should be recorded also.

7. When the probe(s) is inserted in a core, place it in the insulated sample box and proceed to the next core. Make sure that there no specimen rests on a needle probe or the lead wires are stressed in any way.

8. When all cores are instrumented and in the box, cover them with insulation and close the box.

1.2.2 Assessing Temperature Stability

The specimens should be allowed to come to thermal equilibrium for at least one hour, preferably longer. To check for thermal equilibrium, perform the test as outlined in the next section, but leave the current source turned off. The resultant print of the test will show the temperature drift in the specimens over a ten minute period. If in doubt, wait.

2. <u>Test Procedures</u>

The test procedure is as follows:

1. Turn on all relevant devices (the disk drive on this particular computer should be turned on first). Be sure that all devices, (including the printer) are on before starting, since inter-device communications can get fouled up if a new device gets switched on in the middle of the run.

2. Adjust the current source to the appropriate level (usually 100 ma). The particular multimeter being used for the current defaults to dc volts on power up. This must be changed to dc amps before the test proceeds.

3. Type in **LOAD "NEEDLE1"** on the computer and press **RETURN.** When the disk drive stops, press the **RUN** key.

4. The computer will ask for a filename to store raw data, and another to store temperature data. When you enter these, be sure that they are not filenames already on the disk by including the hole and core numbers of one of the tested cores in the name, for example:

   C7A19BR for the raw data
   C7A19BT for the temperature-data

   Record these file names on the data sheet.

5. The program will ask you to choose between the NOW option and the DRIFT option, choose **NOW.** At present, a bug in the DRIFT subroutine causes the system to hang up.

6. After pressing the NOW key, the probes are heated for approximately 5 minutes.

   a. record the current supplied by the current source

   The rest is automated, including printing out of raw data and temperature data. After the heaters are turned off, the computer continues to monitor probe temperature for another 5 minutes. The entire run procedure takes 15-20 minutes. Save the printouts for future reference.

   b. record the voltage drop across each probe on the data sheet

This information is asked for in the conductivity calculation program.

7. Return to step 3 for subsequent runs.

Appendix IV

Sample Database Reports

including:

1. Description by soil and ice
2. Indexed by box
3. Description of ice
4. Thermal conductivity and related data
5. Description of soil

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
** Borehole Number 10A								
1 A	4	0.2	0.8	PEAT		NFN		BROKEN
1 B	4	0.2	0.8	PEAT/SILTY FINE SAND		NBN		PEAT/MINERAL CONTACT/BROKEN
** Borehole Number 10B								
1 A	4	0.2	0.9	PEAT		VR	GRAINS	BROKEN
1 B	4	0.2	0.9	PEAT		NBN		BROKEN
1 C	4	0.2	0.9	PEAT		NBN		COLOUR CHANGE/BROKEN
2 A	4	0.9	1.7	PEAT		NBN		
2 B	4	0.9	1.7	PEAT		VS	VEIN	BROKEN
2 C	4	0.9	1.7	PEAT		VS		BROKEN
3 A	4	1.7	2.6	PEAT		VS		BROKEN
3 B	4	1.7	2.6	PEAT		VS	LENS	BROKEN
3 C	4	1.7	2.6	PEAT		NBN		MINERAL SOIL CONTACT
** Borehole Number 11								
1 A	4	0.2	0.8	PEAT/FINE SAND		NBN		MINERAL SOIL CONTACT
1 B	3	0.2	0.8	FINE SAND	ORGANICS	VS	GRAINS	BROKEN
1 C	3	0.2	0.8	FINE SAND/SILTY SAND		VS	LENS/VEIN	
2 A	3	0.8	1.5	FINE SAND		NBN		
2 B	3	0.8	1.5	FINE SAND		NB		
2 C	3	0.8	1.5	FINE SAND		NBN		
3 A	3	1.5	2.3	FINE SAND	CALCEROU	NBN		
3 B	3	1.5	2.3	SILTY CLAY	CALC/GRA	VS	LENS	BROKEN
3 C	3	1.5	2.3	SILTY CLAY	GRAV/CAL	VS	LENS	
4	3	2.3	2.6	SILTY CLAY	CAL/GRAV	VS	LENS	BROKEN
** Borehole Number 12A								
1 A	3	0.2	0.9	PEAT/SILTY CLAY		VS	LENS	SOIL CONTACT/BROKEN
1 B	3	0.2	0.9	SILT	FEW GRAV	VS	LENSES	BROKEN/GRADING TO FINER LENSES AT B
1 C	3	0.2	0.9	SILT		VS	LENS/VEIN	LENSES ARE <1, VEINS 2 MM
2 A	3	0.9	1.7	SILT		VS	LENS/VEIN	BROKEN
2 B	3	0.9	1.7	SILT/SILTY SAND	GRAVEL	VS	LENS/VEIN	BROKEN/SOIL CONTACT, ICE DIFFERS
2 C	3	0.9	1.7	SILTY FINE SAND	GRAVEL	VS	LENS/VEIN	
3 A	2	1.7	2.5	SILT		VS	LENS/VEIN	BROKEN
3 B	2	1.7	2.5	SILT/SILTY SAND		VS	LENS/VEIN	BROKEN
3 C	2	1.7	2.5	SILTY FINE SAND	GRAVEL	VS	LENS/VEIN	BROKEN

Norman Wells Permafrost Core data
Description by soil and ice

** Borehole Number 12B

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
1 A	2	0.0	0.6	PEAT		NB		BROKEN
1 B	2	0.0	0.6	PEAT		NB		
1 C	2	0.0	0.6	PEAT		NB		
2 A	2	0.6	1.2	PEAT		NB		
2 B	2	0.6	1.2	PEAT		NF		BROKEN
2 C	2	0.6	1.2	PEAT		VR	GRAINS	BROKEN
3 A	2	1.2	1.7	PEAT		VS	LENS	BROKEN
3 B	2	1.2	1.7	PEAT		NB		BROKEN
4 A	2	1.7	2.3	PEAT		NB		BROKEN
4 B	2	1.7	2.3	PEAT		VR	GRAINS/SNOWLIKE STUF	BROKEN
4 C	2	1.7	2.3	PEAT		VS	LENS	
5 A	1	2.3	2.8	PEAT		VC	RANDOM	BROKEN
5 B	1	2.3	2.8	PEAT		NB		BROKEN
5 C	1	2.3	2.8	PEAT/SILTY CLAY		VS	LENSES/GRAINS	BROKEN
6 A	1	2.8	3.2	SILTY CLAY		VS	LENS/VEIN	
6 B	1	2.8	3.2	CLAY/SILT		VS	LENS/VEIN	BROKEN
7 A	1	3.2	3.8	SILT		VS	LENS	
7 B	1	3.2	3.8	SILT		VS	LENS	BROKEN END
7 C	1	3.2	3.8	SILT		VS	LENS/GRINS	
8 A	1	3.8	4.8	SILT		VS	LENS/GRAINS	
8 B	1	3.8	4.8	SILT		VS	LENS/GRAINS	
8 C	1	3.8	4.8	CLAYEY SILT	FEW GRAV	VS	LENS/VEIN/GRAINS	BROKEN
9 A	1	4.8	5.5	SILT	FEW GRAV	VS	LENS/GRAINS	BROKEN
9 B	1	4.8	5.5	CLAYEY SILT		VS	LENS/GRAINS	FEW LENSES: MOSTLY GRAINS
9 C	1	4.8	5.5	CLAYEY SILT		VS	LENS/GRAINS	
10 A	1	5.5	6.3	SANDY SILT?	FEW GRAV	VS	LENS/GRAINS	TOO BROKEN TO ESTIMATE ICE DIA/THIC
10 B	1	5.5	6.3	SANDY SILT?	MANY GRA	NB		
10 C	1	5.5	6.3	SILT	GRAVEL	VS	GRAINS	BROKEN
11 A	1	6.3	7.4	SILTY FINE SAND	GRAVEL	VS	LENS/GRAINS	
11 B	1	6.3	7.4	CLAYEY SILT	MANY GRA	VS	LENS	BROKEN
11 C	1	6.3	7.4	SILTY FINE SAND	MANY GRA	VS	LENS	PREVIUOSLY THAWED AND RE-FROZEN

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
** Borehole Number 7A								
1	19	0.3	0.6	PEAT		VC		
2 A	19	0.6	1.2	PEAT/SILTY CLAY	ORGANICS	VS	LENSES	ONE LARGE LENS ONLY
2 B	19	0.6	1.2	PEAT/SILTY CLAY		VS	LENS	CONDUCTIVITY: PEAT 1.397 SILT 2.171
3 A	19	1.2	1.7	SILTY CLAY		VS	LENS	
3 B	19	1.2	1.7	SILTY CLAY		VS	LENSES	
4	19	1.7	2.2	SILTY CLAY	GRAVEL	NB		
5	19	2.2	2.5	SILTY CLAY	GRAVEL	VS	LENS	
6 A	19	2.5	3.1	SILTY CLAY	GRAVEL	VS	LENS	
6 B	19	2.5	3.1	DENSE SILTY CLAY	GRAVEL	VS	LENS/VEIN	
7 A	19	3.1	3.7	DENSE SILTY CLAY	GRAVEL	VS	LENSES	
7 B	19	3.1	3.7	DENSE SILTY CLAY	GRAVEL	NB		
7 C	19	3.1	3.7	CLAY	GRAVEL	VS	1/2	
8 A	19	3.7	4.5	CLAY	GRAVEL	VS	LENS/VEIN	
8 B	19	3.7	4.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
8 C	19	3.7	4.5	CLAY	GRAVEL	VS	LENS/VEIN	
9 A	19	4.5	5.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
9 B	19	4.5	5.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS	RETIC. MERGING INTO LARGE GRAINS
9 C	18	4.5	5.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
10 A	18	5.2	6.0	SILTY CLAY	CALC.	VS	LENS	BROKEN AT LENS
10 B	18	5.2	6.0	SILTY CLAY	GRAVEL	NB		
10 C	18	5.2	6.0	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS	
11 A	18	6.0	6.6	SILTY CLAY	GRAVEL	VS	LENSES	
11 B	18	6.0	6.6	SILTY CLAY		VS	LENS/VEIN	
12 A	18	6.6	6.6	SILTY CLAY	GRAVEL	VS	LENSES	
12 B	18	6.6	7.2	SILTY CLAY	GRAVEL	NB		ICE COATING VISIBLE IN FRACTURE
12 C	18	6.6	7.2	SILTY CLAY	GRAVEL	VR	GRAINS	ONE LARGE ICE MASS
13 A	18	7.2	7.7	SILTY CLAY`	GRAVEL	VR	VEIN	FRACTURED CORE
13 B	18	7.2	7.7	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS	
14 A	18	7.7	8.0	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	
14 B	18	7.7	8.0	SILTY CLAY	GRAVEL	NB		
15 A	18	8.0	8.4	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	LARGE ICE LENS AT CORE END
15 B	18	8.0	8.4	SILTY CLAY	GRAVEL	NB		
15 C	18	8.0	8.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
16	18	8.4	8.6	SILTY CLAY	GRAVEL	VS	LENS	
17 A	18	10.0	10.4	SILTY CLAY	GRAVEL	NB		
17 B	17	10.0	10.4	SILTY CLAY	GRAVEL	VS	LENSES	TWO LENSES IN CENTER OF CORE
18 A	17	10.4	11.2	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	BROKEN
18 B	17	10.4	11.2	SILTY CLAY	GRAVEL	NB		ONE LARGE STONE-8 CM DIAMETER
18 C	17	10.4	11.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN/ ONE LARGE LENS ONLY
19 A	17	11.2	12.0	SILTY CLAY	GRAVEL	VR	GRAINS	
19 B	17	11.2	12.0	SILTY CLAY	GRAVEL	VS	LENS	
19 C	17	11.2	12.0	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN / MANY LARGE LENSES
20 A	17	12.0	12.7	SILTY CLAY	GRAVEL	NB		BROKEN
20 B	17	12.0	12.7	SILTY CLAY	GRAVEL	NB		BROKEN
20 C	17	12.0	12.7	SILTY CLAY	GRAVEL	VS	LENS	BROKEN AT THICK LENS
21 A	17	12.7	13.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN / LARGE VEIN, WITH THIN LENS
21 B	17	12.7	13.5	SILTY CLAY	GRAVEL	VS	LENS	BROKEN
21 C	17	12.7	13.5	SILTY CLAY	GRAVEL	VR	GRAINS	WITH A THICK LENS AT CORE END
22 A	17	13.5	14.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN	

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
22 B	17	13.5	14.3	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	LARGE GRAIN CLUSTERS
22 C	17	13.5	14.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS	BROKEN :GRAINS IN LENS/VEIN PATTERN
23 A	17	14.3	15.0	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	GRAINS IN LENS PATTERNS
23 B	17	14.3	15.0	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	CLEAR GRAINS/CLOUDY LENS 50% EXCESS
23 C	17	14.3	15.0	DENSE CLAY		VS	GRAINS-SOME LENSLIKE	5mm LENSLIKE STRUCTURE/ICIER AT END
24 A	17	15.0	15.5	SILTY CLAY	GRAVEL	VS	VEIN	THICKER LENS AT CORE END
24 B	17	15.0	15.5	SILTY CLAY	GRAVEL	VS	VEIN/GRAINS	GRAINS IN LENS PATTERN
24 C	17	15.0	15.5	SILTY CLAY	GRAVEL	VR	GRAINS	
25 A	17	15.5	16.3	SILTY CLAY	GRAVEL	VR	GRAINS	
25 B	17	15.5	16.3	SILTY CLAY	GRAVEL	VS	VEIN	
25 C	17	15.5	16.3	SILTY CLAY	GRAVEL	VS	VEIN	BROKEN
26 A	17	16.3	16.9	SILTY CLAY		NB		
26 B	16	16.3	16.9	SILTY CLAY		NB		
26 C	16	16.3	16.9	SILTY CLAY		VS	VEIN	
27 A	16	16.9	18.3	SILTY CLAY		VS	LENS	2 LENSES ONLY
27 B	16	16.9	18.3	SILTY CLAY		VS	VEIN	
27 C	16	16.9	18.3	SILTY CLAY		VS	LENS	ONE LENS ONLY / BROKEN
28 A	16	18.3	18.3	LAYERED SILTY CLAY		VS	VEIN	
28 B	16	18.3	19.2	LAYERED SILTY CLAY		NB		BROKEN
28 C	16	18.3	19.2	LAYERD SILTY CLAY		NB		BROKEN
29 A	16	19.2	19.2	CLAY		NB		BROKEN
29 B	16	19.2	20.3	CLAY		NB		BROKEN
29 C	16	19.2	20.3	CLAY		VS	LENS	ONE LENS ONLY

