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GROUND ICE AND WATER CONTENTS OF FROZEN SOILS IN THE MACKENZIE VALLEY, NORTHWEST TERRITORIES

by

J.S.O. Lau and D.E. Lawrence

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We express our gratitude to the many government departments and agencies, industrial consortia, and consultants (Appendix I) who provided information for the development of the data bank.

1. Summary

This paper presents, largely in graphical form, the relationship of ground ice and moisture with depth for a large number of NTS map-areas in Mackenzie Valley. The results are derived from data from borehole records from a wide variety of sources, which currently form part of the Mackenzie Valley Geotechnical Data Bank (GSC Open Files 350 and 421 to 425).

The methods of analyses for ground ice distribution and contents and moisture contents are discussed. The results of the analyses for each of the above headings are discussed on a regional basis: southern, central, northern regions and Mackenzie Delta.

In general, ice and moisture contents are low in sands and gravels and increase as the amount of fines increases. The amount of ice and water in all fine grained soils increases exponentially towards the surface. Below about 20 feet, ice and water contents are relatively constant for a given soil type. There is an increase in the amount of frozen soil and the amount of visible ice from south to north within Mackenzie Valley. Various examples are used to illustrate the findings within the report; however, graphs for all map-areas are included in the appendices.

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The information presented here is based on averages of large quantities of data, and this serves to show trends rather than to show site conditions. The methods, however, could be used to advantage for specific sites where detailed information was available.

2. Introduction

2.1 General Nature of Scope of Study

This report presents an analysis of moisture and ground ice conditions of various soil and terrain types in Mackenzie Valley. The work was done under Geological Survey of Canada Project 720026 and was supported (approximately 50%) by funds from the Mackenzie Highway Environmental Working Group of the Department of Indian Affairs and Northern Development. Principal undertakings of this project were:

1. the creation of the Mackenzie Valley Geotechnical Data Bank, the data base used for the analysis presented in this report, which is available on magnetic tape or micro-fiche through the open file system of the Geological Survey of Canada (O.F. 350 and 421 to 425);
2. an interim report submitted to the Mackenzie Highway Environmental Working Group "Review of Geological and Geotechnical Data, Mackenzie Valley" which sets out the rationale and early organization of the data bank. It also reviews sampling methods and materials classifications used by consultants;
3. analysis of data - this report.

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2.2 Objectives

The general objectives of the project were to use existing information, mainly borehole logs and geotechnical test data, to examine the relationship between the distribution of ground ice and the material type, topography, hydrogeology, climate, etc. of that site. Evaluation of further data requirements and development of a predictive capability for materials, ground ice, and terrain performance in areas of low density of geotechnical data was anticipated.

As the type and reliability of information in the data bank are variable, the approach was to use information of roughly the same standard regardless of the source, time of year, expertise, or local conditions under which the data were gathered. Data used have been restricted to the following: soil type, soil moisture, permafrost description, terrain type, stratigraphic depth. Analysis was carried out on a map-sheet basis.

The modified Unified Soil Classification System (USCS) was used as it is widely known. More detailed soils information, i.e. grain size distribution, would have been cumbersome to use; also, the number of samples having grain size information was small compared to the number for which USCS was available.

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Soil moisture was the most commonly gathered test data having a high degree of relevance to soils behaviour. Also a high degree of reliability can be placed on this information (as compared to some other test data). Numerical data were presented by consultants; in all cases moisture was expressed as a percentage of the dry weight.

Permafrost classifications were available for most soils. Some reservation is expressed concerning the reliability of these descriptions for several reasons:

1. the variability of the size and type of sample on which the descriptions were undertaken; the NRC permafrost classification system (NRC technical memorandum #75) was designed for use on undisturbed samples or field exposures but has been applied, in many cases, to disturbed samples or drill cuttings.
2. the number of people of various technical capabilities who have undertaken the descriptions, often under adverse conditions.
3. the possibility of warming and thawing of samples during sampling and drilling, before they can be described. One should be cognisant of the above limitations when making use of the interpretation made using the data.

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2.3 Relationship to Engineering Work

The ability to predict soil moisture and ground ice conditions for various soil types at depth for different locations throughout the Mackenzie Valley would be most useful in many facets of engineering work presently being carried out or planned for the Mackenzie Valley. In the preliminary routing of roads and pipelines where geotechnical information may be sparse or lacking, knowledge of probable moisture and ground ice conditions encountered would assist in routing and also costing of various construction modes.

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3. Study Area

3.1 General

The area under consideration for this study, in broad terms, was the Mackenzie Valley and Delta, from the Northwest Territories-Alberta border (60°N) to the Beaufort Sea. Upland and mountain areas are not included.

Physiographic areas included are parts of the Mackenzie, Peel, and Anderson Plains and the Mackenzie Delta; also included are small portions of the Great Slave Plain and the Yukon Coastal Plain.

3.2 Areas of detailed analysis

Data are available for 30, 1:250,000 NTS map areas; however due to the number of boreholes and the amount and type of information available, statistically meaningful analysis was carried out in less than half of these areas (14).

The primary objective was to have results on all soil types throughout the Valley. This was accomplished in that the fourteen areas for which analysis was carried out give results for the south (2 map areas), central (6 map areas), and northern (5 map areas) parts of the Valley and the Delta.

The results and discussion of the analysis are grouped according to these areas (Sect. 5). The areas having the most boreholes are Fort Good Hope 106I (1816), Fort Norman 96C (1372), Norman Wells 96E (1329).

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It should be noted that the data are not scattered across the breadth of the valley, but are largely concentrated in a few lines running the length of the valley. These lines follow the alignments of the various proposed highway and pipeline routes in the valley. Hence, although the Mackenzie Valley is divided into four regions for descriptive purposes in the discussion of results, it should be noted that the results do not give a true regional picture, but rather a longitudinal profile, from Fort Simpson (95H) to Mackenzie Delta (107C) parallel to the Mackenzie River (Fig. 3.1).

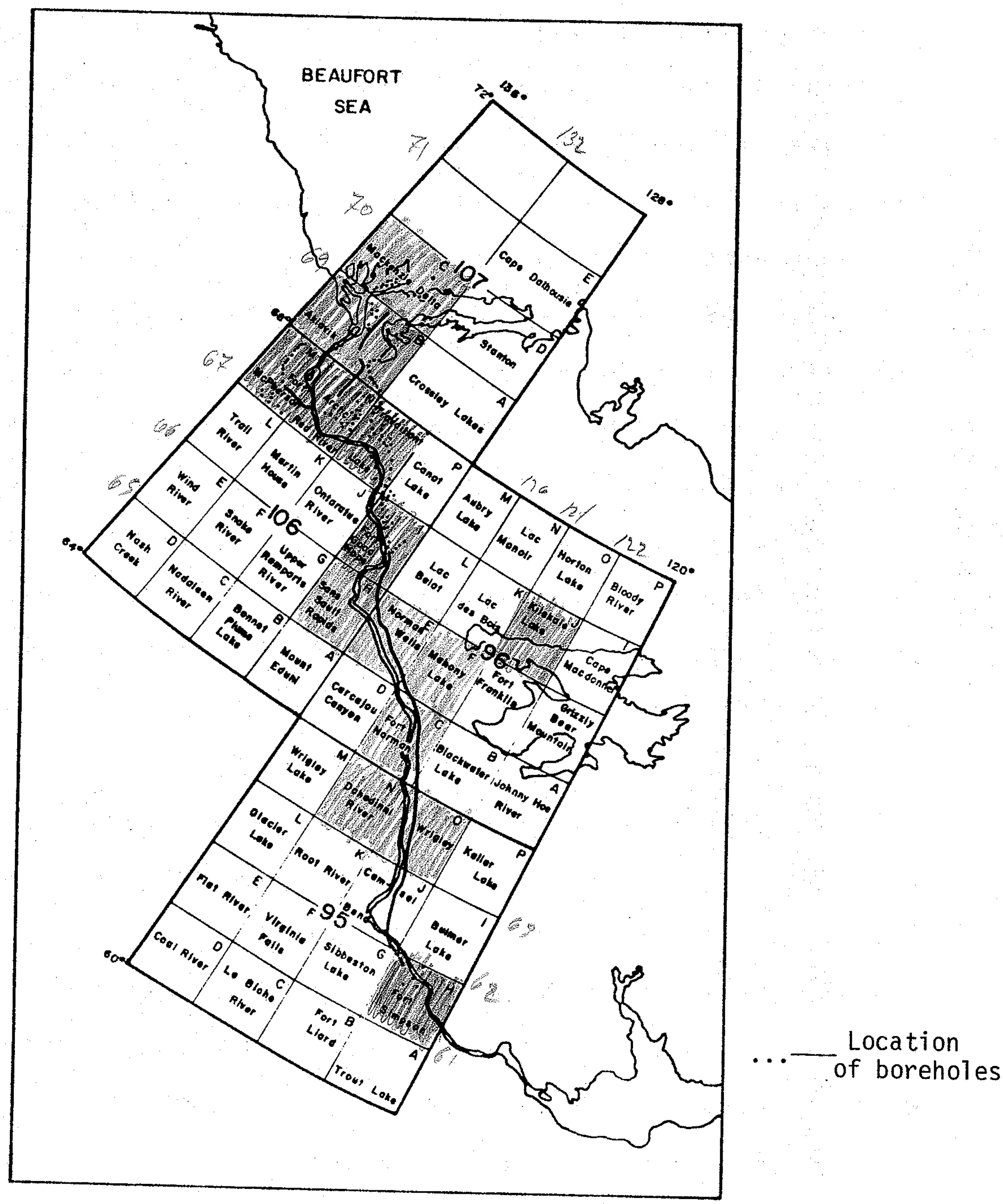

Figure 3.1 Distribution of data in the Mackenzie Valley

4. Methods and Sources of Data

4.1 Collection of Data

The data for this study were gathered entirely from existing sources (Appendix I). During the period from 1969 to 1975 over 12,000 boreholes were drilled in the Mackenzie Valley and Delta, mainly for geotechnical purposes related to routing of the proposed highway and pipelines. It is the stratigraphic and soils test data from these boreholes, combined with terrain information provided principally from 1:125,000 scale surficial geology maps of the Geological Survey of Canada, which form the data base (Mackenzie Valley Geotechnical Data Bank) for this study.

The geotechnical reports containing the borehole information were obtained from various government agencies, industrial consortia and their consultants; without their co-operation the assembly of a data base of this magnitude would have been impossible.

4.2 Data Bank

A data bank was established to permanently store geological, geotechnical, and related information available within the Mackenzie Valley for future retrieval and analysis. The first step was to transfer drillhole information from the geotechnical report to a data record sheet. Each record contains a 5-character data number which is used as a record identifier; a header line of 71 characters of which 27 variables may be used to specify the location, topography and technical aspects of the drilling site; a 2-character number of

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horizon-records; up to 18 lines of 71 characters that are available to describe soil stratigraphy in which up to 29 geotechnical and permafrost characteristics can be recorded (Lawrence, 1974a); and a 74 character uncoded comment line in which other explanatory data can be recorded. See Appendix II for details of recorded information and format. Actual values are used for most variables, with limited use of coding, so that the completeness and accuracy of the data bank depend mainly on the quality of the original record.

Information recorded on the data record sheets is keypunched and fed into the data bank by the use of the "MACIN" computer program written in COBOL language. The information is stored as records on seven-track tape, each record being 1,430 characters in length. The data bank "MAC-VAL" was developed using the method outlined in the flow chart (Figure 4.1). Accordingly, information from 11,677 drillholes has been stored in the Mackenzie Valley Geotechnical Data Bank.

A retrieval system using COBOL programming is utilized to retrieve the data (Figure 4.2). The "GET-MAP" program reads the master file "MAC-VAL" and creates a sub-set on disc or tape. The "RETRIEVE" program reads a standard file (master file or the sub-set created by the "GET-MAP" program), performs selective retrieval on various parameters and creates a statistics and location file and a semi-formatted report file on disc which can be copied to

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paper. The "REPORT-WRITER" program reads a standard file and creates a fully formatted disc file for paper listing of report and for micro-fiche. The "LOCATE" program reads the statistics and location file and generates location maps.

For the GSC open file system, the data bank can be copied on an open file tape and micro-fiche can be produced by the use of the "COM" program.

4.3 Data Analysis

Information from a specified map-area of the National Topographic System can be retrieved by using the "GET-MAP" program (Figure 4.2). Selective retrieval of various parameters such as the terrain type and season of drilling is possible by using the "RETRIEVE" program. The "SCATTER" computer program is used to generate one-page cross-tabulation frequency plots of water content vs. depth, ice content vs. depth and permafrost type vs. depth for a specified soil group of the Unified Soil Classification System (Appendix III). Mean water content and mean ice content and their standard deviations at each depth are also calculated. Consequently, by the use of these three computer programs, information can be retrieved from the data bank systematically according to the topographic position, geological conditions, and the soil texture.

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Mackenzie Valley Geotechnical

Data Bank

Data Coding and Input Section

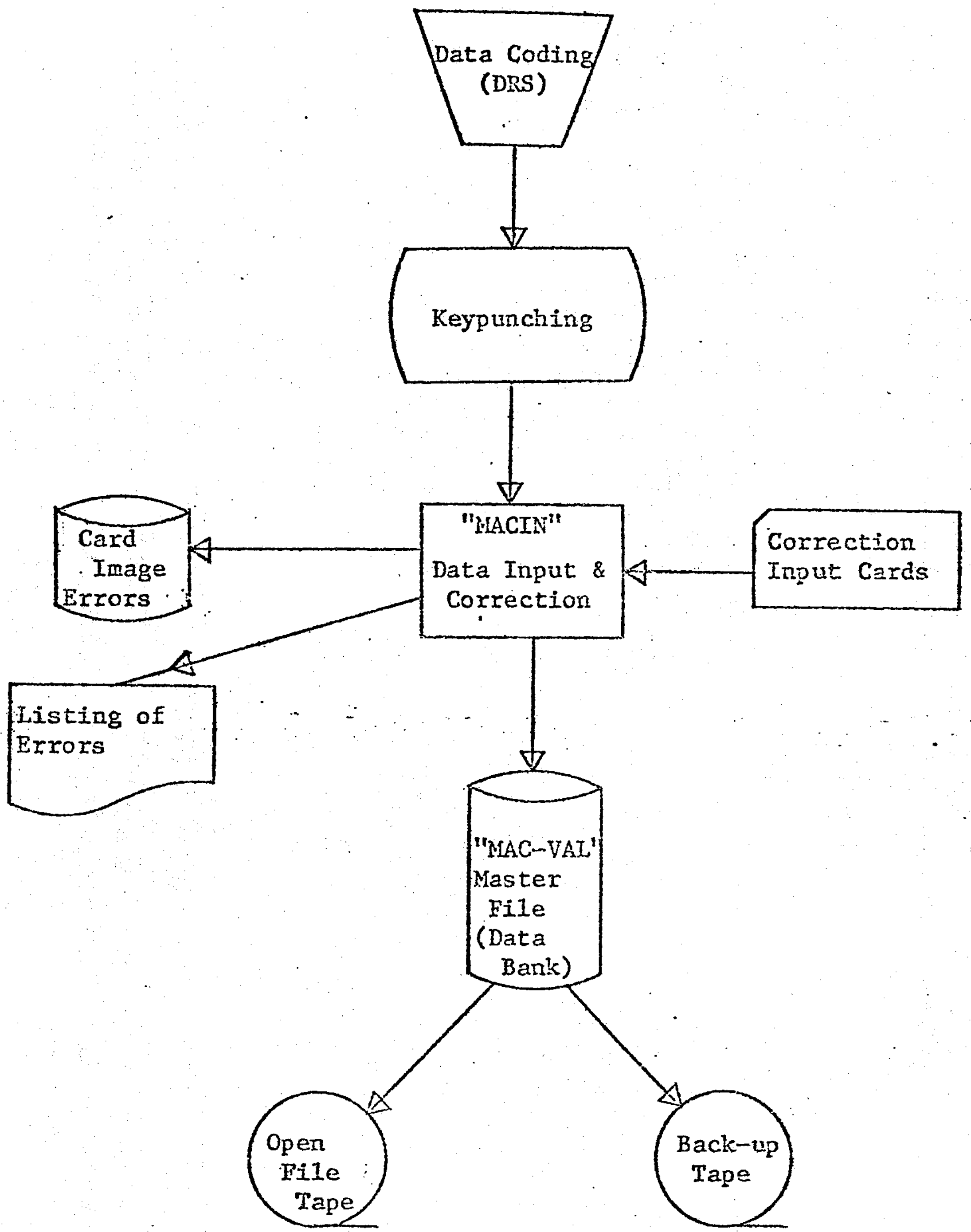

Figure 4.1 Flow Chart of the development of the data bank

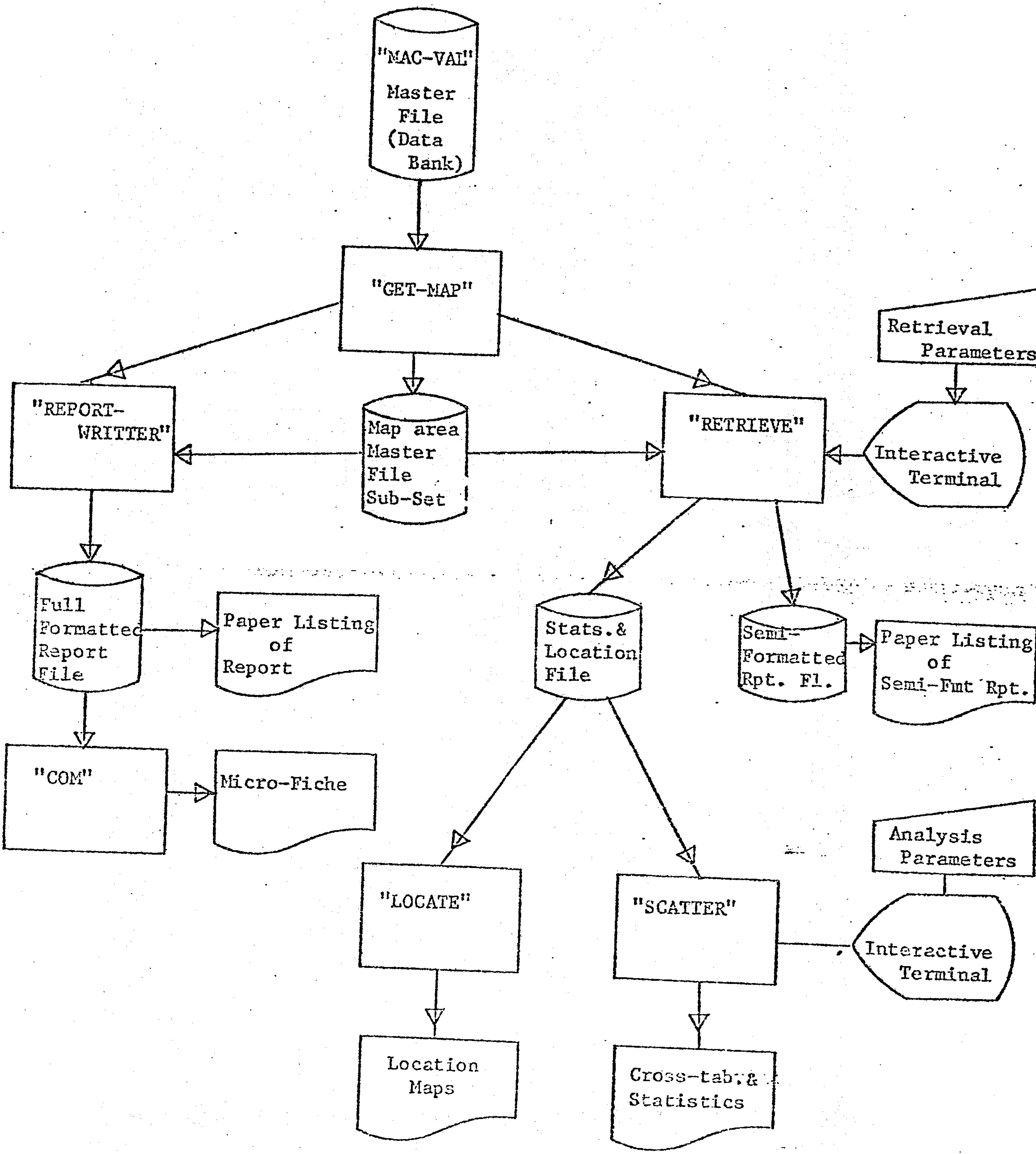

Figure 4.2 Flow chart of the retrieval system

4.3.1 Ground Ice Distribution

To study the distribution of ground ice, a cumulative frequency plot of the occurrence of various types of ice (ICE, V, N and F) and unfrozen soil against depth (Lau and Lawrence, 1976a) was used for various soil types and map-areas. Permafrost has been classified according to the NRC Technical Memorandum No. 79 in most of the geotechnical and geological investigations carried out in the Mackenzie Valley, and thus its use is extended to this study. In symbolic form, visible ice greater than one inch thick is designated as ICE, visible ice less than one inch thick as V, non-visible ice as N, and frozen soils with unknown ice type as F. (Table 4.1). It should be noted that the NRC system is intended for the description of undisturbed samples. However, it has been used indiscriminately by many in the description of disturbed samples. As a result, the erroneous classification of samples is possible. The frequency and amount of ground ice reported when using disturbed sampling methods are considerably less than those using continuous undisturbed sampling methods or estimated by geological observation (Lawrence, 1974b). Hence, in this study, the description of permafrost should be treated as tentative description.

4.3.2 Water content

In the frequency plots of water content vs. depth, the data in some cases are scattered, and therefore statistical analysis of the data was desirable. Since all the data at a given depth can be represented by the mean value of the data, the mean water content at each depth was used for data analysis.

It should be noted that this mean is only a sample mean, $\bar{x}$. An estimate of the true mean or the mean of a population, μ, is necessary to make the analysis more meaningful. The interval estimate (Freund, 1967) is used to estimate the true mean. Accordingly, the error created when using a sample mean to estimate the true mean is given by $\bar{x} - \mu$. The fact that the magnitude of this error is less than $Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$ can be expressed by means of the inequality

$$-Z_{\alpha/2} \frac{\sigma}{\sqrt{n}} < \bar{x} - \mu < Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

or $$\bar{x} - Z_{\alpha/2} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

where $Z_{\alpha/2}$ is defined as the value for which the area under the standard normal distribution to its right to equal to $\alpha/2$. The confidence interval, i.e. the interval from $\bar{x} - Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$ to $\bar{x} + Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$, can then be calculated with a degree of confidence equal to 0.95. However, there is one complication involved: σ, the standard deviation of the mean of the population, has to be estimated. There is no choice but to replace σ with the sample standard deviation, S. This is reasonable provided the sample size is sufficiently large (n = 30 or more) and the large sample confidence interval for μ becomes

$$\bar{x} - Z_{\alpha/2} \frac{s}{\sqrt{n}} < \mu < \bar{x} + Z_{\alpha/2} \frac{s}{\sqrt{n}}$$

When the sample size is less than 30, the small sample confidence interval for μ is given by

$$\bar{x} - t_{\alpha/2} \frac{s}{\sqrt{n}} < \mu < \bar{x} + t_{\alpha/2} \frac{s}{\sqrt{n}}$$

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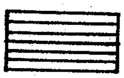
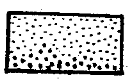
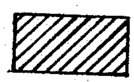
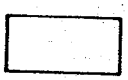
	ICE	Ice is discernible by eye and is greater than one inch thick.
	V - VISIBLE ICE	Ice is discernible by eye and is less than one inch thick.
	N - ICE NOT VISIBLE	Ice is not discernible by eye. The impression received by the unaided eye is that none of the frozen water occupies space in excess of the original voids in the soil.
	F - FROZEN, TYPE UNKNOWN	
	SOILS NOT FROZEN	

Table 4.1 The categories, symbols and descriptions for the various types of ground ice.

where $t_{\alpha/2}$ is defined as the value for which the area under the t-distribution to its right is equal to $\alpha/2$ It should be pointed out that the sample size at each depth varies from 1 to 297.

Both the mean value, $\bar{x}$, and the confidence interval at each depth are plotted against the corresponding depth. The mean water content curve is defined as the line passing through all the confidence intervals at various depths and as close as possible to the mean values without sacrificing the smoothness of the curve. No preferential selection or refinement of data were undertaken when data are only grouped according to their topographic position and the soil texture. Whereas, when the data are further grouped in genetic categories, preferential selection of data was undertaken (Lau and Lawrence, 1976b).