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
** Borehole Number 7B								
1	16	0.8	1.2	SILTY CLAY	GRAVEL	VS	LENSES	
2	16	1.2	1.7	SILTY CLAY	GRAVEL	VS	LENS	
3 A	16	1.7	2.5	SILTY CLAY	GRAVEL	VS	LENS	
3 B	15	1.7	2.5	SILTY CLAY	GRAVEL	VS	LENS	
4 A	15	2.5	2.8	SILTY CLAY		VS	LENSES	
4 B	15	2.8	3.2	SILTY CLAY	CALC	VS	LENS/VEIN	
5 A	15	3.2	3.6	SILTY CLAY	CAL/GRAV	VS	LENS	
5 B	15	3.6	4.0					
6 A	15	4.5	4.8	SILTY CLAY	GRAVEL	VS	LENS	BROKEN
6 B	15	4.5	4.8	SILTY CLAY	GRAVEL	VS	LENS	
7 A	15	4.8	5.5	SILTY CLAY	GRAVEL	VS	LENS	
7 B	15	4.8	5.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
7 C	15	4.8	5.5	SILTY CLAY	GRAVEL	VS	LENSES	
8 A	15	5.5	6.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN	LARGE STONES 8 CM DIAM.
8 B	15	5.5	6.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
8 C	15	5.5	6.3	SILTY CLAY	GRAVEL	NB		
9 A	15	6.3	7.1	SILTY CLAY		VR	GRAINS	
9 B	15	6.3	7.1	SILTY CLAY	GRAVEL	VR	GRAINS	
9 C	14	6.3	7.1	CLAYEY SILT	GRAVEL	VS	LENSES	
10 A	14	7.1	7.8	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	
10 B	14	7.1	7.8	SILTY CLAY	GRAVEL	VR	GRAINS	
10 C	14	7.1	7.8	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	
11 A	14	7.8	8.6	SILTY CLAY	GRAVEL	VS	LENS	
11 B	14	7.8	8.6	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	
11 C	14	7.8	8.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS	BROKEN
12 A	14	8.6	8.6	SILTY CLAY	GRAVEL	VS	LENSES	ONE CLOUDY LENS 20+
12 B	14	8.6	9.4	CLAY	GRAVEL	VR	GRAINS	
12 C	14	8.6	9.4	SILTY CLAY	GRAVEL	VS	GRAINS/RANDOM	ICE BODIES 30 MM DIA.
13 A	14	9.4	10.1	CLAY	GRAVEL	VS	LENS/GRAINS	LARGE ICE MASS AT CORE END
13 B	14	9.4	10.1	SILTY CLAY		VR	GRAINS	HIGH ICE CONTENT
13 C	14	9.4	10.1	CLAY	FINE GRA	VR	GRAINS	
14 A	14	10.1	10.9	SILTY CLAY	GRAVEL	VR	GRAINS	HIGH ICE CONTENT
14 B	14	10.1	10.9	SILTY CLAY	GRAVEL	VS	LENS/GRAINS	BROKEN/ GRAINS IN LENS PATTERNS
14 C	14	10.1	10.9	SILTY CLAY	GRAVEL	VS	GRAINS	
15 A	13	10.9	11.7	SILTY CLAY	GRAVEL	VS	LENS VEIN	
15 B	13	10.9	11.7	CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
15 C	13	10.9	11.7	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
16 A	13	11.7	12.4	SILTY CLAY	GRAVEL	NB		
16 B	13	11.7	12.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN	LENS AT BREAK IN CORE
16 C	13	11.7	12.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
17 A	13	12.4	13.2	SILTY CLAY		VS	LENS	LENS AT END
17 B	13	12.4	13.2	SILTY CLAY	GRAVEL	NB		
17 C	13	12.4	13.2	SILTY CLAY		NB		
18 A	13	13.2	14.0	SILTY CLAY		NB		BROKEN
18 B	13	13.2	14.0	SILTY CLAY	GRAVEL	VS	LENS	BROKEN - ONE LENS ONLY
18 C	13	13.2	14.0	SILTY CLAY	GRAVEL	NB		
19 A	13	14.0	14.6	SILTY CLAY	GRAVEL	VS	LENS	
19 B	13	14.0	14.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN	ONE LENS ONLY
20 A	13	14.6	15.4	SILTY CLAY	GRAVEL'	VS	LENS/VEIN	

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
20 B	13	14.6	15.4	SILTY CLAY	GRAVEL	VR	LENS/VEIN	
20 C	13	14.6	15.4	SILTY CLAY	GRAVEL	VS	VEIN	ONE VEIN ONLY GRAVEL LAYER
21 A	12	15.4	16.1	SILTY CLAY	GRAVEL	VS	VEIN	BROKEN
21 B	12	15.4	16.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
21 C	12	15.4	16.1	SILTY CLAY		NB		BROKEN
22 A	12	16.1	16.9	CLAYEY SILT	GRAVEL	NB		
22 B	12	16.1	16.9	SILTY FINE SAND		NB		
22 C	12	16.1	16.9	SILTY CLAY/SILTY SND		VS	LENS/VEIN	LENSES IN CLAY: SANDY TOP/CLAY BOT.
23 A	12	16.9	17.7	SILTY CLAY		NB		
23 B	12	16.9	17.7	SILTY FINE SAND		NB		BROKEN
23 C	12	16.9	17.7	SILTY FINE SAND		NB		BROKEN
24 A	12	17.7	18.4	SILTY CLAY/SILTY SAN	GRAVEL	NB		GRAVEL IN CLAY ONLY
24 B	12	17.7	18.4	SILTY FINE SAND		NB		BROKEN
24 C	12	17.7	18.4	SILTY FINE SAND		NB		
25 A	12	18.4	19.2	SILTY SAND		NB		BROKEN
25 B	12	18.4	19.2	silty clay		NB		BROKEN
25 C	12	18.4	19.2	SILTYCLAY/SILTY SAND		NB		
26 A	12	19.2	20.0	SILTY FINE SAND		NB		
26 B	12	19.2	20.0	SILTY FINE SAND		NB		
26 C	12	19.2	20.0	SILTYCLAY/SILTY SAND	GRAVEL	NB		CONTACT ZONE/ GRAVEL IN CLAY ONLY
27 A	11	20.0	20.5	SAND		NB		BROKEN
27 B	11	20.0	20.5	SAND		NB		BROKEN

Norman Wells Permafrost Core data
Description by soil and ice

Core #		BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
** Borehole Number 7C									
1	A	11	0.0	0.8	SILTY CLAY	ORG/GRAV	VS	LENS/VEIN	
1	B	11	0.0	0.8	SILTY CLAY		VS	LENS/VEIN	HIGH ICE VOLUME
2	A	11	0.8	1.5	SILTY CLAY		VR	GRAINS	
2	B	11	0.8	1.5	CLAYEY SILT	CALC.	VS	LENS/VEIN	
2	C	11	0.8	1.5	SILTY CLAY	CALC	VS	LENS	BROKEN
3	A	11	1.5	2.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
3	B	11	1.5	2.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
3	C	11	1.5	2.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
4	A	11	2.3	3.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
4	B	11	2.3	3.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
4	C	11	2.3	3.1	SILTY CLAY		VS	LENS/VEIN	
5	A	11	3.1	3.8	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
5	B	11	3.1	3.8	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
5	C	11	3.1	3.8	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
6	A	10	3.8	4.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
6	B	10	3.8	4.6	SILTY CLAY		VS	LENS/VEIN	
6	C	10	3.8	4.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
7	A	10	4.6	5.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
7	B	10	4.6	5.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
7	C	10	4.6	5.4	SILTY CLAY	GRAVEL	NB		BROKEN
8	A	10	5.4	6.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
8	B	10	5.4	6.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
8	C	10	5.4	6.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
9	A	10	6.1	6.9	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
9	B	10	6.1	6.9	SILTY CLAY	GRAVEL	VS	LENS/VEIN	BROKEN
9	C	10	6.1	6.9	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
10	A	10	6.9	7.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
11	A	10	10.8	11.5	SILTY CLAY	GRAVEL	VR	LENSES/RANDOM	20 MM DIA. ICE BODIES
11	B	10	10.8	11.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN	
11	C	9	10.8	11.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN	GRAVEL LAYER
12	A	9	12.1	12.9	SILTY CLAY	GRAVEL	VR	GRAINS	
12	B	9	12.1	12.9	DENSE CLAY	GRAVEL	NBN		
12	C	9	12.1	12.9	LAYERED SILT/CLAY		VS	LENS/VEIN	
13	A	9	12.9	13.7	LAYERED SILT/CLAY		VS	LENS/VEIN	BROKEN
13	B	9	12.9	13.7	SILTY CLAY		NBN		BROKEN
13	C	9	12.9	13.7	CLAYEY SILT		NBN		BROKEN
14	A	9	13.7	14.6	SILTY CLAY		VS	LENS	BROKEN
14	B	9	13.7	14.6	LAYERED SILTY CLAY	GRAVEL	VR	GRAINS	BROKEN
14	C	9	13.7	14.6	LAYERED SILTY CLAY		VS	LENS/VEIN	BROKEN
15	A	9	14.6	15.4	LAYERED SILTY CLAY		NB		BROKEN
15	B	9	14.6	15.4	CLAYEY SILT		VR	GRAINS	BROKEN
15	C	9	14.6	15.4	SILTY FINE SAND		NB		BROKEN
16	A	9	15.4	16.1	CLAYEY SILT		VS	VEIN	
16	B	9	15.4	16.1	SILTY FINE SAND		VS	VEIN	BROKEN
16	C	9	15.4	16.1	SAND		VS	VEIN	BROKEN
17	A	9	16.1	16.9	CLAY/SILT CONTACT		VS	LENS/VEIN	
17	B	8	16.1	16.9	SILTY CLAY/FIN SAND		VS	LENS	CONTACT /BROKEN
17	C	8	16.1	16.9	CLAY/SILTY CLAY CONT		VS	LENS	BROKEN
18	A	8	16.9	17.4	FINE SAND	GRAVEL	NB		

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
18 B	8	16.9	17.4	FINE SAND		NB		
18 C	8	16.9	17.4	FINE SAND		NB		
19 A	8	17.4	18.1	FINE SAND		NB		
19 B	8	17.4	18.1	SAND		NB		

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
** Borehole Number 8A								
1 A	8	0.2	0.8	SAND	ORGANIC	NB		
1 B	8	0.2	0.8	SAND	FEW ORG.	NB		
2 A	8	0.8	1.5	SAND		NB		NOTE: PHOTO NUMBER IS INCORRECT C1C
2 B	8	0.8	1.5	SAND	ORGANICS	NB		
2 C	8	0.8	1.5	SAND	ORGANICS	NB		
3 A	8	1.5	2.2	SAND		NB		
3 B	8	1.5	2.2	SAND		NB		
3 C	8	1.5	2.2	SAND		NB		
4 A	8	2.0	2.6	SAND		NB		
4 B	8	2.0	2.6	SAND		NB		BROKEN
4 C	8	2.0	2.6	SAND		NB		
5 A	7	2.6	3.1	SAND		NB		
5 B	7	2.6	3.1	SAND		NB		
6 A	7	3.1	3.9	SAND		NB		SOME CLAY LAYERS
6 B	7	3.1	3.9	SAND/SILTY CLAY		VS	LENSES	LENSES IN CLAY: SOIL TYPE CONTACT
6 C	7	3.1	3.9	FINE SAND		NB		
7 A	7	3.9	4.8	FINE SAND		NB		
7 B	7	3.9	4.8	FINE SAND		NB		BROKEN
7 C	7	3.9	4.8	FINE SAND		NB		
8 A	7	4.8	5.5	SAND/SILTY CLAY		VS	LENS	LENSES IN CLAY / CONTACT ZONE
8 B	7	4.8	5.5	SILTY CLAY		VS	LENS/VEIN	BROKEN
8 C	7	4.8	5.5	DENSE CLAY		VR	GRAINS	
9 A	7	5.5	6.1	SILTY CLAY		VS	LENS/VEIN	BROKEN
9 B	7	5.5	6.1	SILTY CLAY		VS	LENS/VEIN	
9 C	7	5.5	6.1	CLAY		VS	LENS/VEIN	50 % EXCESS ICE (ICE k=2.202)
10 A	7	6.1	7.0	CLAY		VS	VEIN/GRAINS	
10 B	7	6.1	7.0	LAYERED SILTY CLAY		VS	LENS/VEIN /GRAINS	THICK LENS CLOUDY BROKEN
10 C	6	6.1	7.0	LAYERED SILTY CLAY		VS	LENS/VEIN/GRAINS	CLOUDY THICK LENS/ BROKEN
11 A	6	7.0	7.8	SILTY CLAY		VS	LENS/GRAINS	
11 B	6	7.0	7.8	CLAY		VS	LENSES/GRAINS	THICK LENS CLOUDY BROKEN
11 C	6	7.0	7.8	CLAY		VS	MASSIVE	MOSTLY ICE: CORE END IS GREY ICE
12 A	6	7.8	8.6	SILTY CLAY		VS	LENS/GRAING	
12 B	6	7.8	8.6	SILTY CLAY		VS	GRAINS	
12 C	6	7.8	8.6	SILTY CLAY		VS	LENS/GRAINS	LARGER ICE LAYER AT CORE END/BROKEN
13 A	6	8.6	9.4	SILTY CLAY		VS	LENS/GRAINS	GRANULAR LENSES
13 B	6	8.6	9.4	DENSE CLAY		VS	LENS/GRAINS	
13 C	6	8.6	9.4	SILTY CLAY		VS	GRAINS	BROKEN

Norman Wells Permafrost Core data
Description by soil and ice

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape	Comments
** Borehole Number 8C								
1 A	6	0.2	0.9	PEAT		NB		
1 B	6	0.2	0.9	PEAT		NB		
1 C	6	0.2	0.9	PEAT	CLAY	NB		
2 A	6	0.9	1.5	PEAT		VS	RANDOM	20 * 10 ICE BODIES
2 B	5	0.9	1.5	PEAT		VX	GRAINS	BROKEN
2 C	5	0.9	1.5	PEAT		VX	GRAINS	BROKEN
3 A	5	1.5	2.0	SANDY CLAY		VS	LENS/VIEN + GRAINS	BROKEN
3 B	5	1.5	2.0	SANDY CLAY		VS	LENS/VEIN + GRAINS	RETICULATE AT ONE END
3 C	5	1.5	2.0	SANDY CLAY		VR	GRAINS	
4 A	5	2.0	2.6	SANDY CLAY		VS	GRAINS	BROKEN
4 B	5	2.0	2.6	SANDY CLAY		VR	GRAINS	
4 C	5	2.0	2.6	SANDY CLAY		VS	GRAINS +1 LARGE LENS	LENS IS SOFT, GRANULAR
5 A	5	2.6	3.2	SANDY CLAY		VR	GRAINS	
5 B	5	2.6	3.2	SANDY CLAY/SILTYCLAY		VR	GRAINS	SOIL TYPE CONTACT ZONE
5 C	5	2.6	3.2	SILTY CLAY/FINE SAND		VS	GRAINS	BROKEN
** Borehole Number 9								
1 A	5	0.2	0.8	SAND/PEAT		NB		
1 B	5	0.2	0.8	SAND/PEAT		VS	LENS	contact : sand conductivity 3.300
2 A	5	0.8	1.4	FINE SAND	ORG/GRAV	NBN		BROKEN
2 B	5	0.8	1.4	CLAYEY SAND	CALC/GRA	NBN		BROKEN