4.3.3 Ice Content

An attempt was made to investigate the mean ice content and depth relationships, using a method similar to that outlined above for the study of the mean water content and depth relationships. However, not enough data were available in most areas to make a meaningful plot of the mean ice content against depth.

5. Results and Discussion

The data analyses for ground ice distribution and mean water content variability with depth were carried out for 14 1:250,000 map-areas (Fig. 5.1). Because of paucity of summer information and the variability of active layer convections during the summer, these were not included; only those holes drilled between November and March have been considered in the analysis.

For descriptive purposes the Mackenzie Valley was divided into four regions (Fig. 5.1). Discussion of results is undertaken according to region as significant differences can be readily seen for each of the areas.

The four regions are delineated as follows:

Area I - Southern Region:
(61°00' to 63°00'N Lat.)
Map-sheets - Fort Simpson (95H)
Camsell Bend (96J)

Area II - Central Region:
(63°00' to 66°00'N Lat.)
Map-sheets - Wrigley (95 0)
Dahadinni River (95N)
Fort Norman (96C)
Mahony Lake (96F)
Norman Wells (96E)
San Sault Rapids (106H)

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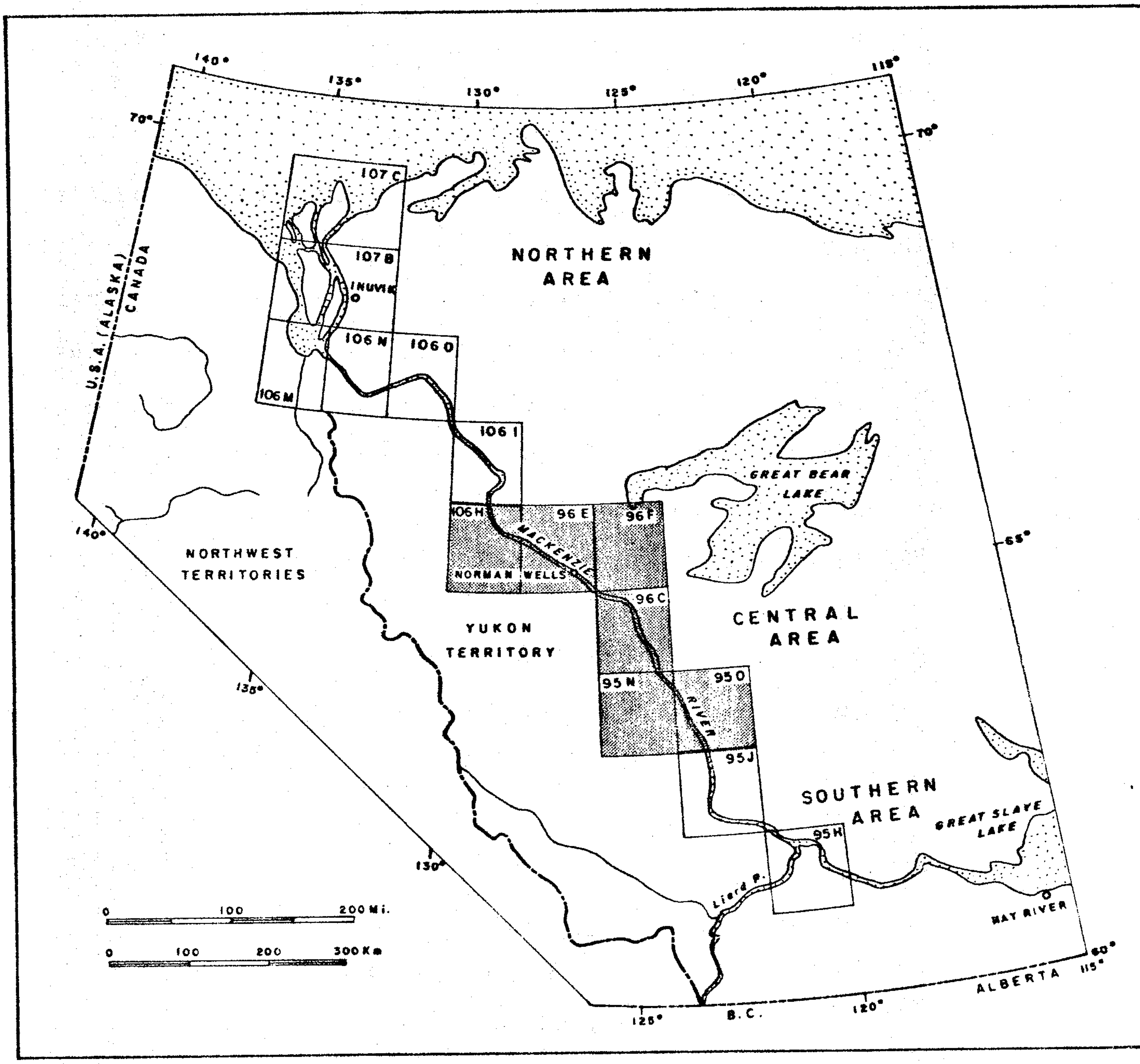

Fig. 5.1 Areas of Investigation

Area III - Northern Region:

(66°00' to 69°00' N Lat.)

Map-sheets - Fort Good Hope (106I)

Travaillant Lake (106 0)

Arctic Red River (106N)

Fort McPherson (106M)

Aklavik (107B)

Area IV - Mackenzie Delta

(69°00 to 70°00' N Lat.)

Map-sheet - Mackenzie Delta (107C)

5.1 Winter Ground Ice Distribution

Soils containing ground ice may present settlement and stability problems if allowed to thaw, especially in the case of fine grained soils. The amount, form, and distribution of ground ice vary considerably with soil type and location in the Mackenzie Valley.

Permafrost data from about 20,000 records retrieved from the Mackenzie Valley Data Bank comprise the base information for this analysis. Only the records from boreholes drilled in the period from November to March are used to investigate the winter ground ice distribution. Cumulative frequency plots of ground ice for the various soil groups (USCS) in 14 NTS map areas are shown in Appendix IV.

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It should be noted that in the discussion of results, all percentage are expressed as the percentage of the total number of data in the specified soil groups. For example, 4% V in coarse grained soils means that the ratio of the number of coarse grained soil samples containing visible ice to the total number of coarse grained soil samples is equal to 4%.

5.1.1 Area I - Southern Region (NTS 95H, 95J)

Coarse grained soils

Most coarse grained soils in the southern region are frozen (90%) in winter with 4% containing visible ice. The high permeability of these soils ensures their free draining in this area, and thus there is little visible ice.

Fine grained soils

Large proportions of the ML and CL soils are frozen (87%) in winter, and visible ice (V) appears in 7% of all samples. However, less than one quarter of the CI and CH soils (23%) are found to be frozen. Ice in the frozen CI and CH soils commonly is of the visible type and visible ice is found in 11% of the samples. Visible ice greater than one inch thick is only observed in the CI soils in Fort Simpson.

Peat

A substantial amount (89%) of the peat in this region freezes in winter, and 66% of the peat samples contain visible ice.

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5.1.2 Area II - Central Region (NTS 95O, 95N, 96C, 96F, 96E, 106H)

Coarse grained soils

In the central region, large proportions of the coarse grained soils are frozen (79%) in winter, and the ice type ranges from N to V. Visible ice appears in 13% of the samples. The amount of visible ice increases as the amount of fines increases. In the central region, the distribution of frozen soil and visible ice is variable, increasing from Wrigley (95O) and Dahadinni River (95N) to Norman Wells (96E), but decreasing from Norman Wells to Sans Sault Rapids (106H) (Table 5.1). Considerable amounts of visible ice (22% V) are found in the Norman Wells map-area (96E) especially in the GC soils (78% V). However, little visible ice (9% V) is observed in the Sans Sault Rapids map-area (106H). Anyway, an increase of the amount of visible ice from the southern region to the central region is observed (Table 5.2).

Fine grained soils

Most fine grained soils are frozen (91%) in winter, and 47% of these soils contain visible ice. Ice greater than one inch thick is observed in the CI soils in Fort Norman (96C) and Mahony Lake (96F) and in the ML and CL soils in Norman Wells (96E). It appears that visible ice is encountered more often in CL and CI soils than in ML and CH soils. The distribution of frozen soil and ice in the fine grained soils is variable, increasing from Wrigley to Norman Wells, but decreasing from Norman Wells to Sans Sault Rapids (Table 5.1), with exceptionally large amounts of visible ice in

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NTS AREA	COARSE GRAINED		FINE GRAINED	
	% frozen	% V	% frozen	% V
95H	57	14	39	19
95J	90	4	75	6
950	79	3	87	22
95N	64	17	90	83
96C	78	9	92	43
96F			95	48
96E	82	22	92	52
106H	65	9	86	48
106I	90	63	90	78
1060	100	94	100	97
106N	59	51	100	97
106M	82	82	100	92
107B	94	68	98	68
107C	88	66	100	96

Table 5.1 The percentage of soils frozen and percentage of soils containing visible ice, tabulated according to NTS map areas.

Dahadinni River map-area. There is also a marked increase of the amount of visible ice from the southern region to the central region (Table 5.2).

Organic Soils and Peat

The organic soils and the peat are almost completely frozen (96%) in winter and contain substantial visible ice. Seventy-seven percent of the organic soil samples and 65% of the peat samples contain visible ice. Ice greater than one inch thick is observed in the OL, OH, and Pt soils in the Fort Norman map-area (96C), OH soils in the Mahony Lake map-area (96F), and Pt soils in the Norman Wells map-area (96E). There is considerably more visible ice in the northern part of this region than in south with 30%, 57%, 90%, 95% V in organic soils in Wrigley, Fort Norman, Norman Wells, Sans Sault Rapids map-areas, respectively, and 42%, 42%, 86% and 92% V in peat in Wrigley, Fort Norman, Norman Wells and Sans Sault Rapids map-areas, respectively.

5.1.3 Area III - Northern Region (NTS 106I, 106O, 106N, 106M, 107B)

Coarse grained soils

In the northern region 93% of the coarse grained soils are frozen in winter, and visible ice (observed in 75% of the samples) is the predominant type of ice. In Travaillant Lake (106O) and Fort McPherson (106M) map-areas, ice is predominantly of the visible type (94% V in Travaillant Lake and 85% V in Fort McPherson). Ice greater than one inch thick is observed in the GM soils in Fort McPherson, SC soils in Travaillant

REGIONS IN THE MACKENZIE VALLEY		Southern Region	Central Region	Northern Region
PERCENTAGE OF SOILS FROZEN (%)	Coarse grained	90	79	92
	Fine grained	71	91	95
	Organic		95	100
	Peat	89	96	98
PERCENTAGE OF SOILS CONTAINING VISIBLE ICE (%)	Coarse grained	4	13	75
	Fine grained	8	47	86
	Organic		77	92
	Peat	66	65	86

Table 5.2 The percentage of soils frozen and percentage of soils containing visible ice in the three regions in the Mackenzie Valley.

Lake and GW and SP soils in Aklavik. The amount of visible ice increases as the amount of fines increases. The distribution of frozen soil and ice in the coarse grained soils is variable (Table 5.1). However, there is a gross increase of the amount of frozen soil and visible ice from the central region to the northern region (Table 5.2).

Fine grained soils

Almost all of the fine grained soils (95%) are found to be frozen at depth in winter, and very large proportions of the ice are classified as visible ice type. Eighty-six percent of the samples contain visible ice. Ice greater than one inch thick is observed in the ML, CL, and CI soils in Travaillant Lake (106O), Arctic Red River (106N), Fort McPherson (106M) and Aklavik (107B). There is more visible ice in CL and CI soils than in ML soils. Nearly all fine grained soils (97%) in Travaillant Lake contain visible ice. In the northern region, the distribution of frozen soil and visible ice is variable (Table 5.1). However, there is noticeably an increase of the amount of frozen soil and visible ice from the central region to the northern region (Table 5.2).

Organic soils and peat

Apparently all organic soils (100%) and peat (98%) are frozen in winter with large proportions of visible ice. Ninety-two percent of the organic soil samples and 86% of the peat samples contain visible ice. Ice greater than one inch thick is encountered in the

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OL soils in Fort Good Hope (106I), Arctic Red River (106N), and Aklavik (107B) and in Pt soils in Fort Good Hope (106J), Travaillant Lake (106O), and Aklavik (107B).