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Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 1							
12B	5 A	2.3	2.8	PEAT		VC	RANDOM
12B	5 B	2.3	2.8	PEAT		NB	
12B	5 C	2.3	2.8	PEAT/SILTY CLAY		VS	LENSES/GRAINS
12B	6 A	2.8	3.2	SILTY CLAY		VS	LENS/VEIN
12B	6 B	2.8	3.2	CLAY/SILT		VS	LENS/VEIN
12B	7 A	3.2	3.8	SILT		VS	LENS
12B	7 B	3.2	3.8	SILT		VS	LENS
12B	7 C	3.2	3.8	SILT		VS	LENS/GRINS
12B	8 A	3.8	4.8	SILT		VS	LENS/GRAINS
12B	8 B	3.8	4.8	SILT		VS	LENS/GRAINS
12B	8 C	3.8	4.8	CLAYEY SILT	FEW GRAV	VS	LENS/VEIN/GRAINS
12B	9 A	4.8	5.5	SILT	FEW GRAV	VS	LENS/GRAINS
12B	9 B	4.8	5.5	CLAYEY SILT		VS	LENS/GRAINS
12B	9 C	4.8	5.5	CLAYEY SILT		VS	LENS/GRAINS
12B	10 A	5.5	6.3	SANDY SILT?	FEW GRAV	VS	LENS/GRAINS
12B	10 B	5.5	6.3	SANDY SILT?	MANY GRA	NB	
12B	10 C	5.5	6.3	SILT	GRAVEL	VS	GRAINS
12B	11 A	6.3	7.4	SILTY FINE SAND	GRAVEL	VS	LENS/GRAINS
12B	11 B	6.3	7.4	CLAYEY SILT	MANY GRA	VS	LENS
** Box Number 2							
12A	3 A	1.7	2.5	SILT		VS	LENS/VEIN
12A	3 B	1.7	2.5	SILT/SILTY SAND		VS	LENS/VEIN
12A	3 C	1.7	2.5	SILTY FINE SAND	GRAVEL	VS	LENS/VEIN
12B	1 A	0.0	0.6	PEAT		NB	
12B	1 B	0.0	0.6	PEAT		NB	
12B	1 C	0.0	0.6	PEAT		NB	
12B	2 A	0.6	1.2	PEAT		NB	
12B	2 B	0.6	1.2	PEAT		NF	
12B	2 C	0.6	1.2	PEAT		VR	GRAINS
12B	3 A	1.2	1.7	PEAT		VS	LENS
12B	3 B	1.2	1.7	PEAT		NB	
12B	4 A	1.7	2.3	PEAT		NB	
12B	4 B	1.7	2.3	PEAT		VR	GRAINS/SNOWLIKE STUF
12B	4 C	1.7	2.3	PEAT		VS	LENS

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 3							
11	1 B	0.2	0.8	FINE SAND	ORGANICS	VS	GRAINS
11	1 C	0.2	0.8	FINE SAND/SILTY SAND		VS	LENS/VEIN
11	2 A	0.8	1.5	FINE SAND		NBN	
11	2 B	0.8	1.5	FINE SAND		NB	
11	2 C	0.8	1.5	FINE SAND		NBN	
11	3 A	1.5	2.3	FINE SAND	CALCEROU	NBN	
11	3 B	1.5	2.3	SILTY CLAY	CALC/GRA	VS	LENS
11	3 C	1.5	2.3	SILTY CLAY	GRAV/CAL	VS	LENS
11	4	2.3	2.6	SILTY CLAY	CAL/GRAV	VS	LENS
12A	1 A	0.2	0.9	PEAT/SILTY CLAY		VS	LENS
12A	1 B	0.2	0.9	SILT	FEW GRAV	VS	LENSES
12A	1 C	0.2	0.9	SILT		VS	LENS/VEIN
12A	2 A	0.9	1.7	SILT		VS	LENS/VEIN
12A	2 B	0.9	1.7	SILT/SILTY SAND	GRAVEL	VS	LENS/VEIN
** Box Number 4							
10A	1 A	0.2	0.8	PEAT		NFN	
10A	1 B	0.2	0.8	PEAT/SILTY FINE SAND		NBN	
10B	1 A	0.2	0.9	PEAT		VR	GRAINS
10B	1 B	0.2	0.9	PEAT		NBN	
10B	1 C	0.2	0.9	PEAT		NBN	
10B	2 A	0.9	1.7	PEAT		NBN	
10B	2 B	0.9	1.7	PEAT		VS	VEIN
10B	2 C	0.9	1.7	PEAT		VS	
10B	3 A	1.7	2.6	PEAT		VS	
10B	3 B	1.7	2.6	PEAT		VS	LENS
10B	3 C	1.7	2.6	PEAT		NBN	
11	1 A	0.2	0.8	PEAT/FINE SAND		NBN	

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 5							
8C	2 B	0.9	1.5	PEAT		VX	GRAINS
8C	2 C	0.9	1.5	PEAT		VX	GRAINS
8C	3 A	1.5	2.0	SANDY CLAY		VS	LENS/VIEN + GRAINS
8C	3 B	1.5	2.0	SANDY CLAY		VS	LENS/VEIN + GRAINS
8C	3 C	1.5	2.0	SANDY CLAY		VR	GRAINS
8C	4 A	2.0	2.6	SANDY CLAY		VS	GRAINS
8C	4 B	2.0	2.6	SANDY CLAY		VR	GRAINS
8C	4 C	2.0	2.6	SANDY CLAY		VS	GRAINS +1 LARGE LENS
8C	5 A	2.6	3.2	SANDY CLAY		VR	GRAINS
8C	5 B	2.6	3.2	SANDY CLAY/SILTYCLAY		VR	GRAINS
8C	5 C	2.6	3.2	SILTY CLAY/FINE SAND		VS	GRAINS
9	1 A	0.2	0.8	SAND/PEAT		NB	
9	1 B	0.2	0.8	SAND/PEAT		VS	LENS
9	2 A	0.8	1.4	FINE SAND	ORG/GRAV	NBN	
** Box Number 6							
8A	10 C	6.1	7.0	LAYERED SILTY CLAY		VS	LENS/VEIN/GRAINS
8A	11 A	7.0	7.8	SILTY CLAY		VS	LENS/GRAINS
8A	11 B	7.0	7.8	CLAY		VS	LENSES/GRAINS
8A	11 C	7.0	7.8	CLAY		VS	MASSIVE
8A	12 A	7.8	8.6	SILTY CLAY		VS	LENS/GRAINS
8A	12 B	7.8	8.6	SILTY CLAY		VS	GRAINS
8A	12 C	7.8	8.6	SILTY CLAY		VS	LENS/GRAINS
8A	13 A	8.6	9.4	SILTY CLAY		VS	LENS/GRAINS
8A	13 B	8.6	9.4	DENSE CLAY		VS	LENS/GRAINS
8A	13 C	8.6	9.4	SILTY CLAY		VS	GRAINS
8C	1 A	0.2	0.9	PEAT		NB	
8C	1 B	0.2	0.9	PEAT		NB	
8C	1 C	0.2	0.9	PEAT	CLAY	NB	
8C	2 A	0.9	1.5	PEAT		VS	RANDOM

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 7							
8A	5 A	2.6	3.1	SAND		NB	
8A	5 B	2.6	3.1	SAND		NB	
8A	6 A	3.1	3.9	SAND		NB	
8A	6 B	3.1	3.9	SAND/SILTY CLAY		VS	LENSES
8A	6 C	3.1	3.9	FINE SAND		NB	
8A	7 A	3.9	4.8	FINE SAND		NB	
8A	7 B	3.9	4.8	FINE SAND		NB	
8A	7 C	3.9	4.8	FINE SAND		NB	
8A	8 A	4.8	5.5	SAND/SILTY CLAY		VS	LENS
8A	8 B	4.8	5.5	SILTY CLAY		VS	LENS/VEIN
8A	8 C	4.8	5.5	DENSE CLAY		VR	GRAINS
8A	9 A	5.5	6.1	SILTY CLAY		VS	LENS/VEIN
8A	9 B	5.5	6.1	SILTY CLAY		VS	LENS/VEIN
8A	9 C	5.5	6.1	CLAY		VS	LENS/VEIN
8A	10 A	6.1	7.0	CLAY		VS	VEIN/GRAINS
8A	10 B	6.1	7.0	LAYERED SILTY CLAY		VS	LENS/VEIN
** Box Number 8							
7C	17 B	16.1	16.9	SILTY CLAY/FIN SAND		VS	LENS
7C	17 C	16.1	16.9	CLAY/SILTY CLAY CONT		VS	LENS
7C	18 A	16.9	17.4	FINE SAND	GRAVEL	NB	
7C	18 B	16.9	17.4	FINE SAND		NB	
7C	18 C	16.9	17.4	FINE SAND		NB	
7C	19 A	17.4	18.1	FINE SAND		NB	
7C	19 B	17.4	18.1	SAND		NB	
8A	1 A	0.2	0.8	SAND	ORGANIC	NB	
8A	1 B	0.2	0.8	SAND	FEW ORG.	NB	
8A	2 A	0.8	1.5	SAND		NB	
8A	2 B	0.8	1.5	SAND	ORGANICS	NB	
8A	2 C	0.8	1.5	SAND	ORGANICS	NB	
8A	3 A	1.5	2.2	SAND		NB	
8A	3 B	1.5	2.2	SAND		NB	
8A	3 C	1.5	2.2	SAND		NB	
8A	4 A	2.0	2.6	SAND		NB	
8A	4 B	2.0	2.6	SAND		NB	
8A	4 C	2.0	2.6	SAND		NB	

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 9							
7C	11 C	10.8	11.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	12 A	12.1	12.9	SILTY CLAY	GRAVEL	VR	GRAINS
7C	12 B	12.1	12.9	DENSE CLAY	GRAVEL	NBN	
7C	12 C	12.1	12.9	LAYERED SILT/CLAY		VS	LENS/VEIN
7C	13 A	12.9	13.7	LAYERED SILT/CLAY		VS	LENS/VEIN
7C	13 B	12.9	13.7	SILTY CLAY		NBN	
7C	13 C	12.9	13.7	CLAYEY SILT		NBN	
7C	14 A	13.7	14.6	SILTY CLAY		VS	LENS
7C	14 B	13.7	14.6	LAYERED SILTY CLAY	GRAVEL	VR	GRAINS
7C	14 C	13.7	14.6	LAYERED SILTY CLAY		VS	LENS/VEIN
7C	15 A	14.6	15.4	LAYERED SILTY CLAY		NB	
7C	15 B	14.6	15.4	CLAYEY SILT		VR	GRAINS
7C	15 C	14.6	15.4	SILTY FINE SAND		NB	
7C	16 A	15.4	16.1	CLAYEY SILT		VS	VEIN
7C	16 B	15.4	16.1	SILTY FINE SAND		VS	VEIN
7C	16 C	15.4	16.1	SAND		VS	VEIN
** Box Number 10							
7C	6 A	3.8	4.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	6 B	3.8	4.6	SILTY CLAY		VS	LENS/VEIN
7C	6 C	3.8	4.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	7 A	4.6	5.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	7 B	4.6	5.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	7 C	4.6	5.4	SILTY CLAY	GRAVEL	NB	
7C	8 A	5.4	6.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	8 B	5.4	6.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	8 C	5.4	6.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	9 A	6.1	6.9	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	9 B	6.1	6.9	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	9 C	6.1	6.9	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	10 A	6.9	7.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	11 A	10.8	11.5	SILTY CLAY	GRAVEL	VR	LENSES/RANDOM
7C	11 B	10.8	11.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN

Norman Wells Permafrost Core data

Hole #	Core		Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 11								
7B	27	A	20.0	20.5	SAND		NB	
7B	27	B	20.0	20.5	SAND		NB	
7C	1	A	0.0	0.8	SILTY CLAY	ORG/GRAV	VS	LENS/VEIN
7C	1	B	0.0	0.8	SILTY CLAY		VS	LENS/VEIN
7C	2	A	0.8	1.5	SILTY CLAY		VR	GRAINS
7C	2	B	0.8	1.5	CLAYEY SILT	CALC.	VS	LENS/VEIN
7C	2	C	0.8	1.5	SILTY CLAY	CALC	VS	LENS
7C	3	A	1.5	2.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	3	B	1.5	2.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	3	C	1.5	2.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	4	A	2.3	3.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	4	B	2.3	3.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	4	C	2.3	3.1	SILTY CLAY		VS	LENS/VEIN
7C	5	A	3.1	3.8	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7C	5	B	3.1	3.8	SILTY CLAY	GRAVEL	VS	LENS/VEIN
** Box Number 12								
7B	21	A	15.4	16.1	SILTY CLAY	GRAVEL	VS	VEIN
7B	21	B	15.4	16.1	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	21	C	15.4	16.1	SILTY CLAY		NB	
7B	22	A	16.1	16.9	CLAYEY SILT	GRAVEL	NB	
7B	22	B	16.1	16.9	SILTY FINE SAND		NB	
7B	22	C	16.1	16.9	SILTY CLAY/SILTY SND		VS	LENS/VEIN
7B	23	A	16.9	17.7	SILTY CLAY		NB	
7B	23	B	16.9	17.7	SILTY FINE SAND		NB	
7B	23	C	16.9	17.7	SILTY FINE SAND		NB	
7B	24	A	17.7	18.4	SILTY CLAY/SILTY SAN	GRAVEL	NB	
7B	24	B	17.7	18.4	SILTY FINE SAND		NB	
7B	24	C	17.7	18.4	SILTY FINE SAND		NB	
7B	25	A	18.4	19.2	SILTY SAND		NB	
7B	25	B	18.4	19.2	silty clay		NB	
7B	25	C	18.4	19.2	SILTYCLAY/SILTY SAND		NB	
7B	26	A	19.2	20.0	SILTY FINE SAND		NB	
7B	26	B	19.2	20.0	SILTY FINE SAND		NB	
7B	26	C	19.2	20.0	SILTYCLAY/SILTY SAND	GRAVEL	NB	

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 13							
7B	15 A	10.9	11.7	SILTY CLAY	GRAVEL	VS	LENS VEIN
7B	15 B	10.9	11.7	CLAY	GRAVEL	VS	LENS/VEIN
7B	15 C	10.9	11.7	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	16 A	11.7	12.4	SILTY CLAY	GRAVEL	NB	
7B	16 B	11.7	12.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	16 C	11.7	12.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	17 A	12.4	13.2	SILTY CLAY		VS	LENS
7B	17 B	12.4	13.2	SILTY CLAY	GRAVEL	NB	
7B	17 C	12.4	13.2	SILTY CLAY		NB	
7B	18 A	13.2	14.0	SILTY CLAY		NB	
7B	18 B	13.2	14.0	SILTY CLAY	GRAVEL	VS	LENS
7B	18 C	13.2	14.0	SILTY CLAY	GRAVEL	NB	
7B	19 A	14.0	14.6	SILTY CLAY	GRAVEL	VS	LENS
7B	19 B	14.0	14.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	20 A	14.6	15.4	SILTY CLAY	GRAVEL`	VS	LENS/VEIN
7B	20 B	14.6	15.4	SILTY CLAY	GRAVEL	VR	LENS/VEIN
** Box Number 14							
7B	9 C	6.3	7.1	CLAYEY SILT	GRAVEL	VS	LENSES
7B	10 A	7.1	7.8	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7B	10 B	7.1	7.8	SILTY CLAY	GRAVEL	VR	GRAINS
7B	10 C	7.1	7.8	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7B	11 A	7.8	8.6	SILTY CLAY	GRAVEL	VS	LENS
7B	11 B	7.8	8.6	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7B	11 C	7.8	8.6	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS
7B	12 A	8.6	8.6	SILTY CLAY	GRAVEL	VS	LENSES
7B	12 B	8.6	9.4	CLAY	GRAVEL	VR	GRAINS
7B	12 C	8.6	9.4	SILTY CLAY	GRAVEL	VS	GRAINS/RANDOM
7B	13 A	9.4	10.1	CLAY	GRAVEL	VS	LENS/GRAINS
7B	13 B	9.4	10.1	SILTY CLAY		VR	GRAINS
7B	13 C	9.4	10.1	CLAY	FINE GRA	VR	GRAINS
7B	14 A	10.1	10.9	SILTY CLAY	GRAVEL	VR	GRAINS
7B	14 B	10.1	10.9	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7B	14 C	10.1	10.9	SILTY CLAY	GRAVEL	VS	GRAINS

Norman Wells Permafrost Core data

Hole #	Core		Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 15								
7B	3	B	1.7	2.5	SILTY CLAY	GRAVEL	VS	LENS
7B	4	A	2.5	2.8	SILTY CLAY		VS	LENSES
7B	4	B	2.8	3.2	SILTY CLAY	CALC	VS	LENS/VEIN
7B	5	A	3.2	3.6	SILTY CLAY	CAL/GRAV	VS	LENS
7B	5	B	3.6	4.0				
7B	6	A	4.5	4.8	SILTY CLAY	GRAVEL	VS	LENS
7B	6	B	4.5	4.8	SILTY CLAY	GRAVEL	VS	LENS
7B	7	A	4.8	5.5	SILTY CLAY	GRAVEL	VS	LENS
7B	7	B	4.8	5.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	7	C	4.8	5.5	SILTY CLAY	GRAVEL	VS	LENSES
7B	8	A	5.5	6.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	8	B	5.5	6.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7B	8	C	5.5	6.3	SILTY CLAY	GRAVEL	NB	
7B	9	A	6.3	7.1	SILTY CLAY		VR	GRAINS
** Box Number 16								
7A	26	B	16.3	16.9	SILTY CLAY		NB	
7A	26	C	16.3	16.9	SILTY CLAY		VS	VEIN
7A	27	A	16.9	18.3	SILTY CLAY		VS	LENS
7A	27	B	16.9	18.3	SILTY CLAY		VS	VEIN
7A	27	C	16.9	18.3	SILTY CLAY		VS	LENS
7A	28	A	18.3	18.3	LAYERED SILTY CLAY		VS	VEIN
7A	28	B	18.3	19.2	LAYERED SILTY CLAY		NB	
7A	28	C	18.3	19.2	LAYERD SILTY CLAY		NB	
7A	29	A	19.2	19.2	CLAY		NB	
7A	29	B	19.2	20.3	CLAY		NB	
7A	29	C	19.2	20.3	CLAY		VS	LENS
7B	1		0.8	1.2	SILTY CLAY	GRAVEL	VS	LENSES
7B	2		1.2	1.7	SILTY CLAY	GRAVEL	VS	LENS
7B	3	A	1.7	2.5	SILTY CLAY	GRAVEL	VS	LENS

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 17							
7A	17 B	10.0	10.4	SILTY CLAY	GRAVEL	VS	LENSES
7A	18 A	10.4	11.2	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7A	18 B	10.4	11.2	SILTY CLAY	GRAVEL	NB	
7A	18 C	10.4	11.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	19 A	11.2	12.0	SILTY CLAY	GRAVEL	VR	GRAINS
7A	19 B	11.2	12.0	SILTY CLAY	GRAVEL	VS	LENS
7A	19 C	11.2	12.0	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	20 A	12.0	12.7	SILTY CLAY	GRAVEL	NB	
7A	20 B	12.0	12.7	SILTY CLAY	GRAVEL	NB	
7A	20 C	12.0	12.7	SILTY CLAY	GRAVEL	VS	LENS
7A	21 A	12.7	13.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	21 B	12.7	13.5	SILTY CLAY	GRAVEL	VS	LENS
7A	21 C	12.7	13.5	SILTY CLAY	GRAVEL	VR	GRAINS
7A	22 A	13.5	14.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	22 B	13.5	14.3	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7A	22 C	13.5	14.3	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS
7A	23 A	14.3	15.0	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7A	23 B	14.3	15.0	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7A	23 C	14.3	15.0	DENSE CLAY		VS	GRAINS-SOME LENSLIKE
7A	24 A	15.0	15.5	SILTY CLAY	GRAVEL	VS	VEIN
7A	24 B	15.0	15.5	SILTY CLAY	GRAVEL	VS	VEIN/GRAINS
7A	24 C	15.0	15.5	SILTY CLAY	GRAVEL	VR	GRAINS
7A	25 A	15.5	16.3	SILTY CLAY	GRAVEL	VR	GRAINS
7A	25 B	15.5	16.3	SILTY CLAY	GRAVEL	VS	VEIN
7A	25 C	15.5	16.3	SILTY CLAY	GRAVEL	VS	VEIN
7A	26 A	16.3	16.9	SILTY CLAY		NB	

Norman Wells Permafrost Core data

Hole #	Core	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Ice Type	Ice shape
** Box Number 18							
7A	9 C	4.5	5.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	10 A	5.2	6.0	SILTY CLAY	CALC.	VS	LENS
7A	10 B	5.2	6.0	SILTY CLAY	GRAVEL	NB	
7A	10 C	5.2	6.0	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS
7A	11 A	6.0	6.6	SILTY CLAY	GRAVEL	VS	LENSES
7A	11 B	6.0	6.6	SILTY CLAY		VS	LENS/VEIN
7A	12 A	6.6	6.6	SILTY CLAY	GRAVEL	VS	LENSES
7A	12 B	6.6	7.2	SILTY CLAY	GRAVEL	NB	
7A	12 C	6.6	7.2	SILTY CLAY	GRAVEL	VR	GRAINS
7A	13 A	7.2	7.7	SILTY CLAY`	GRAVEL	VR	VEIN
7A	13 B	7.2	7.7	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS
7A	14 A	7.7	8.0	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7A	14 B	7.7	8.0	SILTY CLAY	GRAVEL	NB	
7A	15 A	8.0	8.4	SILTY CLAY	GRAVEL	VS	LENS/GRAINS
7A	15 B	8.0	8.4	SILTY CLAY	GRAVEL	NB	
7A	15 C	8.0	8.4	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	16	8.4	8.6	SILTY CLAY	GRAVEL	VS	LENS
** Box Number 19							
7A	1	0.3	0.6	PEAT		VC	
7A	2 A	0.6	1.2	PEAT/SILTY CLAY	ORGANICS	VS	LENSES
7A	2 B	0.6	1.2	PEAT/SILTY CLAY		VS	LENS
7A	3 A	1.2	1.7	SILTY CLAY		VS	LENS
7A	3 B	1.2	1.7	SILTY CLAY		VS	LENSES
7A	4	1.7	2.2	SILTY CLAY	GRAVEL	NB	
7A	5	2.2	2.5	SILTY CLAY	GRAVEL	VS	LENS
7A	6 A	2.5	3.1	SILTY CLAY	GRAVEL	VS	LENS
7A	6 B	2.5	3.1	DENSE SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	7 A	3.1	3.7	DENSE SILTY CLAY	GRAVEL	VS	LENSES
7A	7 B	3.1	3.7	DENSE SILTY CLAY	GRAVEL	NB	
7A	7 C	3.1	3.7	CLAY	GRAVEL	VS	1/2
7A	8 A	3.7	4.5	CLAY	GRAVEL	VS	LENS/VEIN
7A	8 B	3.7	4.5	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	8 C	3.7	4.5	CLAY	GRAVEL	VS	LENS/VEIN
7A	9 A	4.5	5.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN
7A	9 B	4.5	5.2	SILTY CLAY	GRAVEL	VS	LENS/VEIN/GRAINS

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
** Borehole Number 10A								
1 A	NFN							BROKEN
1 B	NBN							PEAT/MINERAL CONTACT/BROKEN
** Borehole Number 10B								
1 A	VR	RANDOM	HARD	GRAINS		5/10		BROKEN
1 B	NBN							BROKEN
1 C	NBN							COLOUR CHANGE/BROKEN
2 A	NBN							
2 B	VS	HORIZ	HARD	VEIN	1/2		ORGANIC	BROKEN
2 C	VS	HORIZ/VERT	HARD		1		ORGANIC	BROKEN
3 A	VS	HORIZ	HARD		1		ORGANIC	BROKEN
3 B	VS	HORIZ	HARD	LENS	1/2		ORGANIC	BROKEN
3 C	NBN							MINERAL SOIL CONTACT
** Borehole Number 11								
1 A	NBN							MINERAL SOIL CONTACT
1 B	VS	HORIZ	HARD	GRAINS		1/2	ORGANIC	BROKEN
1 C	VS	HORIZ	HARD	LENS/VEIN	<1		ORGANIC	
2 A	NBN							
2 B	NB							
2 C	NBN							
3 A	NBN							
3 B	VS	HORIZ	HARD	LENS	<1/1/2/5			BROKEN
3 C	VS	HORIZ	HARD	LENS	<1/1/2			
4	VS	HORIZ	HARD	LENS	<1			BROKEN
** Borehole Number 12A								
1 A	VS	HORIZ/RETIC.	HARD	LENS	<1/1/2			SOIL CONTACT/BROKEN
1 B	VS	HORIZ	HARD	LENSES	<1/1/2		ORGANIC	BROKEN/GRADING TO FINER LENSES AT B
1 C	VS	HORIZ/VERT	HARD	LENS/VEIN	<1/2			LENSES ARE <1, VEINS 2 MM
2 A	VS	HORIZ/VERT	HARD	LENS/VEIN	1/2			BROKEN
2 B	VS	HOR/VERT/DIA	HARD	LENS/VEIN	<1,1			BROKEN/SOIL CONTACT, ICE DIFFERS
2 C	VS	RETIC.	HARD	LENS/VEIN	<1			
3 A	VS	HOR/VERT/DIA	HARD	LENS/VEIN	1/2			BROKEN
3 B	VS	HORIZ/VERT	HARD	LENS/VEIN	1/2			BROKEN
3 C	VS	HORIZ/DIAG	HARD	LENS/VEIN	2/3			BROKEN

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
** Borehole Number 12B								
1 A	NB							BROKEN
1 B	NB							
1 C	NB							
2 A	NB							
2 B	NF							BROKEN
2 C	VR	RANDOM	SOFT	GRAINS		5/10		BROKEN
3 A	VS	HORIZ	HARD	LENS	10+			BROKEN
3 B	NB							BROKEN
4 A	NB							BROKEN
4 B	VR	HORIZ/RANDOM	H/S	GRAINS/SNOWLIKE STUF				BROKEN
4 C	VS	HORIZ	SOFT	LENS	10+			
5 A	VC	RANDIM	HARD	RANDOM				BROKEN
5 B	NB							BROKEN
5 C	VS	RETICULATED	HARD	LENSES/GRAINS	2/5	*		BROKEN
6 A	VS	RETICULATED	HARD	LENS/VEIN	2/5			
6 B	VS	RETICULATED	HARD	LENS/VEIN	1/2/5/10			BROKEN
7 A	VS	HORIZ	HARD	LENS	1/2/5			
7 B	VS	HORIZ	HARD	LENS	<1 TO 10			BROKEN END
7 C	VS	HORIZ	HARD	LENS/GRINS	<1/1/2/5	1/2/5		
8 A	VS	HORIZ	HARD	LENS/GRAINS	1/2/5/10	1/2/5		
8 B	VS	HORIZ	HARD	LENS/GRAINS	<1,1,2	<1/1/2/5		
8 C	VS	HORIZ	HARD	LENS/VEIN/GRAINS	2	1 TO 40	CLEAR/GREY	BROKEN
9 A	VS	HORIZ	HARD	LENS/GRAINS	<1 TO 30	1/2/5		BROKEN
9 B	VS	HOR/VERT/RND	HARD	LENS/GRAINS	2/5	1/2/5		FEW LENSES: MOSTLY GRAINS
9 C	VS	HORIZ	HARD	LENS/GRAINS	10+	<1/1/2/5		
10 A	VS	HORIZ	HARD	LENS/GRAINS				TOO BROKEN TO ESTIMATE ICE DIA/THIC
10 B	NB							
10 C	VS	HORIZ	HARD	GRAINS		<1 TO 10		BROKEN
11 A	VS	HORIZ	HARD	LENS/GRAINS	1/2/5	1/2/5		
11 B	VS	HORIZ	HARD	LENS	<1/30			BROKEN
11 C	VS	HORIZ/DIAG	HARD	LENS	1/2			PREVIUOSLY THAWED AND RE-FROZEN

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
** Borehole Number 7A								
1	VC							
2 A	VS	HORIZ	HARD	LENSES	40MM			ONE LARGE LENS ONLY
2 B	VS	HORIZ	HARD	LENS	3MM			CONDUCTIVITY: PEAT 1.397 SILT 2.171
3 A	VS	HORIZ	HARD	LENS	2 MM			
3 B	VS	HORIZ	HARD	LENSES	<1			
4	NB							
5	VS	HORIZ	HARD	LENS	<1/1			
6 A	VS	HORIZ	HARD	LENS	1/2			
6 B	VS	HORIZ	HARD	LENS/VEIN	1/2		CLEAR	
7 A	VS	HORIZ/DIAG	HARD	LENSES	1/2			
7 B	NB							
7 C	VS	RETICULATE	HARD	1/2				
8 A	VS	RETICULATE	HARD	LENS/VEIN	1/2			
8 B	VS	HORIZ	HARD	LENS/VEIN	<1/1			
8 C	VS	HORIZ	HARD	LENS/VEIN	1/2			
9 A	VS	RETICULATE	HARD	LENS/VEIN	1/2/3			
9 B	VS	RETICULATE	HARD	LENS/VEIN/GRAINS	1/2			RETIC. MERGING INTO LARGE GRAINS
9 C	VS	DIAG	HARD	LENS/VEIN	2/5/10			
10 A	VS	HORIZ	HARD	LENS	2			BROKEN AT LENS
10 B	NB							
10 C	VS	HORIZ	HARD	LENS/VEIN/GRAINS	5 MM	2MM		
11 A	VS	HORIZ/DIAG	HARD	LENSES	1/2/5			
11 B	VS	HORIZ/VERT	HARD	LENS/VEIN	5 MM			
12 A	VS	HOR/VERT/DIA	HARD	LENSES	5/10/30+			
12 B	NB							ICE COATING VISIBLE IN FRACTURE
12 C	VR	RANDOM	HARD	GRAINS		50*50MM		ONE LARGE ICE MASS
13 A	VR	HORIZ/VERT	HARD	VEIN	?			FRACTURED CORE
13 B	VS	HORIZ	HARD	LENS/VEIN/GRAINS	1 MM			
14 A	VS	HORIZ	HARD	LENS/GRAINS	2 MM			
14 B	NB							
15 A	VS	HORIZ	HARD	LENS/GRAINS	2 MM			LARGE ICE LENS AT CORE END
15 B	NB							
15 C	VS	HORIZ/DIAG	HARD	LENS/VEIN	1/2/5/10			
16	VS	HORIZ	HARD	LENS	5 MM			
17 A	NB							
17 B	VS	HORIZ	HARD	LENSES	10 MM			TWO LENSES IN CENTER OF CORE
18 A	VS	HORIZONTAL	HARD	LENS/GRAINS	2			BROKEN
18 B	NB							ONE LARGE STONE-8 CM DIAMETER
18 C	VS	HORIZ	HARD	LENS/VEIN	30 MM			BROKEN/ ONE LARGE LENS ONLY
19 A	VR	RANDOM	HARD	GRAINS				
19 B	VS	HORIZ	H/S	LENS	10 MM			
19 C	VS	HORIZ/VERT	HARD	LENS/VEIN	5/10/20			BROKEN / MANY LARGE LENSES
20 A	NB							BROKEN
20 B	NB							BROKEN
20 C	VS	HORIZ	HARD	LENS	2/10			BROKEN AT THICK LENS
21 A	VS	HORIZ/VERT	HARD	LENS/VEIN	2/5/10			BROKEN / LARGE VEIN, WITH THIN LENS
21 B	VS	HORIZ	HARD	LENS	2/5/30+			BROKEN
21 C	VR	RANDOM	HARD	GRAINS				WITH A THICK LENS AT CORE END