5.1.4 Area IV - Mackenzie Delta (NTS 107C)

Ground ice, predominantly in the form of visible ice, (observed in 66% of the samples) is present in most of the coarse grained soils (88%) in Mackenzie Delta (107C); however, ice greater than one inch thick was not recorded. ML soils predominate in the Mackenzie Delta and are the only fine grained soil on which analyses was undertaken; visible ice (observed in 96% of the ML soils) is by far the most frequently occurring ice type. The winter ground ice distribution in the surficial soils in Mackenzie Delta (107C) is, in general, very similar to that in the northern region.

Data from a 1974 winter drilling program offshore in the shallow water of the Mackenzie Delta enable the plotting of ground ice distribution in seabed materials. In contrast to widespread ground ice in the surficial soils, less than half seabed soils are frozen (27%) in winter. However, frozen soil is encountered even at a depth of 44 feet below the seabed. Visible ice is observed only in the SM and ML soils (3% V in SM soils and 4% V in ML soils).

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5.1.5 Summary and conclusion

(1) Most of the coarse grained soils in the Mackenzie Valley and Delta are frozen at depth in winter. The occurrence of ice varies from non-visible to visible with ice greater than one inch thick. There is generally an increase in the percentage of coarse grained soils frozen and the percentage of coarse grained soils containing visible ice northward in the Mackenzie Valley.

(2) For the gravels, the amount of visible ice increases as the amount of fines increases. For the sands, the amount of visible ice increases as the amount of fines increases.

(3) Except in the southern region, most of the fine grained soils in the Mackenzie Valley and Delta are found to be frozen in winter and the percentage of fine grained soils frozen increases northward. Less than half of the CI and CH soils in the southern region are frozen. Visible ice is the most frequently recorded ice type with the amount increasing noticeably from south to north. In the northern region, almost all the ice recorded is visible ice.

(4) It appears that visible ice is encountered more often in the CL and CI soils than in the ML and CH soils.

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(5) Considerable proportions of the H_2O in some fine grained soils in the southern and central regions and in Fort Good Hope map-area exist in the liquid phase in winter, thus reducing the amount of heat required to cause thawing.

(6) Nearly all the organic soils and the peat freeze in winter, with large amount of visible ice. There is a general increase of the percentage of organic soils and peat frozen and the percentage of organic soils and peat containing visible ice from south to north in the Mackenzie Valley.

(7) Frozen soils and visible ice are encountered more frequently in the fine grained soils than in the coarse grained soils, and more frequently in the organic soils than in the fine grained soils.

(8) In sharp contrast to the widespread ground ice in the surficial soils, less than half of the soils below seabed offshore in the shallow water of the Mackenzie Delta are frozen in winter.

5.2 Winter Mean Water Content

Relationship exists between the winter mean water content and depth for various soil groups (USCS) in Norman Wells (NTS 96E) and Camsell Bend (NTS 95J) (Lau & Lawrence 1976b). The winter mean water contents of most of the coarse grained soils in those areas were found to be constant regardless of depth. Fine grained soils were found to show an exponential rise in water content towards the

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ground surface. Over 21,000 data points are available for the study of the winter mean water content and depth relationship in the Mackenzie Valley. Table 5.3 shows the numbers of records available for analysis according to soil group and NTS map areas. The winter mean water content vs. depth plots for the various soil types (USCS) for the 14 NTS map areas are illustrated in Appendix V. It should be noted that large samples (n = 30 or more) are found only in the upper 20 feet for many soils; this is due to the fact that data were derived from shallow boreholes, the majority of which did not exceed 20-25' in depth. Consequently, most of the confidence intervals used in plotting the winter mean water content curves are small sample confidence intervals. Although logically correct inferences can be made on the basis of small samples, the small sample confidence intervals are apt to be very wide in some cases and the results are apt to involve considerable errors. For some coarse grained soils, the data available are so few and the confidence intervals are so wide that the winter mean water content curve is approximated by a straight line whose value is equivalent to the winter mean water content of the soil group. The winter mean water contents of those soil groups are calculated and the results are shown in Table 5.4. The straight line portions of the winter mean water content curves of the fine grained soils are also approximated due to the paucity of data at depths greater than 20 feet.

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NTS AREA	SOIL GROUP														
	GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	CI	CH	OL	OH	PT
95H	2	0	1	0	47	2	94	1	22	23	88	3	1	0	17
95J	11	1	5	0	68	69	260	95	683	101	153	26	0	0	23
95N	8	16	18	28	5	1	21	1	9	63	0	0	0	2	9
95O	23	54	33	13	38	43	104	14	184	195	0	4	9	1	19
96C	66	71	47	171	13	122	858	18	112	276	494	110	64	28	103
96E	95	34	88	41	46	208	296	18	466	774	797	304	94	49	94
96F	0	0	2	0	0	0	12	0	2	16	177	15	0	7	2
106H	17	0	25	15	10	0	19	0	116	141	110	6	9	11	25
106I	43	25	41	75	18	21	111	102	326	1740	1238	2	67	9	96
106M	13	4	43	64	10	22	18	25	117	128	50	1	2	1	2
106N	7	17	34	11	0	11	25	7	64	421	739	23	7	2	12
106O	32	15	0	58	21	134	134	64	136	695	812	191	55	4	54
107B	72	25	50	17	104	113	175	38	361	164	38	12	24	7	22
107C	29	10	3	0	75	48	102	13	374	47	9	3	6	0	1

Table 5.3 The numbers of records of water content available for the various soil groups. Tabulated according to NTS map area.

5.2.1 Area I - Southern Region (NTS 95H, 95J)

Coarse grained soils

The winter mean water contents of the coarse grained soils are lower (<20%) in the Cansell Bend map-area than in the Fort Simpson area (20%-30%) (Appendix V). The winter mean water contents of the GW and GP soils in Camsell Bend are constant with depth while the SW soils show an increase of the winter mean water content with depth. The SW and SM curves in Fort Simpson and the SM and SC curves in Camsell Bend show a decrease of water content as the depth increases.

In general, the winter mean water contents of gravels and sands with little or no fines are relatively constant with depth except for SW soils. With appreciable amount of fines, the winter mean water contents show an exponential rise towards the ground surface. It appears that the winter mean water contents increase as the amount of fines increases. Sands have higher winter mean water content than gravels.

Fine grained soils

The winter mean water contents of the fine grained soils are higher than those of the coarse grained soils. Figure 5.2 shows the winter mean water content curves of the fine grained soils. The winter mean water contents of the ML and CL soils decrease as the depth increases with diminishing rate of decrease to a depth of about 17 feet, and then a slight increase with depth. The winter mean

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NTS AREA	WINTER MEAN WATER CONTENT (%)							
	SOIL GROUP							
	GW	GP	GM	GC	SW	SP	SM	SC
95H					*		*	
95J	6.5				†	10.0	*	*
95N	7.0	4.2	15.0	*	2.0		*	
95O	7.5	5.4	9.0	9.2	9.7	12.5	*	*
96C	5.4	7.0	12.5	*	8.0	10.0	*	20.7
96E	8.0	9.0	10.0	*	†	17.0	*	*
96F							*	
106H	6.0		14.0	*	12.0		*	
106I	9.6	6.5	11.4	*	9.7	13.0	*	*
106M	7.2		*	*	8.3	10.8	*	*
106N		9.0	9.8	12.0		13.8	17.8	
106O	6.0	6.5		*	†	‡	‡	‡
107B	7.7	*	*	11.5	9.0	13.5	19.0	18.5
107C[1]	7.0	8.0			†	†	19.2	
107C[2]							25.0	†

* Curve which shows an exponential rise towards the surface.

† Straight line which increases with depth.

‡ Curve which increases with depth.

1 Surficial soils

2 Material below seabed

Table 5.4 The winter mean water contents of some coarse grained soil groups.

water contents of the CI soils increase with depth. This difference may be attributable to the fact that most of the ML and CL soils are frozen while less than one quarter of the CI soils are found to be frozen at depth in winter (Section 5.1.1). Ice in the soil voids restricts water penetration into the ML and CL soils, and water is held at or near the surface by the vegetation mat, giving the ML and CL soils higher values of winter mean water content near the surface. In CI soils, less ice is present in the voids, and water can penetrate more easily. There appears to be some correlation between the winter mean water content and winter ground ice distribution.

Peat

The winter mean water contents of the peat are very high with values varying between 28% and 372%.

5.2.2 Area II - Central Region (NTS 95O, 95N, 96C, 96F, 96E, 106H)

Coarse grained soils

In the central region, the winter mean water contents of the coarse grained soils are low (<25%). Water contents of the GW, GP, GM, SW, and SP soils are constant with depth as are those of the GC soils in Wrigley and the SC soils in Fort Norman. The variation in water contents of these soils from one map area to another is small (Table 5.4). Water contents of the SM and most of the GC and SC soils decrease with depth (Figures 5.3, 5.4 and 5.5). Mean water contents of the GC soils do not vary substantially from one map area to another. The SM and SC soils show an apparent increase

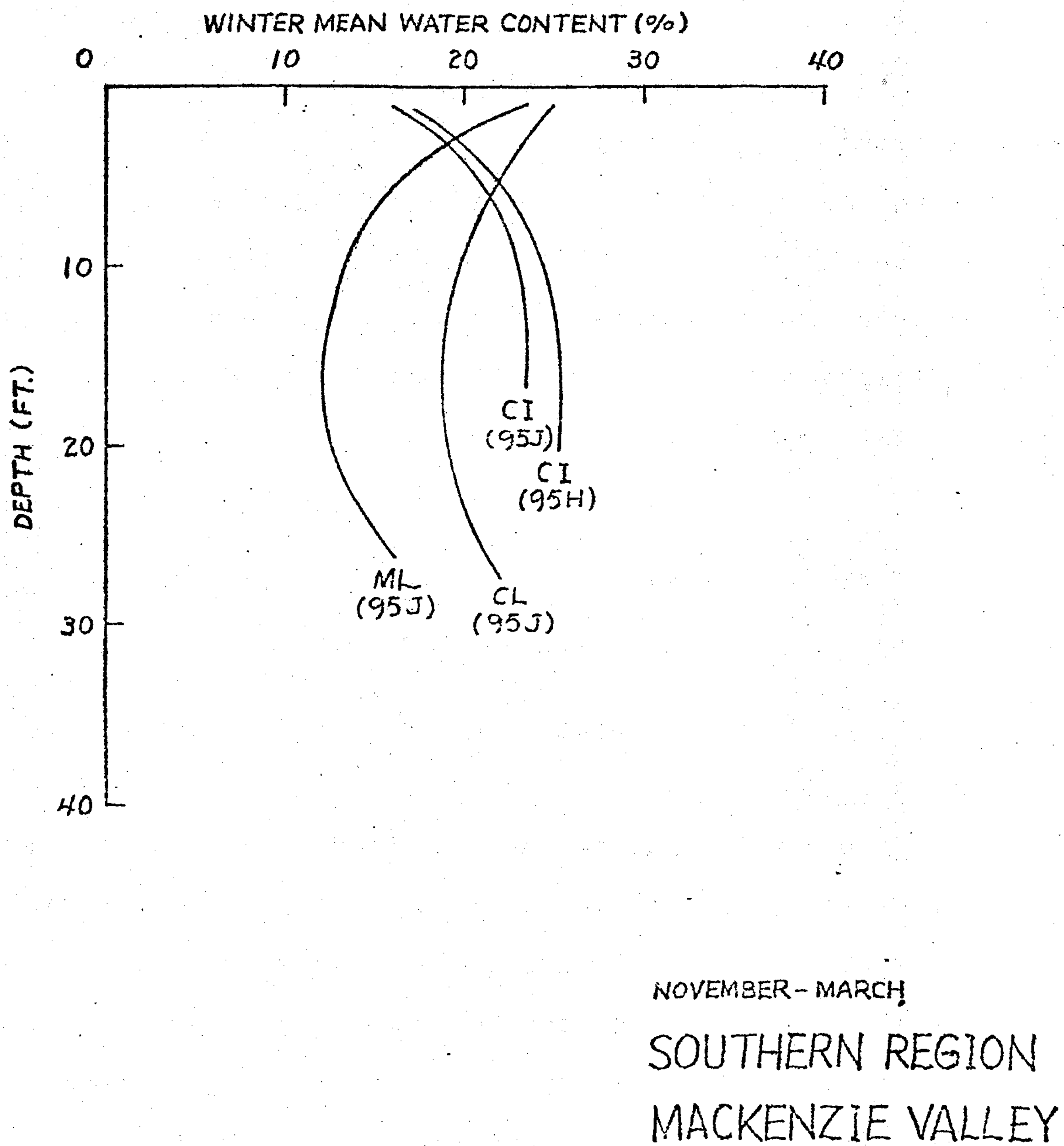
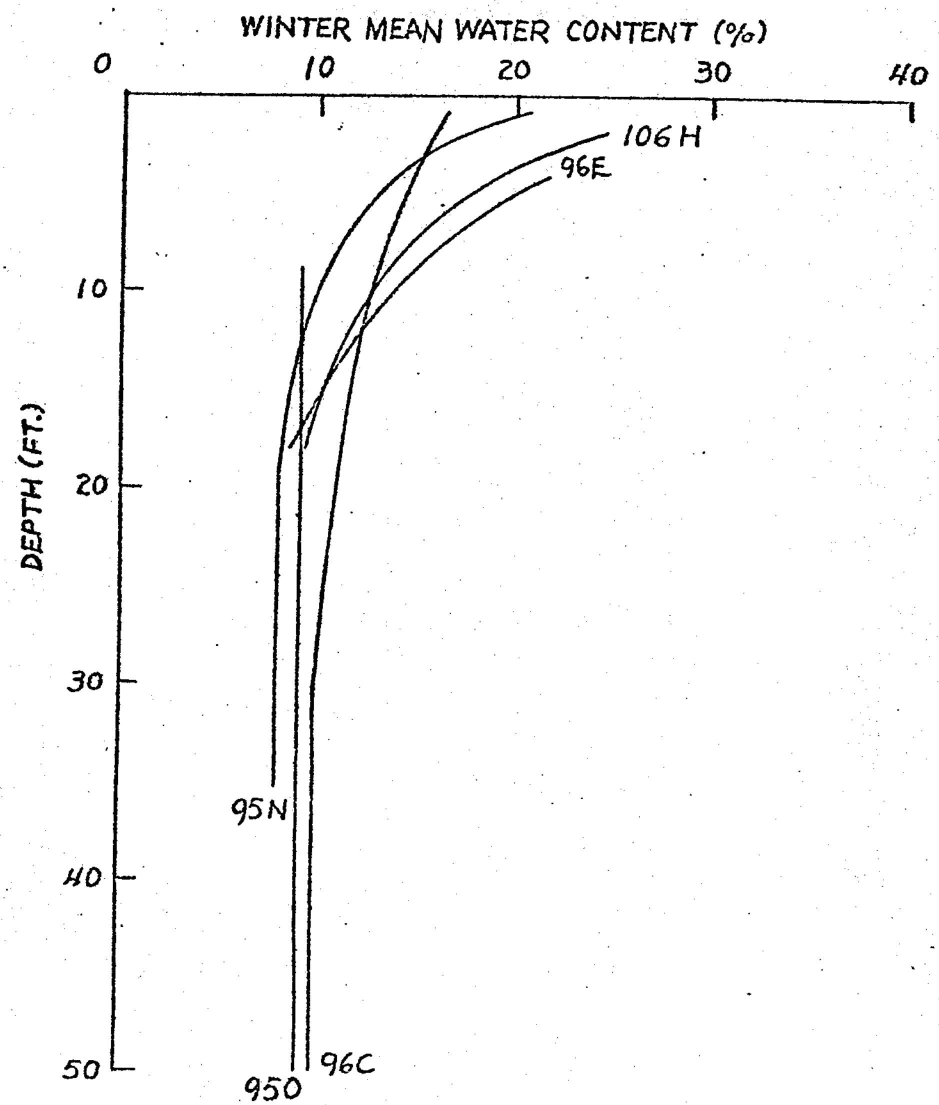


Figure 5.2 Winter mean water content vs. depth for fine grained soil groups in the Southern Region

SOIL GROUP = GC



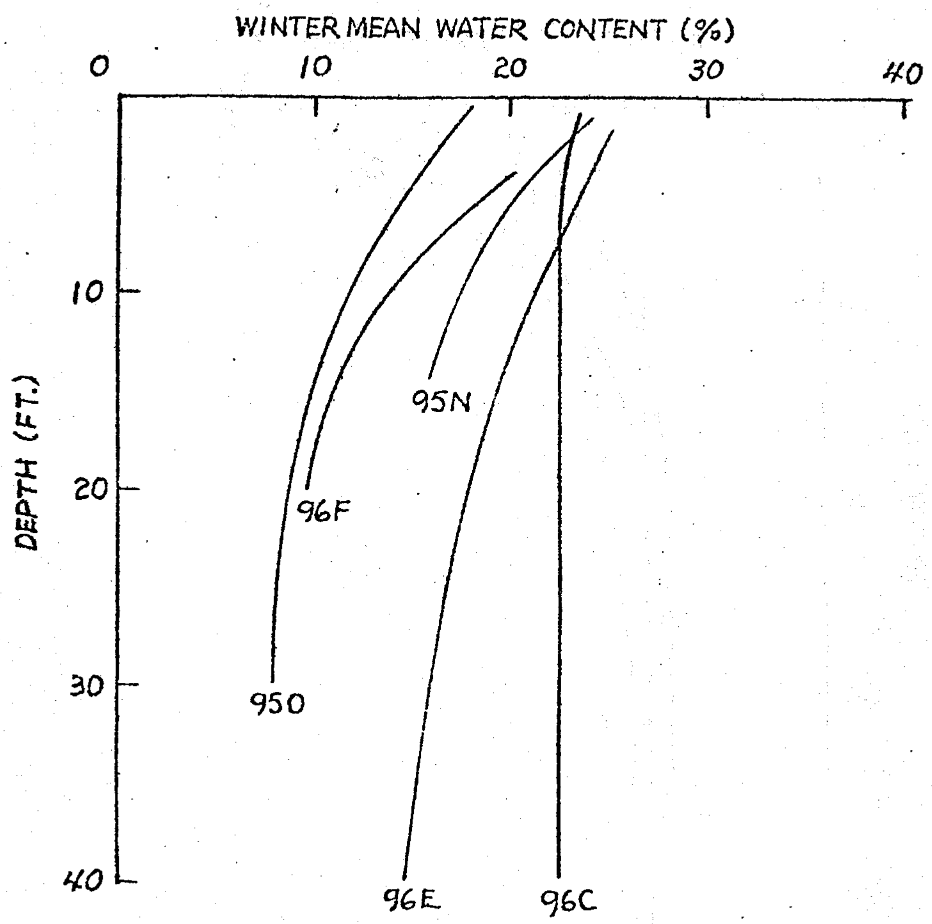
NOVEMBER–MARCH

CENTRAL REGION

MACKENZIE VALLEY

Figure 5.3 Winter mean water content vs. depth for the GC soils in the Central Region

SOIL GROUP = SM

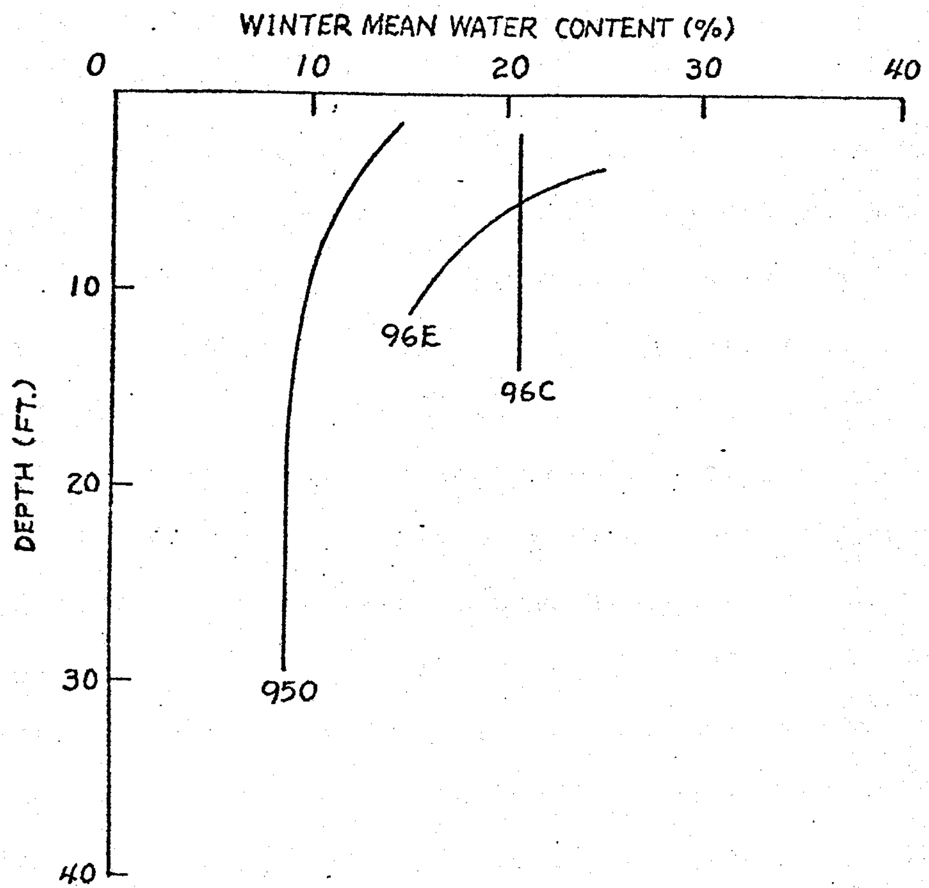


NOVEMBER – MARCH

CENTRAL REGION
MACKENZIE VALLEY

Figure 5.4 Winter mean water content vs. depth for the SM soils in the Central Region.

SOIL GROUP = SC



NOVEMBER–MARCH

CENTRAL REGION
MACKENZIE VALLEY

Figure 5.5 Winter mean water content vs. depth for the SC soils in the Central Region of the winter mean water content from south to north. In general, sand is found to have a higher winter mean water content than gravel; the winter mean water content increases as the amount of fines increase.

Fine grained soils

Water contents of the fine grained soils are higher than those of the coarse grained soils. In the upper 2 feet, the water contents of the fine grained soils are high, 25%-45% for ML soils, 30%-50% for CL soils, 35%-55% for CI soils and 33%-37% for CH soils (Figures 5.6, 5.7, 5.8 and 5.9). The winter mean water contents of the fine grained soils decrease rapidly with depth down to about 10 feet, then gradually to about 20 feet, where winter mean water contents become constant, 20% for ML soils, 18%-24% for CL soils, 10-17% for CI soils and 12% for CH soils. A study of the winter ground ice distribution in the central region shows that most of the fine grained soils are frozen in winter with considerable visible ice (Section 5.1.2). The relationship of ground ice and water contents of the fine grained soils is similar to that outlined for the ML and CL soils in the southern region. The variation of winter mean water contents of the ML, CL, CI and CH soils from one map area to another is generally small, except in the upper 10 feet of soil. From the results, it also appears that the winter mean water contents