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
22 A	VS	HORIZ/VERT	HARD	LENS/VEIN	5/10			
22 B	VS	HORIZ	HARD	LENS/GRAINS	5/10			LARGE GRAIN CLUSTERS
22 C	VS	HORIZ/VERT	HARD	LENS/VEIN/GRAINS				BROKEN :GRAINS IN LENS/VEIN PATTERN
23 A	VS	HORIZ/DIAG	HARD	LENS/GRAINS	2/5			GRAINS IN LENS PATTERNS
23 B	VS	HORIZ	HARD	LENS/GRAINS	30+			CLEAR GRAINS/CLOUDY LENS 50% EXCESS
23 C	VS	RANDOM/DIAG	HARD	GRAINS-SOME LENSLIKE		TO 2 MM		5mm LENSLIKE STRUCTURE/ICIER AT END
24 A	VS	DIAG	HARD	VEIN	2/5			THICKER LENS AT CORE END
24 B	VS	DIAG	HARD	VEIN/GRAINS				GRAINS IN LENS PATTERN
24 C	VR	RANDOM	HARD	GRAINS				
25 A	VR	RANDOM	HARD	GRAINS				
25 B	VS	DIAG	HARD	VEIN	2/5/10			
25 C	VS	VERT	HARD	VEIN	10+			BROKEN
26 A	NB							
26 B	NB							
26 C	VS	VERT	HARD	VEIN	5 MM			
27 A	VS	HORIZ	HARD	LENS	1 MM			2 LENSES ONLY
27 B	VS	DIAG	HARD	VEIN	10 MM			
27 C	VS	HORIZ	HARD	LENS	<1 MM			ONE LENS ONLY / BROKEN
28 A	VS	VERT/DIAG	HARD	VEIN	2 MM			
28 B	NB							BROKEN
28 C	NB							BROKEN
29 A	NB							BROKEN
29 B	NB							BROKEN
29 C	VS	HORIZ/DIAG	HARD	LENS	2 MM			ONE LENS ONLY

Norman Wells Permafrost Core data
Description of ice

** Borehole Number 7B

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
1	VS	HORIZ	HARD	LENSES	<1 MM			
2	VS	HORIZ	HARD	LENS	1/2			
3 A	VS	HORIZ	HARD	LENS	1/2			
3 B	VS	HORIZ	HARD	LENS	1 MM			
4 A	VS	HORIZ	HARD	LENSES	<1 MM			
4 B	VS	HORIZ/VERT	HARD	LENS/VEIN	<1			
5 A	VS	HORIZ/VERT	HARD	LENS	<1			
5 B								
6 A	VS	HORIZ	HARD	LENS	1-2			BROKEN
6 B	VS	HORIZ/DIAG	HARD	LENS	1/2			
7 A	VS	RANDOM	HARD	LENS	<1 MM			
7 B	VS	RETICULATED	HARD	LENS/VEIN				
7 C	VS	HORIZ/DIAG	HARD	LENSES	1/2			
8 A	VS	HORIZ/DIAG	HARD	LENS/VEIN	2/5			LARGE STONES 8 CM DIAM.
8 B	VS	HORIZ/DIAG	HARD	LENS/VEIN	1/2			BROKEN
8 C	NB							
9 A	VR	RANDOM	HARD	GRAINS				
9 B	VR	RANDOM	HARD	GRAINS			COLOURLESS	
9 C	VS	HORIZ	HARD	LENSES	5/10			
10 A	VS	HORIZ	HARD	LENS/GRAINS	1/2			
10 B	VR	RANDOM	HARD	GRAINS				
10 C	VS	HORIZ	HARD	LENS/GRAINS				
11 A	VS	HORIZ	HARD	LENS	1/2			
11 B	VS	HORIZ	HARD	LENS/GRAINS	2			
11 C	VS	HORIZ/DIAG	HARD	LENS/VEIN/GRAINS	<1-5	1-3	COLOURLESS	BROKEN
12 A	VS	HOR/VERT/DIA	HARD	LENSES	5-10/20+			ONE CLOUDY LENS 20+
12 B	VR	RANDOM	HARD	GRAINS				
12 C	VS	HORIZ	HARD	GRAINS/RANDOM		2		ICE BODIES 30 MM DIA.
13 A	VS	HORIZ/DIAG	HARD	LENS/GRAINS	1/2			LARGE ICE MASS AT CORE END
13 B	VR	RANDOM	HARD	GRAINS				HIGH ICE CONTENT
13 C	VR	RANDOM	HARD	GRAINS				
14 A	VR	RANDOM	HARD	GRAINS				HIGH ICE CONTENT
14 B	VS	HORIZ	HARD	LENS/GRAINS	5/10			BROKEN/ GRAINS IN LENS PATTERNS
14 C	VS	HORIZ	HARD	GRAINS				
15 A	VS	HORIZ/VERT	HARD	LENS VEIN	2/5			
15 B	VS	HORIZ/VERT	HARD	LENS/VEIN	5/10			BROKEN
15 C	VS	HORIZ/DIAG	HARD	LENS/VEIN	1/2/5/10			
16 A	NB							
16 B	VS	HORIZ	HARD	LENS/VEIN	?			LENS AT BREAK IN CORE
16 C	VS	DIAG	HARD	LENS/VEIN	1/2			
17 A	VS	HORIZ	HARD	LENS	?			LENS AT END
17 B	NB							
17 C	NB							
18 A	NB							BROKEN
18 B	VS	HORIZ'	HARD	LENS	1.5			BROKEN - ONE LENS ONLY
18 C	NB							
19 A	VS	RANDOM	HARD	LENS	1/2			
19 B	VS	DIAGONAL	HARD	LENS/VEIN	1.5			ONE LENS ONLY

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
20 A	VS	HORIZ	HARD	LENS/VEIN	5 MM			
20 B	VR	RANDOM	HARD	LENS/VEIN	5 MM			
20 C	VS	VERT/DIAG	HARD	VEIN	1 MM			ONE VEIN ONLY GRAVEL LAYER
21 A	VS	VERT	HARD	VEIN	1			BROKEN
21 B	VS	HOR/VERT/DIA	HARD	LENS/VEIN	1/2			
21 C	NB							BROKEN
22 A	NB							
22 B	NB							
22 C	VS	VERT	HARD	LENS/VEIN	<1			LENSES IN CLAY: SANDY TOP/CLAY BOT.
23 A	NB							
23 B	NB							BROKEN
23 C	NB							BROKEN
24 A	NB							GRAVEL IN CLAY ONLY
24 B	NB							BROKEN
24 C	NB							
25 A	NB							BROKEN
25 B	NB							BROKEN
25 C	NB							
26 A	NB							
26 B	NB							
26 C	NB							CONTACT ZONE/ GRAVEL IN CLAY ONLY
27 A	NB							BROKEN
27 B	NB							BROKEN

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
** Borehole Number 7C								
1 A	VS	RETIC.	HARD	LENS/VEIN	<1/1			
1 B	VS	RETIC.	HARD	LENS/VEIN	1 MM			HIGH ICE VOLUME
2 A	VR	RANDOM	HARD	GRAINS				
2 B	VS	HORIZ/VERT	HARD	LENS/VEIN	<1/1 MM			
2 C	VS	HORIZ	HARD	LENS	<1,1 MM			BROKEN
3 A	VS	RANDOM	HARD	LENS/VEIN	1/2			
3 B	VS	HORIZ	HARD	LENS/VEIN	1/2			
3 C	VS	HORIZ	HARD	LENS/VEIN	<1/1			
4 A	VS	HOR/VERT/DIA	HARD	LENS/VEIN	1/2			
4 B	VS	HOR/VERT/DIA	HARD	LENS/VEIN	1/2			BROKEN
4 C	VS	HORIZ/VERT	HARD	LENS/VEIN	1/2			
5 A	VS	HORIZ/VERT	HARD	LENS/VEIN	1/2			BROKEN
5 B	VS	HOR/VERT/DIA	HARD	LENS/VEIN	1/2			
5 C	VS	HOR/VERT/DIA	HARD	LENS/VEIN	1/2			
6 A	VS	HOR/VERT/DIA	HARD	LENS/VEIN	<1/1/2			
6 B	VS	HORIZ	HARD	LENS/VEIN	2 TO 5			
6 C	VS	HORIZ	HARD	LENS/VEIN	2 TO 5			BROKEN
7 A	VS	HORIZ	HARD	LENS/VEIN	1/2			BROKEN
7 B	VS	HORIZ	HARD	LENS/VEIN	<1			BROKEN
7 C	NB							BROKEN
8 A	VS	HORIZ/DIAG	HARD	LENS/VEIN	1 TO 2			
8 B	VS	HORIZ/DIAG	HARD	LENS/VEIN	1/5 / 10			BROKEN
8 C	VS	HORIZ/DIAG	HARD	LENS/VEIN	1/2/3			BROKEN
9 A	VS	HORIZ/DIAG	HARD	LENS/VEIN	1/2/3			BROKEN
9 B	VS	HORIZ/VERT	HARD	LENS/VEIN	2/5/10			BROKEN
9 C	VS	HORIZ/DIAG	HARD	LENS/VEIN	2/5			
10 A	VS	VERT/DIAG	HARD	LENS/VEIN	2MM			
11 A	VR	RANDOM	HARD	LENSES/RANDOM	1/2			20 MM DIA. ICE BODIES
11 B	VS	HOR/VER/DIAG	HARD	LENS/VEIN	2/5 TO10			
11 C	VS	VERT/DIAG	HARD	LENS/VEIN	1/2			GRAVEL LAYER
12 A	VR	RANDOM	HARD	GRAINS		2/5/10		
12 B	NBN							
12 C	VS	HOR/VT	HARD	LENS/VEIN	1/2/5/10		COLOURLESS	
13 A	VS	HORIZ/VERT	HSRD	LENS/VEIN	1/2/5			BROKEN
13 B	NBN							BROKEN
13 C	NBN							BROKEN
14 A	VS	HORIZ	HARD	LENS	1/2/5			BROKEN
14 B	VR	RANDOM	HARD	GRAINS		1/2/5		BROKEN
14 C	VS	HORIZ/VERT	HARD	LENS/VEIN	2/5			BROKEN
15 A	NB							BROKEN
15 B	VR	ONE CLUSTER	HARD	GRAINS		<1,1		BROKEN
15 C	NB							BROKEN
16 A	VS	DIAGONAL	HARD	VEIN	10			
16 B	VS	VERT	HARD	VEIN	10			BROKEN
16 C	VS	DIAG	HARD	VEIN	10			BROKEN
17 A	VS	HORIZ/VERT	HARD	LENS/VEIN	<1,1,2			
17 B	VS	HORIZ	HARD	LENS	2/5			CONTACT /BROKEN
17 C	VS	DIAG	HARD	LENS	2			BROKEN

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
18 A	NB							
18 B	NB							
18 C	NB							
19 A	NB							
19 B	NB							

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
** Borehole Number 8A								
1 A	NB							
1 B	NB							
2 A	NB							NOTE: PHOTO NUMBER IS INCORRECT C1C
2 B	NB							
2 C	NB							
3 A	NB							
3 B	NB							
3 C	NB							
4 A	NB							
4 B	NB							BROKEN
4 C	NB							
5 A	NB							
5 B	NB							
6 A	NB							SOME CLAY LAYERS
6 B	VS	HORIZ/VERT	HARD	LENSES	2/5/8			LENSES IN CLAY: SOIL TYPE CONTACT
6 C	NB							
7 A	NB							
7 B	NB							BROKEN
7 C	NB							
8 A	VS	HORIZ	HARD	LENS	2/5/10			LENSES IN CLAY / CONTACT ZONE
8 B	VS	HORIZ/VERT	HARD	LENS/VEIN	<1 TO 10			BROKEN
8 C	VR	RANDOM	HARD	GRAINS		1/2/5		
9 A	VS	HORIZ/VERT	HARD	LENS/VEIN	<1/1/2			BROKEN
9 B	VS	HORIZ/VERT	HARD	LENS/VEIN	<1		CLEAR	
9 C	VS	HORIZ	SOFT	LENS/VEIN	120 MM			50 % EXCESS ICE (ICE k=2.202)
10 A	VS	VERT	HARD	VEIN/GRAINS	<1MM	5 MM	CLEAR	
10 B	VS	HORIZ/VERT	H/S	LENS/VEIN /GRAINS	<1/5/50+			THICK LENS CLOUDY BROKEN
10 C	VS	HORIZ/VERT	H/S	LENS/VEIN/GRAINS	<1/5/50+			CLOUDY THICK LENS/ BROKEN
11 A	VS	HORIZ	HARD	LENS/GRAINS	5/10	1/2/5		
11 B	VS	HORIZ	H/S	LENSES/GRAINS	5/20+	1/2/5		THICK LENS CLOUDY BROKEN
11 C	VS	HORIZ	H/S	MASSIVE	SEE BELO		GREY/CLEAR	MOSTLY ICE: CORE END IS GREY ICE
12 A	VS	HORIZ	HARD	LENS/GRAINS	<1	2/5/10		
12 B	VS	HORIZ	HARD	GRAINS		1/2/5/10		
12 C	VS	HORIZ	HARD	LENS/GRAINS	1 MM	1/2/5		LARGER ICE LAYER AT CORE END/BROKEN
13 A	VS	HORIZ	HARD	LENS/GRAINS	15+	2/5/10		GRANULAR LENSES
13 B	VS	HORIZ/DIAG	HARD	LENS/GRAINS	5/10	1/2/5/10		
13 C	VS	HORIZ	HARD	GRAINS		1/2/5/10		BROKEN