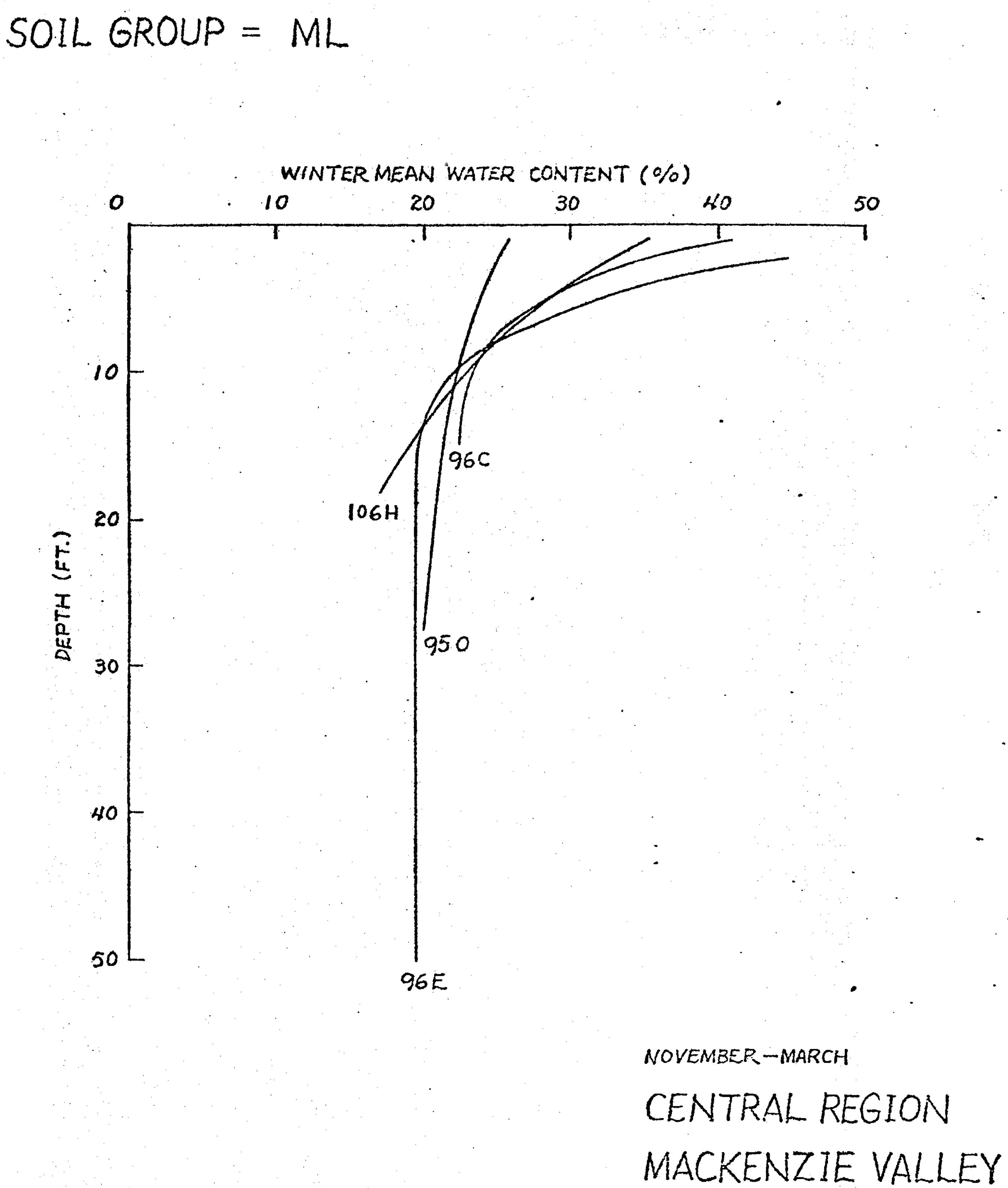


Figure 5.6 Winter mean water content vs. depth for the ML soils in the Central Region

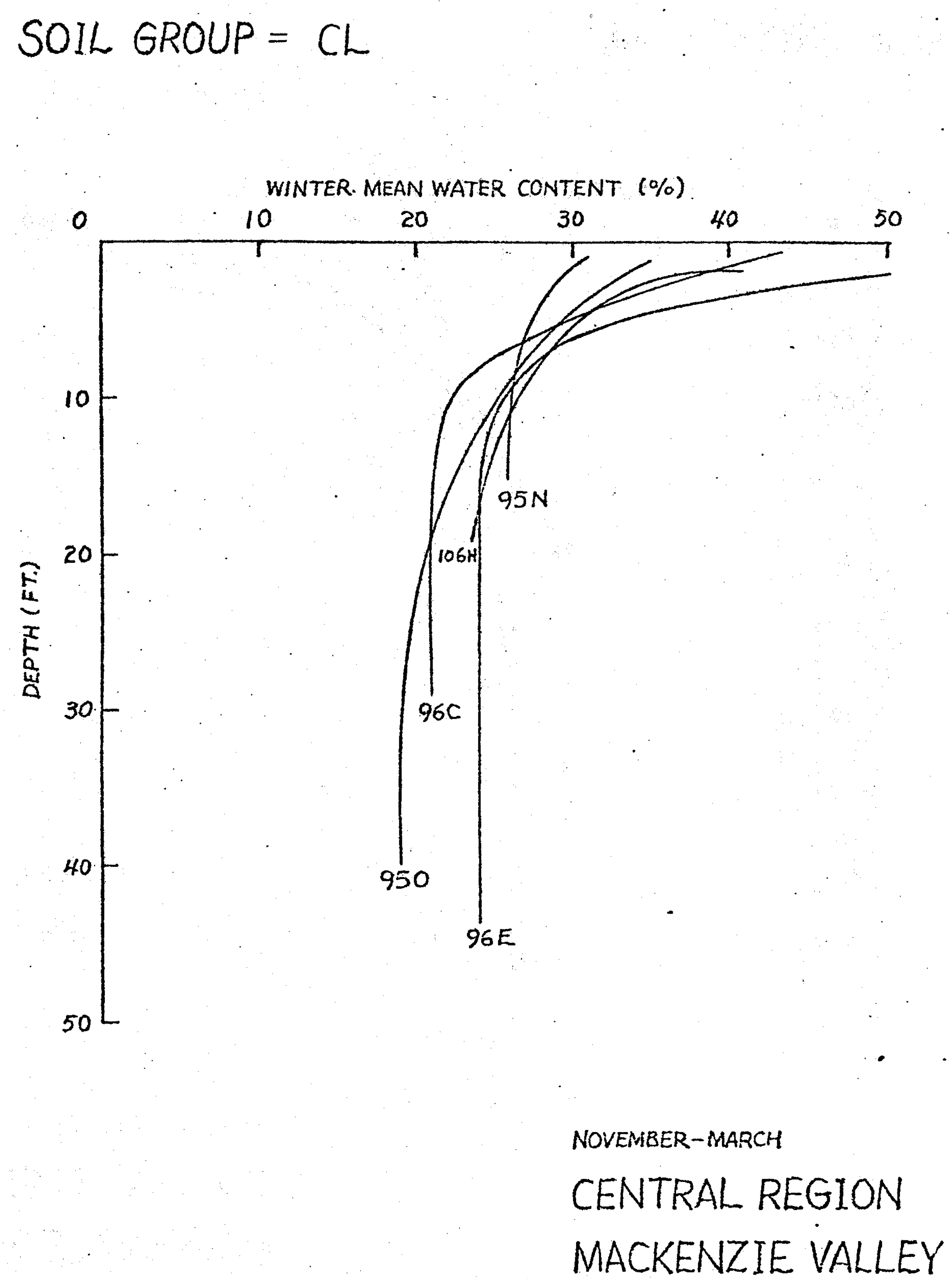
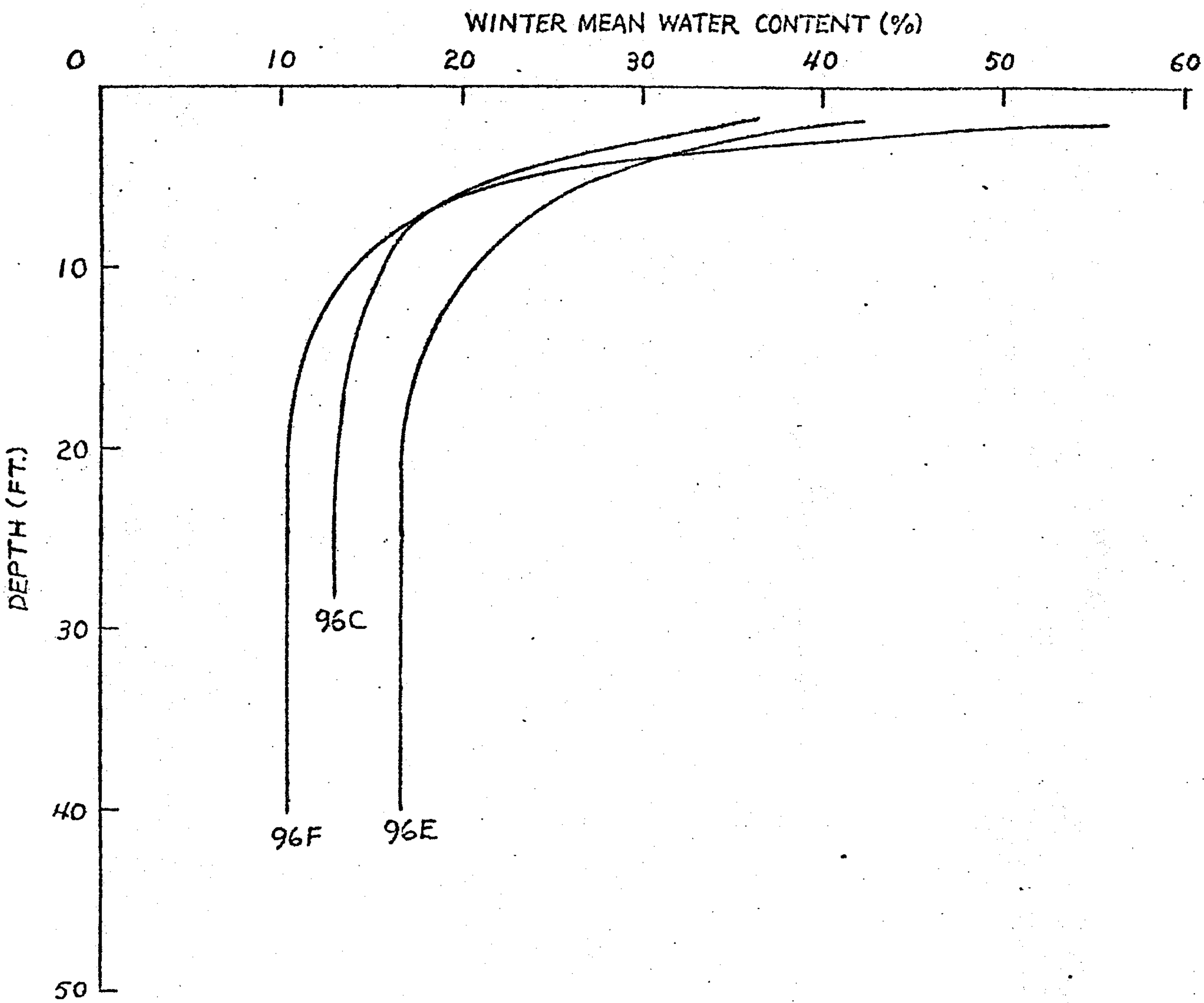


Figure 5.7 Winter mean water content vs. depth for the CL soils in the Central Region

SOIL GROUP = CI



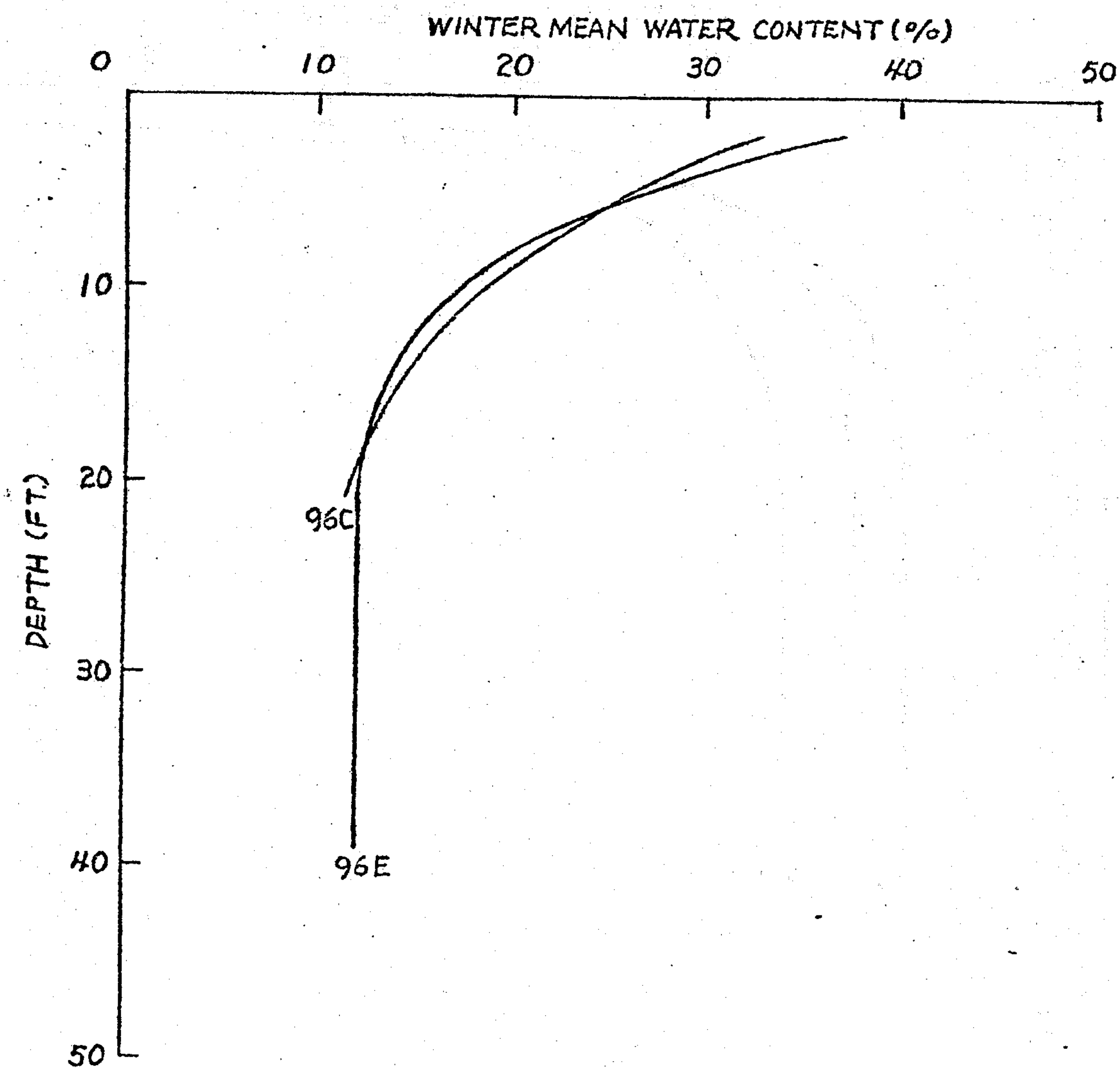
NOVEMBER-MARCH

CENTRAL REGION

MACKENZIE VALLEY

Figure 5.8 Winter mean water content vs. depth for the CI soils in the Central Region.

SOIL GROUP = CH



NOVEMBER – MARCH

CENTRAL REGION

MACKENZIE VALLEY

Figure 5.9 Winter mean water content vs. depth for the CH soils in the Central Region.

decrease as the plasticity increases. Mean water contents of the fine grained soils in the central region are in general higher than those in the southern region, except in the case of CI soils at a depth below 6 feet.

Organic soils and Peat

Water contents of the organic soils and peat are extremely high, ranging from 20% to in excess of 1000% of organic soils and 35% to in excess of 1000% for peat.

Variability based on soil genesis

The data in Norman Wells are also grouped according to deposit type. Plotting of the winter mean water content against depth (Figures 5.10, 5.11, 5.12, 5.13) reveals that fine grained, alluvial soils always show greater mean water content values for a given depth as compared to glaciolacustrine soils and glaciolacustrine soils always have higher mean water contents than morainal soils.

5.2.3 Area III - Northern Region (NTS 106I, 106O, 106N, 106M, 107B)

Coarse grained soils

In the northern region, the winter mean water contents of the coarse grained soils are low (<20%), except in Travaillant Lake where the coarse grained soils are more variable, winter mean water contents (4%-26%). The winter mean water contents of the GW soils, most of the GP, GM, SW and SP soils, the GC and SM soils in Arctic