Norman Wells Permafrost Core data
Description of ice

Core #	NRC Ice Type	Ice Orientation	Ice Hardness	Ice shape	lens/vein thick-ness	Grain diameters	Ice Colour	Comments
** Borehole Number 8C								
1 A	NB							
1 B	NB							
1 C	NB							
2 A	VS	HORIZ	SOFT	RANDOM				20 * 10 ICE BODIES
2 B	VX	RANDOM	HARD	GRAINS		1		BROKEN
2 C	VX		HARD	GRAINS		1/2	COLOURLESS	BROKEN
3 A	VS	HORIZ/RETIC	HARD	LENS/VIEN + GRAINS	1/2/10	1/2/5		BROKEN
3 B	VS	RAND/RETIC	HARD	LENS/VEIN + GRAINS	1/2	1/2/5		RETICULATE AT ONE END
3 C	VR	RANDOM	HARD	GRAINS		1/2/5		
4 A	VS	HORIZ	HARD	GRAINS		2/5/10		BROKEN
4 B	VR	RANDOM	HARD	GRAINS		1/2/5/10		
4 C	VS	HORIZ	H/S	GRAINS +1 LARGE LENS 70 MM		5/10 +		LENS IS SOFT, GRANULAR
5 A	VR	RANDOM	HARD	GRAINS		1/2/5/10		
5 B	VR	RANDOM	HARD	GRAINS		1/2/5/10		SOIL TYPE CONTACT ZONE
5 C	VS	RANDOM	HARD	GRAINS		1/2/5/10		BROKEN
** Borehole Number 9								
1 A	NB							
1 B	VS	HORIZ	HARD	LENS	<1		ORGANIC	contact : sand conductivity 3.300
2 A	NBN							BROKEN
2 B	NBN							BROKEN

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
** Borehole Number 10A							
1 A	0.2	0.8	PEAT		0.78	NFN	0.933
1 B	0.2	0.8	PEAT/SILTY FINE		1.13	NBN	2.259
** Borehole Number 10B							
1 A	0.2	0.9	PEAT		0.69	VR	1.796
1 B	0.2	0.9	PEAT		0.85	NBN	1.942
1 C	0.2	0.9	PEAT		0.84	NBN	1.753
2 A	0.9	1.7	PEAT		0.81	NBN	2.102
2 B	0.9	1.7	PEAT		0.77	VS	1.465
2 C	0.9	1.7	PEAT		0.85	VS	1.427
3 A	1.7	2.6	PEAT		0.79	VS	1.815
3 B	1.7	2.6	PEAT		0.75	VS	1.512
** Borehole Number 11							
1 A	0.2	0.8	PEAT/FINE SAND		0.87	NBN	1.591
1 B	0.2	0.8	FINE SAND	ORGANICS	1.58	VS	3.374
1 C	0.2	0.8	FINE SAND/SILTY SAND		1.57	VS	1.193
2 A	0.8	1.5	FINE SAND		1.81	NBN	3.472
2 B	0.8	1.5	FINE SAND		1.82	NB	3.511
2 C	0.8	1.5	FINE SAND		1.93	NBN	3.571
3 A	1.5	2.3	FINE SAND	CALCEROU	1.88	NBN	3.045
3 B	1.5	2.3	SILTY CLAY	CALC/GRA	1.93	VS	2.983
3 C	1.5	2.3	SILTY CLAY	GRAV/CAL	1.88	VS	2.104
** Borehole Number 12A							
1 A	0.2	0.9	PEAT/SILTY CLAY		0.92	VS	0.842
1 B	0.2	0.9	SILT	FEW GRAV	1.65	VS	3.301
1 C	0.2	0.9	SILT		1.86	VS	2.274
2 A	0.9	1.7	SILT		1.88	VS	1.865
2 B	0.9	1.7	SILT/SILTY SAND	GRAVEL	1.92	VS	2.565
2 C	0.9	1.7	SILTY FINE SAND	GRAVEL	1.92	VS	2.803
3 A	1.7	2.5	SILT		1.96	VS	2.262
3 B	1.7	2.5	SILT/SILTY SAND		1.94	VS	2.351

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
** Borehole Number 12B							
1 A	0.0	0.6	PEAT		0.68	NB	1.304
1 B	0.0	0.6	PEAT		0.69	NB	0.000
1 C	0.0	0.6	PEAT		0.77	NB	0.514
2 A	0.6	1.2	PEAT		0.84	NB	1.929
2 B	0.6	1.2	PEAT		0.70	NF	0.000
2 C	0.6	1.2	PEAT		0.76	VR	1.484
3 A	1.2	1.7	PEAT		0.75	VS	0.000
3 B	1.2	1.7	PEAT		0.86	NB	1.932
4 A	1.7	2.3	PEAT		0.77	NB	1.210
4 B	1.7	2.3	PEAT		0.93	VR	0.000
4 C	1.7	2.3	PEAT		0.83	VS	2.276
5 A	2.3	2.8	PEAT		0.81	VC	2.115
5 B	2.3	2.8	PEAT		0.77	NB	1.118
5 C	2.3	2.8	PEAT/SILTY CLAY		0.98	VS	1.620
6 A	2.8	3.2	SILTY CLAY		1.24	VS	2.372
6 B	2.8	3.2	CLAY/SILT		1.19	VS	1.604
7 A	3.2	3.8	SILT		1.52	VS	2.929
7 B	3.2	3.8	SILT		1.53	VS	2.398
7 C	3.2	3.8	SILT		1.60	VS	2.755
8 A	3.8	4.8	SILT		1.74	VS	3.102
8 B	3.8	4.8	SILT		1.76	VS	3.288
8 C	3.8	4.8	CLAYEY SILT	FEW GRAV	1.56	VS	2.677
9 A	4.8	5.5	SILT	FEW GRAV	1.55	VS	2.832
9 B	4.8	5.5	CLAYEY SILT		1.79	VS	2.686
9 C	4.8	5.5	CLAYEY SILT		1.74	VS	2.546
10 A	5.5	6.3	SANDY SILT?	FEW GRAV	1.45	VS	0.000
10 B	5.5	6.3	SANDY SILT?	MANY GRA	1.67	NB	0.000
10 C	5.5	6.3	SILT	GRAVEL	1.87	VS	2.425
11 A	6.3	7.4	SILTY FINE SAND	GRAVEL	1.96	VS	2.940
11 B	6.3	7.4	CLAYEY SILT	MANY GRA	1.98	VS	2.600
11 C	6.3	7.4	SILTY FINE SAND	MANY GRA	1.73	VS	2.705

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
** Borehole Number 7A							
1	0.3	0.6	PEAT		0.84	VC	0.000
2 A	0.6	1.2	PEAT/SILTY CLAY	ORGANICS	0.95	VS	1.480
2 B	0.6	1.2	PEAT/SILTY CLAY		1.01	VS	1.397
3 A	1.2	1.7	SILTY CLAY		1.65	VS	0.000
3 B	1.2	1.7	SILTY CLAY		1.57	VS	2.366
4	1.7	2.2	SILTY CLAY	GRAVEL	1.90	NB	2.106
5	2.2	2.5	SILTY CLAY	GRAVEL	1.91	VS	2.009
6 A	2.5	3.1	SILTY CLAY	GRAVEL	1.67	VS	2.104
6 B	2.5	3.1	DENSE SILTY CLAY	GRAVEL	1.81	VS	2.076
7 A	3.1	3.7	DENSE SILTY CLAY	GRAVEL	1.84	VS	0.000
7 B	3.1	3.7	DENSE SILTY CLAY	GRAVEL	1.85	NB	2.254
7 C	3.1	3.7	CLAY	GRAVEL	1.90	VS	2.301
8 A	3.7	4.5	CLAY	GRAVEL	1.77	VS	0.000
8 B	3.7	4.5	SILTY CLAY	GRAVEL	1.94	VS	2.055
8 C	3.7	4.5	CLAY	GRAVEL	1.99	VS	2.039
9 A	4.5	5.2	SILTY CLAY	GRAVEL	1.80	VS	2.029
9 B	4.5	5.2	SILTY CLAY	GRAVEL	2.11	VS	2.407
9 C	4.5	5.2	SILTY CLAY	GRAVEL	1.89	VS	2.169
10 A	5.2	6.0	SILTY CLAY	CALC.	1.92	VS	1.863
10 B	5.2	6.0	SILTY CLAY	GRAVEL	1.93	NB	2.336
10 C	5.2	6.0	SILTY CLAY	GRAVEL	1.96	VS	1.995
11 A	6.0	6.6	SILTY CLAY	GRAVEL	1.72	VS	2.359
11 B	6.0	6.6	SILTY CLAY		1.81	VS	2.234
12 A	6.6	6.6	SILTY CLAY	GRAVEL	1.63	VS	2.466
12 B	6.6	7.2	SILTY CLAY	GRAVEL	1.70	NB	2.815
12 C	6.6	7.2	SILTY CLAY	GRAVEL	1.66	VR	2.355
13 A	7.2	7.7	SILTY CLAY`	GRAVEL	1.57	VR	0.000
13 B	7.2	7.7	SILTY CLAY	GRAVEL	2.00	VS	2.357
14 A	7.7	8.0	SILTY CLAY	GRAVEL	1.72	VS	1.951
14 B	7.7	8.0	SILTY CLAY	GRAVEL	1.93	NB	2.517
15 A	8.0	8.4	SILTY CLAY	GRAVEL	2.12	VS	2.104
15 B	8.0	8.4	SILTY CLAY	GRAVEL	1.91	NB	2.499
15 C	8.0	8.4	SILTY CLAY	GRAVEL	*******	VS	0.000
16	8.4	8.6	SILTY CLAY	GRAVEL	*******	VS	0.000
17 A	10.0	10.4	SILTY CLAY	GRAVEL	1.96	NB	2.148
17 B	10.0	10.4	SILTY CLAY	GRAVEL	1.98	VS	2.231
18 A	10.4	11.2	SILTY CLAY	GRAVEL	1.84	VS	2.226
18 B	10.4	11.2	SILTY CLAY	GRAVEL	1.78	NB	2.017
18 C	10.4	11.2	SILTY CLAY	GRAVEL	1.77	VS	2.084
19 A	11.2	12.0	SILTY CLAY	GRAVEL	1.76	VR	2.366
19 B	11.2	12.0	SILTY CLAY	GRAVEL	1.79	VS	2.327
19 C	11.2	12.0	SILTY CLAY	GRAVEL	1.60	VS	2.059
20 A	12.0	12.7	SILTY CLAY	GRAVEL	2.03	NB	2.143
20 B	12.0	12.7	SILTY CLAY	GRAVEL	2.01	NB	2.186
20 C	12.0	12.7	SILTY CLAY	GRAVEL	1.80	VS	2.293
21 A	12.7	13.5	SILTY CLAY	GRAVEL	1.53	VS	0.000
21 B	12.7	13.5	SILTY CLAY	GRAVEL	1.45	VS	2.034
21 C	12.7	13.5	SILTY CLAY	GRAVEL	1.74	VR	1.954

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
22 A	13.5	14.3	SILTY CLAY	GRAVEL	1.95	VS	2.013
22 B	13.5	14.3	SILTY CLAY	GRAVEL	1.70	VS	0.000
22 C	13.5	14.3	SILTY CLAY	GRAVEL	1.60	VS	2.307
23 A	14.3	15.0	SILTY CLAY	GRAVEL	1.94	VS	2.334
23 B	14.3	15.0	SILTY CLAY	GRAVEL	1.52	VS	0.000
23 C	14.3	15.0	DENSE CLAY		1.75	VS	2.349
24 A	15.0	15.5	SILTY CLAY	GRAVEL	1.94	VS	2.085
24 B	15.0	15.5	SILTY CLAY	GRAVEL	1.95	VS	2.238
24 C	15.0	15.5	SILTY CLAY	GRAVEL	2.03	VR	2.175
25 A	15.5	16.3	SILTY CLAY	GRAVEL	1.94	VR	2.228
25 B	15.5	16.3	SILTY CLAY	GRAVEL	2.04	VS	2.214
25 C	15.5	16.3	SILTY CLAY	GRAVEL	1.90	VS	0.000
26 A	16.3	16.9	SILTY CLAY		2.07	NB	2.778
26 B	16.3	16.9	SILTY CLAY		1.98	NB	2.323
26 C	16.3	16.9	SILTY CLAY		2.00	VS	2.106
27 A	16.9	18.3	SILTY CLAY		1.89	VS	2.188
27 B	16.9	18.3	SILTY CLAY		1.84	VS	2.051
27 C	16.9	18.3	SILTY CLAY		2.00	VS	0.000
28 A	18.3	18.3	LAYERED SILTY CLAY		1.95	VS	2.161
28 B	18.3	19.2	LAYERED SILTY CLAY		1.97	NB	1.710
28 C	18.3	19.2	LAYERD SILTY CLAY		1.94	NB	1.722
29 A	19.2	19.2	CLAY		1.94	NB	0.000
29 B	19.2	20.3	CLAY		1.92	NB	1.560
29 C	19.2	20.3	CLAY		1.94	VS	2.898

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #		Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
** Borehole Number 7B								
1		0.8	1.2	SILTY CLAY	GRAVEL	1.47	VS	1.933
2		1.2	1.7	SILTY CLAY	GRAVEL	1.61	VS	1.983
3	A	1.7	2.5	SILTY CLAY	GRAVEL	1.87	VS	1.983
3	B	1.7	2.5	SILTY CLAY	GRAVEL	1.86	VS	2.319
4	A	2.5	2.8	SILTY CLAY		1.86	VS	2.403
4	B	2.8	3.2	SILTY CLAY	CALC	2.02	VS	2.166
5	A	3.2	3.6	SILTY CLAY	CAL/GRAV	2.01	VS	2.150
5	B	3.6	4.0			2.20		2.464
6	A	4.5	4.8	SILTY CLAY	GRAVEL	2.03	VS	2.581
6	B	4.5	4.8	SILTY CLAY	GRAVEL	2.04	VS	2.360
7	A	4.8	5.5	SILTY CLAY	GRAVEL	2.19	VS	2.514
7	B	4.8	5.5	SILTY CLAY	GRAVEL	1.96	VS	1.837
7	C	4.8	5.5	SILTY CLAY	GRAVEL	1.98	VS	2.360
8	A	5.5	6.3	SILTY CLAY	GRAVEL	1.72	VS	0.000
8	B	5.5	6.3	SILTY CLAY	GRAVEL	1.99	VS	2.064
8	C	5.5	6.3	SILTY CLAY	GRAVEL	2.16	NB	2.742
9	A	6.3	7.1	SILTY CLAY		1.99	VR	2.557
9	B	6.3	7.1	SILTY CLAY	GRAVEL	1.46	VR	2.234
9	C	6.3	7.1	CLAYEY SILT	GRAVEL	2.09	VS	2.326
10	A	7.1	7.8	SILTY CLAY	GRAVEL	1.87	VS	2.360
10	B	7.1	7.8	SILTY CLAY	GRAVEL	1.95	VR	1.882
10	C	7.1	7.8	SILTY CLAY	GRAVEL	2.20	VS	2.441
11	A	7.8	8.6	SILTY CLAY	GRAVEL	1.99	VS	1.931
11	B	7.8	8.6	SILTY CLAY	GRAVEL	1.98	VS	2.693
11	C	7.8	8.6	SILTY CLAY	GRAVEL	1.87	VS	2.232
12	A	8.6	8.6	SILTY CLAY	GRAVEL	1.93	VS	2.196
12	B	8.6	9.4	CLAY	GRAVEL	2.13	VR	2.327
12	C	8.6	9.4	SILTY CLAY	GRAVEL	1.95	VS	2.150
13	A	9.4	10.1	CLAY	GRAVEL	1.69	VS	0.000
13	B	9.4	10.1	SILTY CLAY		1.26	VR	0.000
13	C	9.4	10.1	CLAY	FINE GRA	1.69	VR	2.025
14	A	10.1	10.9	SILTY CLAY	GRAVEL	1.71	VR	2.327
14	B	10.1	10.9	SILTY CLAY	GRAVEL	1.95	VS	2.153
14	C	10.1	10.9	SILTY CLAY	GRAVEL	1.98	VS	1.961
15	A	10.9	11.7	SILTY CLAY	GRAVEL	1.99	VS	2.537
15	B	10.9	11.7	CLAY	GRAVEL	1.92	VS	2.288
15	C	10.9	11.7	SILTY CLAY	GRAVEL	1.93	VS	2.696
16	A	11.7	12.4	SILTY CLAY	GRAVEL	2.12	NB	2.490
16	B	11.7	12.4	SILTY CLAY	GRAVEL	2.07	VS	2.681
16	C	11.7	12.4	SILTY CLAY	GRAVEL	2.13	VS	2.459
17	A	12.4	13.2	SILTY CLAY		2.16	VS	2.475
17	B	12.4	13.2	SILTY CLAY	GRAVEL	1.97	NB	1.960
17	C	12.4	13.2	SILTY CLAY		2.04	NB	2.576
18	A	13.2	14.0	SILTY CLAY		1.89	NB	2.470
18	B	13.2	14.0	SILTY CLAY	GRAVEL	1.90	VS	2.195
18	C	13.2	14.0	SILTY CLAY	GRAVEL	2.16	NB	2.338
19	A	14.0	14.6	SILTY CLAY	GRAVEL	1.98	VS	2.696
19	B	14.0	14.6	SILTY CLAY	GRAVEL	2.03	VS	2.381

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
20 A	14.6	15.4	SILTY CLAY	GRAVEL`	2.08	VS	2.581
20 B	14.6	15.4	SILTY CLAY	GRAVEL	2.10	VR	2.411
20 C	14.6	15.4	SILTY CLAY	GRAVEL	2.14	VS	3.131
21 A	15.4	16.1	SILTY CLAY	GRAVEL	1.89	VS	2.613
21 B	15.4	16.1	SILTY CLAY	GRAVEL	1.96	VS	2.326
21 C	15.4	16.1	SILTY CLAY		2.05	NB	2.768
22 A	16.1	16.9	CLAYEY SILT	GRAVEL	1.94	NB	3.190
22 B	16.1	16.9	SILTY FINE SAND		2.00	NB	3.530
22 C	16.1	16.9	SILTY CLAY/SILTY SND		2.04	VS	2.960
23 A	16.9	17.7	SILTY CLAY		1.91	NB	2.612
23 B	16.9	17.7	SILTY FINE SAND		1.96	NB	3.365
23 C	16.9	17.7	SILTY FINE SAND		1.89	NB	4.003
24 A	17.7	18.4	SILTY CLAY/SILTY SAN	GRAVEL	2.23	NB	3.109
24 B	17.7	18.4	SILTY FINE SAND		2.15	NB	3.868
24 C	17.7	18.4	SILTY FINE SAND		1.97	NB	3.727
25 A	18.4	19.2	SILTY SAND		1.93	NB	2.913
25 B	18.4	19.2	silty clay		2.01	NB	0.000
25 C	18.4	19.2	SILTYCLAY/SILTY SAND		*******	NB	0.000
26 A	19.2	20.0	SILTY FINE SAND		1.97	NB	3.745
26 B	19.2	20.0	SILTY FINE SAND		2.01	NB	3.343
26 C	19.2	20.0	SILTYCLAY/SILTY SAND	GRAVEL	2.37	NB	3.239
27 A	20.0	20.5	SAND		1.95	NB	4.218
27 B	20.0	20.5	SAND		1.56	NB	0.000

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
** Borehole Number 7C							
1 A	0.0	0.8	SILTY CLAY	ORG/GRAV	1.86	VS	1.895
1 B	0.0	0.8	SILTY CLAY		1.33	VS	1.678
2 A	0.8	1.5	SILTY CLAY		*******	VR	0.000
2 B	0.8	1.5	CLAYEY SILT	CALC.	1.87	VS	2.557
2 C	0.8	1.5	SILTY CLAY	CALC	1.75	VS	0.000
3 A	1.5	2.3	SILTY CLAY	GRAVEL	1.87	VS	2.414
3 B	1.5	2.3	SILTY CLAY	GRAVEL	1.94	VS	2.054
3 C	1.5	2.3	SILTY CLAY	GRAVEL	1.98	VS	2.195
4 A	2.3	3.2	SILTY CLAY	GRAVEL	2.01	VS	0.000
4 B	2.3	3.1	SILTY CLAY	GRAVEL	1.98	VS	2.156
4 C	2.3	3.1	SILTY CLAY		1.94	VS	2.165
5 A	3.1	3.8	SILTY CLAY	GRAVEL	1.96	VS	1.905
5 B	3.1	3.8	SILTY CLAY	GRAVEL	2.10	VS	2.295
5 C	3.1	3.8	SILTY CLAY	GRAVEL	2.02	VS	2.292
6 A	3.8	4.6	SILTY CLAY	GRAVEL	1.99	VS	2.453
6 B	3.8	4.6	SILTY CLAY		1.94	VS	2.573
6 C	3.8	4.6	SILTY CLAY	GRAVEL	2.03	VS	2.197
7 A	4.6	5.4	SILTY CLAY	GRAVEL	1.86	VS	2.275
7 B	4.6	5.4	SILTY CLAY	GRAVEL	1.94	VS	0.000
7 C	4.6	5.4	SILTY CLAY	GRAVEL	1.82	NB	2.235
8 A	5.4	6.1	SILTY CLAY	GRAVEL	2.01	VS	2.263
8 B	5.4	6.1	SILTY CLAY	GRAVEL	2.10	VS	2.648
8 C	5.4	6.1	SILTY CLAY	GRAVEL	2.04	VS	2.229
9 A	6.1	6.9	SILTY CLAY	GRAVEL	2.01	VS	2.630
9 B	6.1	6.9	SILTY CLAY	GRAVEL	2.03	VS	2.119
9 C	6.1	6.9	SILTY CLAY	GRAVEL	2.06	VS	2.245
10 A	6.9	7.4	SILTY CLAY	GRAVEL	2.09	VS	2.036
11 A	10.8	11.5	SILTY CLAY	GRAVEL	2.21	VR	2.645
11 B	10.8	11.5	SILTY CLAY	GRAVEL	1.96	VS	2.202
11 C	10.8	11.5	SILTY CLAY	GRAVEL	2.08	VS	2.802
12 A	12.1	12.9	SILTY CLAY	GRAVEL	1.92	VR	2.270
12 B	12.1	12.9	DENSE CLAY	GRAVEL	2.10	NBN	2.602
12 C	12.1	12.9	LAYERED SILT/CLAY		1.99	VS	2.158
13 A	12.9	13.7	LAYERED SILT/CLAY		1.86	VS	1.887
13 B	12.9	13.7	SILTY CLAY		1.97	NBN	2.059
13 C	12.9	13.7	CLAYEY SILT		1.88	NBN	2.751
14 A	13.7	14.6	SILTY CLAY		1.95	VS	1.860
14 B	13.7	14.6	LAYERED SILTY CLAY	GRAVEL	1.79	VR	2.493
14 C	13.7	14.6	LAYERED SILTY CLAY		1.90	VS	2.677
15 A	14.6	15.4	LAYERED SILTY CLAY		1.92	NB	3.265
15 B	14.6	15.4	CLAYEY SILT		1.93	VR	3.461
15 C	14.6	15.4	SILTY FINE SAND		1.89	NB	3.919
16 A	15.4	16.1	CLAYEY SILT		2.03	VS	2.389

Norman Wells Permafrost Core data
Thermal Conductivity Values

Core #	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Thermal Conductivity
** Borehole Number 8C							
1 A	0.2	0.9	PEAT		0.93	NB	1.269
1 B	0.2	0.9	PEAT		0.96	NB	1.707
1 C	0.2	0.9	PEAT	CLAY	0.97	NB	1.881
2 A	0.9	1.5	PEAT		0.83	VS	1.862
2 B	0.9	1.5	PEAT		0.63	VX	1.269
2 C	0.9	1.5	PEAT		0.88	VX	1.583
3 A	1.5	2.0	SANDY CLAY		1.10	VS	2.576
3 B	1.5	2.0	SANDY CLAY		1.43	VS	1.978
3 C	1.5	2.0	SANDY CLAY		1.55	VR	2.219
4 A	2.0	2.6	SANDY CLAY		1.53	VS	2.859
4 B	2.0	2.6	SANDY CLAY		1.40	VR	2.589
4 C	2.0	2.6	SANDY CLAY		1.18	VS	2.485
5 A	2.6	3.2	SANDY CLAY		1.46	VR	2.743
5 B	2.6	3.2	SANDY CLAY/SILTYCLAY		1.55	VR	0.000
5 C	2.6	3.2	SILTY CLAY/FINE		1.18	VS	0.000
** Borehole Number 9							
1 A	0.2	0.8	SAND/PEAT		1.31	NB	1.992
1 B	0.2	0.8	SAND/PEAT		1.51	VS	1.894
2 A	0.8	1.4	FINE SAND	ORG/GRAV	1.96	NBN	3.785
2 B	0.8	1.4	CLAYEY SAND	CALC/GRA	2.05	NBN	2.596

Norman Wells Permafrost Core data
Description by soil

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Comments
** Borehole Number 10A								
1 A	4	0.2	0.8	PEAT		0.78	NFN	BROKEN
1 B	4	0.2	0.8	PEAT/SILTY FINE SAND		1.13	NBN	PEAT/MINERAL CONTACT/BROKEN
** Borehole Number 10B								
1 A	4	0.2	0.9	PEAT		0.69	VR	BROKEN
1 B	4	0.2	0.9	PEAT		0.85	NBN	BROKEN
1 C	4	0.2	0.9	PEAT		0.84	NBN	COLOUR CHANGE/BROKEN
2 A	4	0.9	1.7	PEAT		0.81	NBN	
2 B	4	0.9	1.7	PEAT		0.77	VS	BROKEN
2 C	4	0.9	1.7	PEAT		0.85	VS	BROKEN
3 A	4	1.7	2.6	PEAT		0.79	VS	BROKEN
3 B	4	1.7	2.6	PEAT		0.75	VS	BROKEN
3 C	4	1.7	2.6	PEAT		0.85	NBN	MINERAL SOIL CONTACT
** Borehole Number 11								
1 A	4	0.2	0.8	PEAT/FINE SAND		0.87	NBN	MINERAL SOIL CONTACT
1 B	3	0.2	0.8	FINE SAND	ORGANICS	1.58	VS	BROKEN
1 C	3	0.2	0.8	FINE SAND/SILTY SAND		1.57	VS	
2 A	3	0.8	1.5	FINE SAND		1.81	NBN	
2 B	3	0.8	1.5	FINE SAND		1.82	NB	
2 C	3	0.8	1.5	FINE SAND		1.93	NBN	
3 A	3	1.5	2.3	FINE SAND	CALCEROU	1.88	NBN	
3 B	3	1.5	2.3	SILTY CLAY	CALC/GRA	1.93	VS	BROKEN
3 C	3	1.5	2.3	SILTY CLAY	GRAV/CAL	1.88	VS	
4	3	2.3	2.6	SILTY CLAY	CAL/GRAV	1.97	VS	BROKEN
** Borehole Number 12A								
1 A	3	0.2	0.9	PEAT/SILTY CLAY		0.92	VS	SOIL CONTACT/BROKEN
1 B	3	0.2	0.9	SILT	FEW GRAV	1.65	VS	BROKEN/GRADING TO FINER LENSES AT B
1 C	3	0.2	0.9	SILT		1.86	VS	LENSES ARE <1, VEINS 2 MM
2 A	3	0.9	1.7	SILT		1.88	VS	BROKEN
2 B	3	0.9	1.7	SILT/SILTY SAND	GRAVEL	1.92	VS	BROKEN/SOIL CONTACT, ICE DIFFERS
2 C	3	0.9	1.7	SILTY FINE SAND	GRAVEL	1.92	VS	
3 A	2	1.7	2.5	SILT		1.96	VS	BROKEN
3 B	2	1.7	2.5	SILT/SILTY SAND		1.94	VS	BROKEN
3 C	2	1.7	2.5	SILTY FINE SAND	GRAVEL	2.04	VS	BROKEN

Norman Wells Permafrost Core data
Description by soil

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Comments
** Borehole Number 7A								
1	19	0.3	0.6	PEAT		0.84	VC	
2 A	19	0.6	1.2	PEAT/SILTY CLAY	ORGANICS	0.95	VS	ONE LARGE LENS ONLY
2 B	19	0.6	1.2	PEAT/SILTY CLAY		1.01	VS	CONDUCTIVITY: PEAT 1.397 SILT 2.171
3 A	19	1.2	1.7	SILTY CLAY		1.65	VS	
3 B	19	1.2	1.7	SILTY CLAY		1.57	VS	
4	19	1.7	2.2	SILTY CLAY	GRAVEL	1.90	NB	
5	19	2.2	2.5	SILTY CLAY	GRAVEL	1.91	VS	
6 A	19	2.5	3.1	SILTY CLAY	GRAVEL	1.67	VS	
6 B	19	2.5	3.1	DENSE SILTY CLAY	GRAVEL	1.81	VS	
7 A	19	3.1	3.7	DENSE SILTY CLAY	GRAVEL	1.84	VS	
7 B	19	3.1	3.7	DENSE SILTY CLAY	GRAVEL	1.85	NB	
7 C	19	3.1	3.7	CLAY	GRAVEL	1.90	VS	
8 A	19	3.7	4.5	CLAY	GRAVEL	1.77	VS	
8 B	19	3.7	4.5	SILTY CLAY	GRAVEL	1.94	VS	
8 C	19	3.7	4.5	CLAY	GRAVEL	1.99	VS	
9 A	19	4.5	5.2	SILTY CLAY	GRAVEL	1.80	VS	
9 B	19	4.5	5.2	SILTY CLAY	GRAVEL	2.11	VS	RETIC. MERGING INTO LARGE GRAINS
9 C	18	4.5	5.2	SILTY CLAY	GRAVEL	1.89	VS	
10 A	18	5.2	6.0	SILTY CLAY	CALC.	1.92	VS	BROKEN AT LENS
10 B	18	5.2	6.0	SILTY CLAY	GRAVEL	1.93	NB	
10 C	18	5.2	6.0	SILTY CLAY	GRAVEL	1.96	VS	
11 A	18	6.0	6.6	SILTY CLAY	GRAVEL	1.72	VS	
11 B	18	6.0	6.6	SILTY CLAY		1.81	VS	
12 A	18	6.6	6.6	SILTY CLAY	GRAVEL	1.63	VS	
12 B	18	6.6	7.2	SILTY CLAY	GRAVEL	1.70	NB	ICE COATING VISIBLE IN FRACTURE
12 C	18	6.6	7.2	SILTY CLAY	GRAVEL	1.66	VR	ONE LARGE ICE MASS
13 A	18	7.2	7.7	SILTY CLAY'	GRAVEL	1.57	VR	FRACTURED CORE
13 B	18	7.2	7.7	SILTY CLAY	GRAVEL	2.00	VS	
14 A	18	7.7	8.0	SILTY CLAY	GRAVEL	1.72	VS	
14 B	18	7.7	8.0	SILTY CLAY	GRAVEL	1.93	NB	
15 A	18	8.0	8.4	SILTY CLAY	GRAVEL	2.12	VS	LARGE ICE LENS AT CORE END
15 B	18	8.0	8.4	SILTY CLAY	GRAVEL	1.91	NB	
15 C	18	8.0	8.4	SILTY CLAY	GRAVEL	********	VS	
16	18	8.4	8.6	SILTY CLAY	GRAVEL	********	VS	
17 A	18	10.0	10.4	SILTY CLAY	GRAVEL	1.96	NB	
17 B	17	10.0	10.4	SILTY CLAY	GRAVEL	1.98	VS	TWO LENSES IN CENTER OF CORE
18 A	17	10.4	11.2	SILTY CLAY	GRAVEL	1.84	VS	BROKEN
18 B	17	10.4	11.2	SILTY CLAY	GRAVEL	1.78	NB	ONE LARGE STONE-8 CM DIAMETER
18 C	17	10.4	11.2	SILTY CLAY	GRAVEL	1.77	VS	BROKEN/ ONE LARGE LENS ONLY
19 A	17	11.2	12.0	SILTY CLAY	GRAVEL	1.76	VR	
19 B	17	11.2	12.0	SILTY CLAY	GRAVEL	1.79	VS	
19 C	17	11.2	12.0	SILTY CLAY	GRAVEL	1.60	VS	BROKEN / MANY LARGE LENSES
20 A	17	12.0	12.7	SILTY CLAY	GRAVEL	2.03	NB	BROKEN
20 B	17	12.0	12.7	SILTY CLAY	GRAVEL	2.01	NB	BROKEN
20 C	17	12.0	12.7	SILTY CLAY	GRAVEL	1.80	VS	BROKEN AT THICK LENS
21 A	17	12.7	13.5	SILTY CLAY	GRAVEL	1.53	VS	BROKEN / LARGE VEIN, WITH THIN LENS
21 B	17	12.7	13.5	SILTY CLAY	GRAVEL	1.45	VS	BROKEN
21 C	17	12.7	13.5	SILTY CLAY	GRAVEL	1.74	VR	WITH A THICK LENS AT CORE END
22 A	17	13.5	14.3	SILTY CLAY	GRAVEL	1.95	VS	

Norman Wells Permafrost Core data
Description by soil

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Comments
** Borehole Number 7B								
1	16	0.8	1.2	SILTY CLAY	GRAVEL	1.47	VS	
2	16	1.2	1.7	SILTY CLAY	GRAVEL	1.61	VS	
3 A	16	1.7	2.5	SILTY CLAY	GRAVEL	1.87	VS	
3 B	15	1.7	2.5	SILTY CLAY	GRAVEL	1.86	VS	
4 A	15	2.5	2.8	SILTY CLAY		1.86	VS	
4 B	15	2.8	3.2	SILTY CLAY	CALC	2.02	VS	
5 A	15	3.2	3.6	SILTY CLAY	CAL/GRAV	2.01	VS	
5 B	15	3.6	4.0			2.20		
6 A	15	4.5	4.8	SILTY CLAY	GRAVEL	2.03	VS	BROKEN
6 B	15	4.5	4.8	SILTY CLAY	GRAVEL	2.04	VS	
7 A	15	4.8	5.5	SILTY CLAY	GRAVEL	2.19	VS	
7 B	15	4.8	5.5	SILTY CLAY	GRAVEL	1.96	VS	
7 C	15	4.8	5.5	SILTY CLAY	GRAVEL	1.98	VS	
8 A	15	5.5	6.3	SILTY CLAY	GRAVEL	1.72	VS	LARGE STONES 8 CM DIAM.
8 B	15	5.5	6.3	SILTY CLAY	GRAVEL	1.99	VS	BROKEN
8 C	15	5.5	6.3	SILTY CLAY	GRAVEL	2.16	NB	
9 A	15	6.3	7.1	SILTY CLAY		1.99	VR	
9 B	15	6.3	7.1	SILTY CLAY	GRAVEL	1.46	VR	
9 C	14	6.3	7.1	CLAYEY SILT	GRAVEL	2.09	VS	
10 A	14	7.1	7.8	SILTY CLAY	GRAVEL	1.87	VS	
10 B	14	7.1	7.8	SILTY CLAY	GRAVEL	1.95	VR	
10 C	14	7.1	7.8	SILTY CLAY	GRAVEL	2.20	VS	
11 A	14	7.8	8.6	SILTY CLAY	GRAVEL	1.99	VS	
11 B	14	7.8	8.6	SILTY CLAY	GRAVEL	1.98	VS	
11 C	14	7.8	8.6	SILTY CLAY	GRAVEL	1.87	VS	BROKEN
12 A	14	8.6	8.6	SILTY CLAY	GRAVEL	1.93	VS	ONE CLOUDY LENS 20+
12 B	14	8.6	9.4	CLAY	GRAVEL	2.13	VR	
12 C	14	8.6	9.4	SILTY CLAY	GRAVEL	1.95	VS	ICE BODIES 30 MM DIA.
13 A	14	9.4	10.1	CLAY	GRAVEL	1.69	VS	LARGE ICE MASS AT CORE END
13 B	14	9.4	10.1	SILTY CLAY		1.26	VR	HIGH ICE CONTENT
13 C	14	9.4	10.1	CLAY	FINE GRA	1.69	VR	
14 A	14	10.1	10.9	SILTY CLAY	GRAVEL	1.71	VR	HIGH ICE CONTENT
14 B	14	10.1	10.9	SILTY CLAY	GRAVEL	1.95	VS	BROKEN/ GRAINS IN LENS PATTERNS
14 C	14	10.1	10.9	SILTY CLAY	GRAVEL	1.98	VS	
15 A	13	10.9	11.7	SILTY CLAY	GRAVEL	1.99	VS	
15 B	13	10.9	11.7	CLAY	GRAVEL	1.92	VS	BROKEN
15 C	13	10.9	11.7	SILTY CLAY	GRAVEL	1.93	VS	
16 A	13	11.7	12.4	SILTY CLAY	GRAVEL	2.12	NB	
16 B	13	11.7	12.4	SILTY CLAY	GRAVEL	2.07	VS	LENS AT BREAK IN CORE
16 C	13	11.7	12.4	SILTY CLAY	GRAVEL	2.13	VS	
17 A	13	12.4	13.2	SILTY CLAY		2.16	VS	LENS AT END
17 B	13	12.4	13.2	SILTY CLAY	GRAVEL	1.97	NB	
17 C	13	12.4	13.2	SILTY CLAY		2.04	NB	
18 A	13	13.2	14.0	SILTY CLAY		1.89	NB	BROKEN
18 B	13	13.2	14.0	SILTY CLAY	GRAVEL	1.90	VS	BROKEN - ONE LENS ONLY
18 C	13	13.2	14.0	SILTY CLAY	GRAVEL	2.16	NB	
19 A	13	14.0	14.6	SILTY CLAY	GRAVEL	1.98	VS	
19 B	13	14.0	14.6	SILTY CLAY	GRAVEL	2.03	VS	ONE LENS ONLY
20 A	13	14.6	15.4	SILTY CLAY	GRAVEL`	2.08	VS	

Norman Wells Permafrost Core data
Description by soil

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Comments
** Borehole Number 7C								
1 A	11	0.0	0.8	SILTY CLAY	ORG/GRAV	1.86	VS	
1 B	11	0.0	0.8	SILTY CLAY		1.33	VS	HIGH ICE VOLUME
2 A	11	0.8	1.5	SILTY CLAY		********	VR	
2 B	11	0.8	1.5	CLAYEY SILT	CALC.	1.87	VS	
2 C	11	0.8	1.5	SILTY CLAY	CALC	1.75	VS	BROKEN
3 A	11	1.5	2.3	SILTY CLAY	GRAVEL	1.87	VS	
3 B	11	1.5	2.3	SILTY CLAY	GRAVEL	1.94	VS	
3 C	11	1.5	2.3	SILTY CLAY	GRAVEL	1.98	VS	
4 A	11	2.3	3.2	SILTY CLAY	GRAVEL	2.01	VS	
4 B	11	2.3	3.1	SILTY CLAY	GRAVEL	1.98	VS	BROKEN
4 C	11	2.3	3.1	SILTY CLAY		1.94	VS	
5 A	11	3.1	3.8	SILTY CLAY	GRAVEL	1.96	VS	BROKEN
5 B	11	3.1	3.8	SILTY CLAY	GRAVEL	2.10	VS	
5 C	11	3.1	3.8	SILTY CLAY	GRAVEL	2.02	VS	
6 A	10	3.8	4.6	SILTY CLAY	GRAVEL	1.99	VS	
6 B	10	3.8	4.6	SILTY CLAY		1.94	VS	
6 C	10	3.8	4.6	SILTY CLAY	GRAVEL	2.03	VS	BROKEN
7 A	10	4.6	5.4	SILTY CLAY	GRAVEL	1.86	VS	BROKEN
7 B	10	4.6	5.4	SILTY CLAY	GRAVEL	1.94	VS	BROKEN
7 C	10	4.6	5.4	SILTY CLAY	GRAVEL	1.82	NB	BROKEN
8 A	10	5.4	6.1	SILTY CLAY	GRAVEL	2.01	VS	
8 B	10	5.4	6.1	SILTY CLAY	GRAVEL	2.10	VS	BROKEN
8 C	10	5.4	6.1	SILTY CLAY	GRAVEL	2.04	VS	BROKEN
9 A	10	6.1	6.9	SILTY CLAY	GRAVEL	2.01	VS	BROKEN
9 B	10	6.1	6.9	SILTY CLAY	GRAVEL	2.03	VS	BROKEN
9 C	10	6.1	6.9	SILTY CLAY	GRAVEL	2.06	VS	
10 A	10	6.9	7.4	SILTY CLAY	GRAVEL	2.09	VS	
11 A	10	10.8	11.5	SILTY CLAY	GRAVEL	2.21	VR	20 MM DIA. ICE BODIES
11 B	10	10.8	11.5	SILTY CLAY	GRAVEL	1.96	VS	
11 C	9	10.8	11.5	SILTY CLAY	GRAVEL	2.08	VS	GRAVEL LAYER
12 A	9	12.1	12.9	SILTY CLAY	GRAVEL	1.92	VR	
12 B	9	12.1	12.9	DENSE CLAY	GRAVEL	2.10	NBN	
12 C	9	12.1	12.9	LAYERED SILT/CLAY		1.99	VS	
13 A	9	12.9	13.7	LAYERED SILT/CLAY		1.86	VS	BROKEN
13 B	9	12.9	13.7	SILTY CLAY		1.97	NBN	BROKEN
13 C	9	12.9	13.7	CLAYEY SILT		1.88	NBN	BROKEN
14 A	9	13.7	14.6	SILTY CLAY		1.95	VS	BROKEN
14 B	9	13.7	14.6	LAYERED SILTY CLAY	GRAVEL	1.79	VR	BROKEN
14 C	9	13.7	14.6	LAYERED SILTY CLAY		1.90	VS	BROKEN
15 A	9	14.6	15.4	LAYERED SILTY CLAY		1.92	NB	BROKEN
15 B	9	14.6	15.4	CLAYEY SILT		1.93	VR	BROKEN
15 C	9	14.6	15.4	SILTY FINE SAND		1.89	NB	BROKEN
16 A	9	15.4	16.1	CLAYEY SILT		2.03	VS	
16 B	9	15.4	16.1	SILTY FINE SAND		2.08	VS	BROKEN
16 C	9	15.4	16.1	SAND		1.86	VS	BROKEN
17 A	9	16.1	16.9	CLAY/SILT CONTACT		2.03	VS	
17 B	8	16.1	16.9	SILTY CLAY/FIN SAND		1.91	VS	CONTACT /BROKEN
17 C	8	16.1	16.9	CLAY/SILTY CLAY CONT		1.93	VS	BROKEN
18 A	8	16.9	17.4	FINE SAND	GRAVEL	1.98	NB	

Norman Wells Permafrost Core data
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18 B	8	16.9	17.4	FINE SAND		2.00	NB	
18 C	8	16.9	17.4	FINE SAND		1.95	NB	
19 A	8	17.4	18.1	FINE SAND		2.11	NB	
19 B	8	17.4	18.1	SAND		1.89	NB	

Norman Wells Permafrost Core data
Description by soil

Core #	BOX	Depth (m) top	bot.	Visual Soil Type (in Cold Room)	Incl.	Wet Density	Ice Type	Comments
** Borehole Number 8C								
1 A	6	0.2	0.9	PEAT		0.93	NB	
1 B	6	0.2	0.9	PEAT		0.96	NB	
1 C	6	0.2	0.9	PEAT	CLAY	0.97	NB	
2 A	6	0.9	1.5	PEAT		0.83	VS	20 * 10 ICE BODIES
2 B	5	0.9	1.5	PEAT		0.63	VX	BROKEN
2 C	5	0.9	1.5	PEAT		0.88	VX	BROKEN
3 A	5	1.5	2.0	SANDY CLAY		1.10	VS	BROKEN
3 B	5	1.5	2.0	SANDY CLAY		1.43	VS	RETICULATE AT ONE END
3 C	5	1.5	2.0	SANDY CLAY		1.55	VR	
4 A	5	2.0	2.6	SANDY CLAY		1.53	VS	BROKEN
4 B	5	2.0	2.6	SANDY CLAY		1.40	VR	
4 C	5	2.0	2.6	SANDY CLAY		1.18	VS	LENS IS SOFT, GRANULAR
5 A	5	2.6	3.2	SANDY CLAY		1.46	VR	
5 B	5	2.6	3.2	SANDY CLAY/SILTYCLAY		1.55	VR	SOIL TYPE CONTACT ZONE
5 C	5	2.6	3.2	SILTY CLAY/FINE SAND		1.18	VS	BROKEN
** Borehole Number 9								
1 A	5	0.2	0.8	SAND/PEAT		1.31	NB	
1 B	5	0.2	0.8	SAND/PEAT		1.51	VS	contact : sand conductivity 3.300
2 A	5	0.8	1.4	FINE SAND	ORG/GRAV	1.96	NBN	BROKEN
2 B	5	0.8	1.4	CLAYEY SAND	CALC/GRA	2.05	NBN	BROKEN

Appendix V

Samples Cut/obtained for Electrical Properties Work
and
Samples Examined via TDR

Samples Cut/Obtained for Electrical Properties Work

Core	Sample
7A	3a 5 6b 7b 8c 9a 11a 19a
7B	4b 10a 14b
8A	12c
8C	2c 3b 5a
10B	2a 3b
11	2b 3b
12A	1c 3b
12B	3a 3b 5b 8b 9a 9b 11a

TDR Determinations

Core	Sample
7A	1b 2a 3b 4a 5 6a 6b 7a 7b 8a 8b 8c 9a 9b 10a 11a 12a 13b 14a 15a 15b 17a 18a 19b 20a 20c 21b 21c 22a 22b 23a 24a 25a 26a 27a 28a 29a
7B	9c 16a 18a
8A	1a 2a 2b 3a 4a 5a 6a 7a 8a 9a 9b 10a 10c 11a 12a 13a
12B	10b 11a 11b 11c