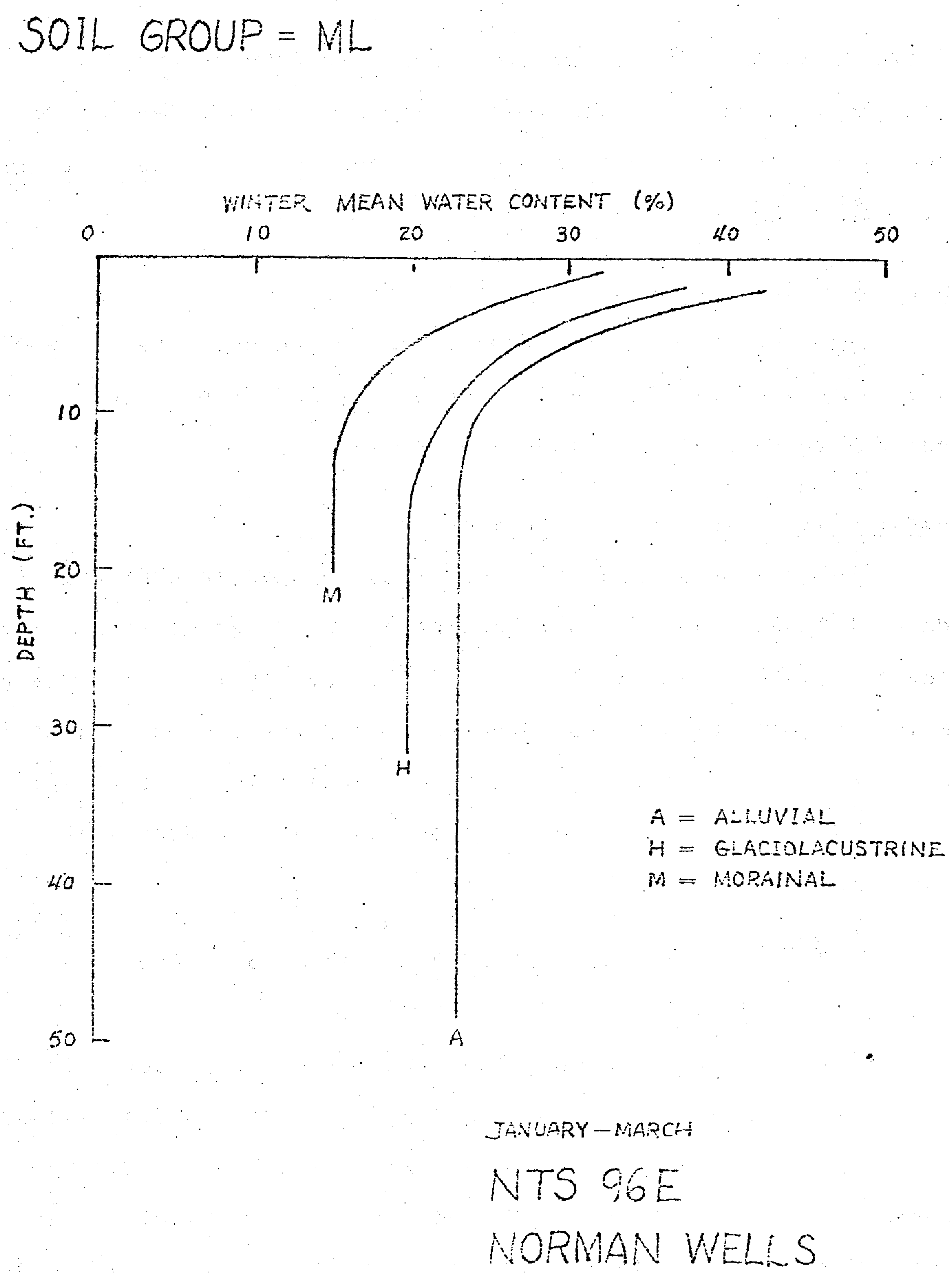


Figure 5.10 Winter mean water content vs. depth for the ML soils in Norman Wells

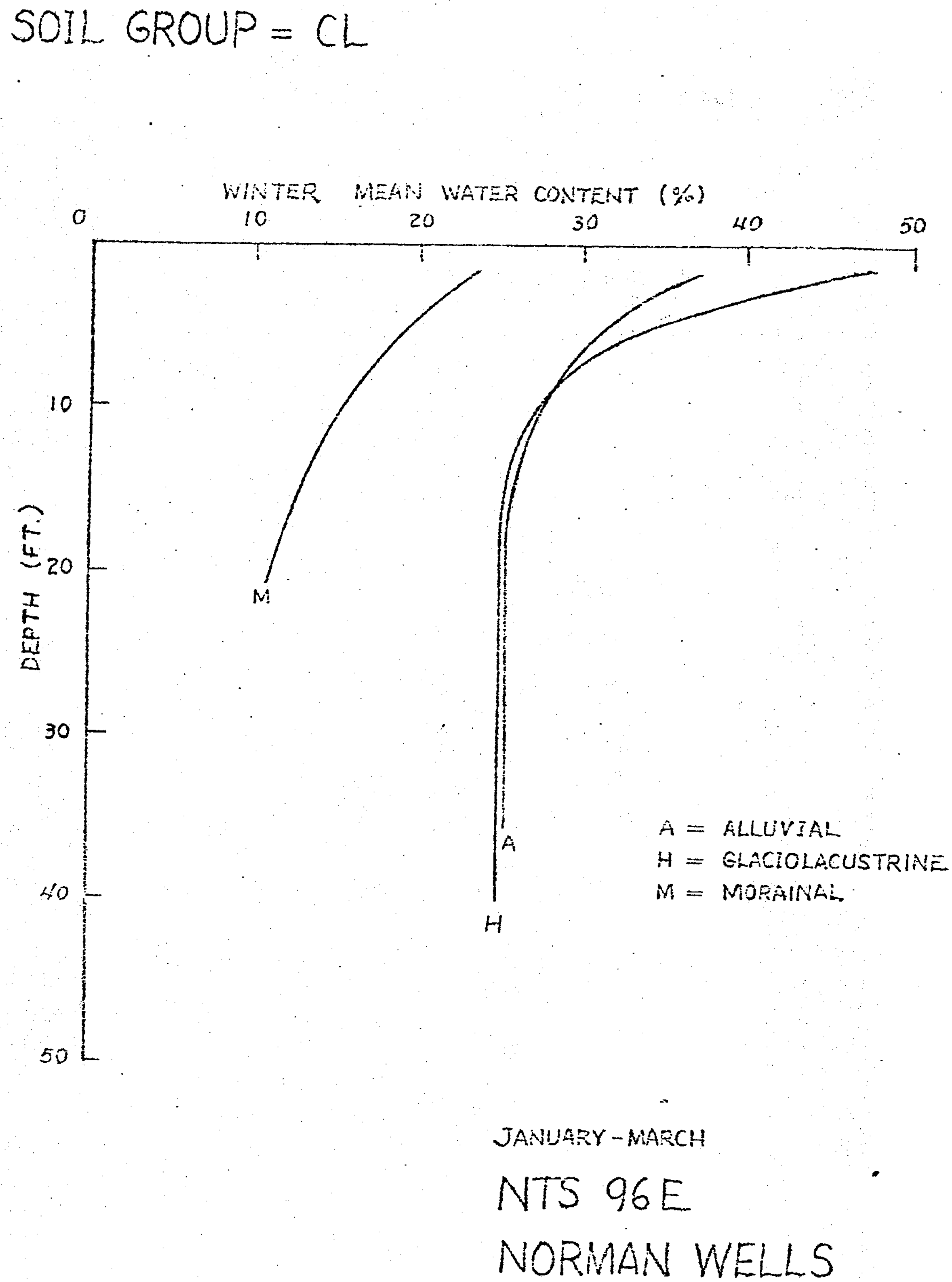


Figure 5.11 Winter mean water content vs. depth for the CL soils in Norman Wells

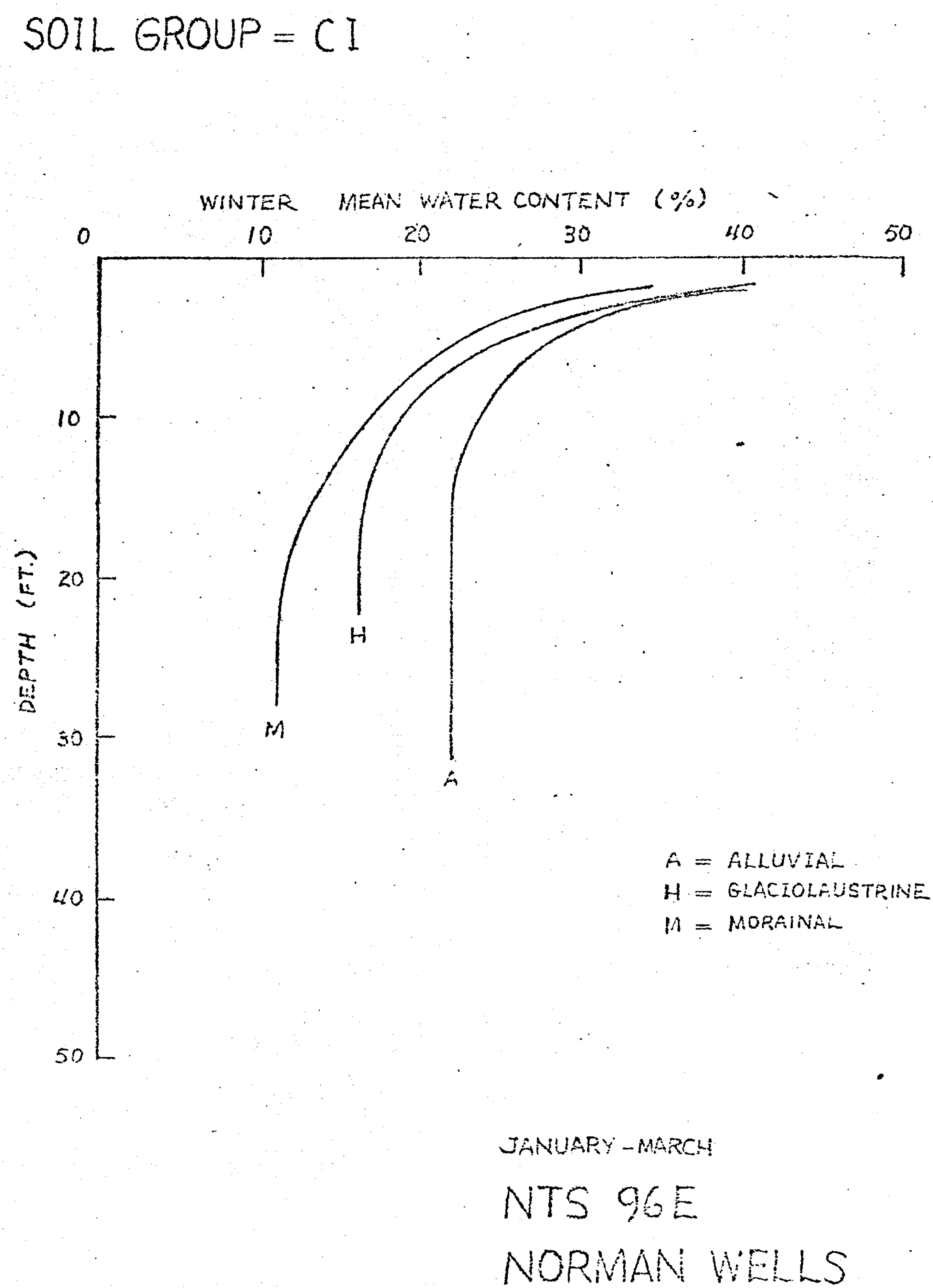


Figure 5.12 Winter mean water content vs. depth for the CI soils in Norman Wells

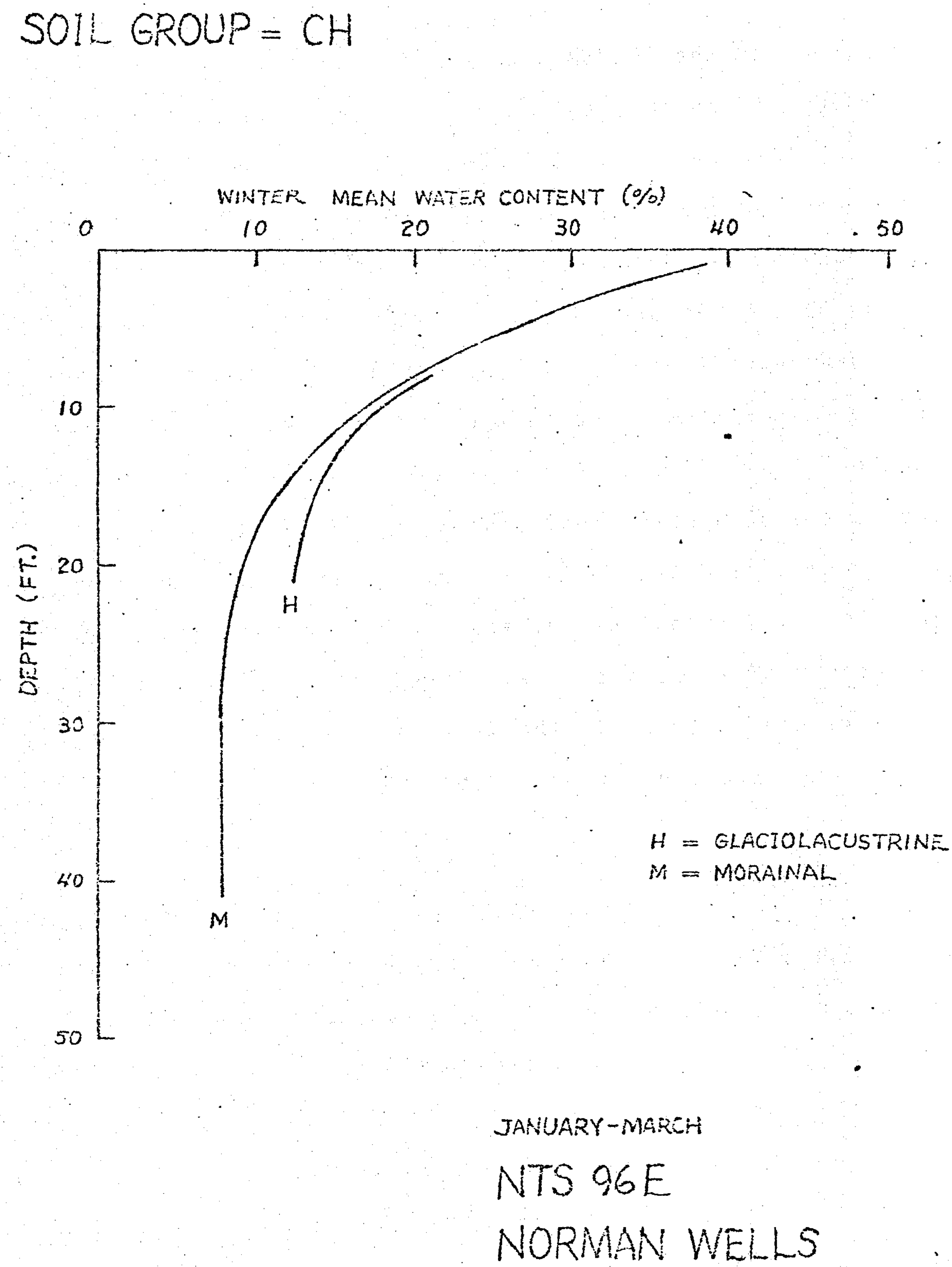


Figure 5.13 Winter mean water content vs. depth for the CH soils in Norman Wells

Red River and the GC, SM and SC soils in Aklavik are constant regardless of depth (Table 5.4). However, some of the GC, SM and SC soils (Figures 5.14, 5.15 and 5.16), the GM soils in Fort McPherson and the GP and GM soils in Aklavik show a decrease of water content as depth increases. The winter mean water contents of the SW, SP, SM and SC soils in the Travaillant Lake are found to increase with depth. In the northern region, the variation of the winter mean water content of gravels from one map area to another is small; a greater variation is observed in sands, mostly due to the high water contents of the sands in Travaillant Lake. In general, sands have higher winter mean water contents than gravels. Water contents of the coarse grained soils increase as the amount of fines increase. Irregular behaviour and high water contents are observed in the Travaillant Lake area, probably due to the widespread of organic deposits.

Fine grained soils

The winter mean water contents of the fine grained soils are higher than those of the coarse grained soils. In the upper 2 feet, the water contents of the fine grained soils are high, 25%-75% for ML soils, 25%-48% for CL soils, 30%-42% for CI soils and 41% for CH soils (Figures 5.17, 5.18, 5.19 and 5.20). The water contents of the ML, CL and CI soils decrease rapidly with increasing depth to about 10 feet, less rapidly to about 20 feet beyond which the winter mean water contents become constant. This behaviour appears to co-relate with the large amount of ground ice present in the

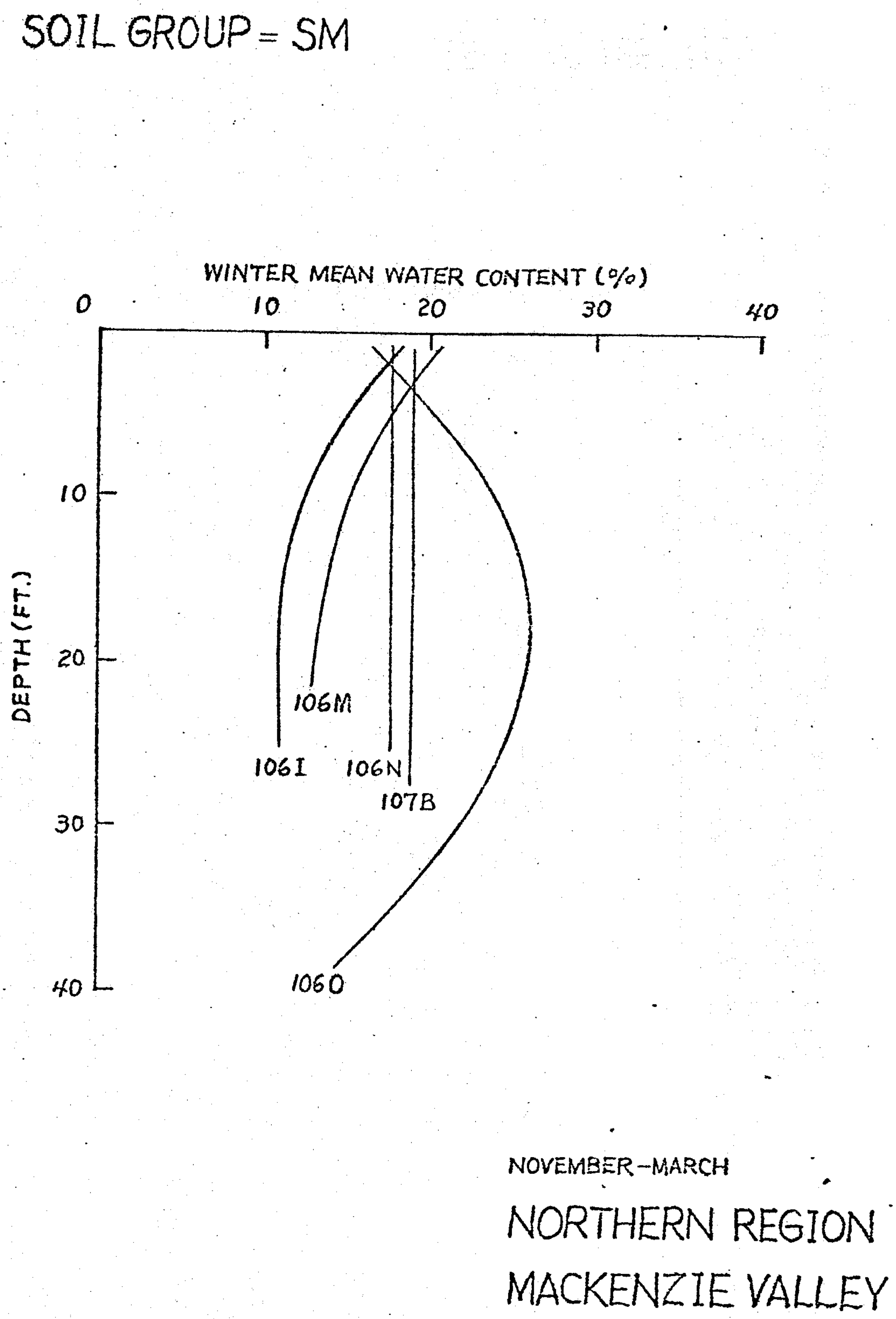


Figure 5.14 Winter mean water content vs. depth for the SM soils in the Northern Region

SOIL GROUP = SC

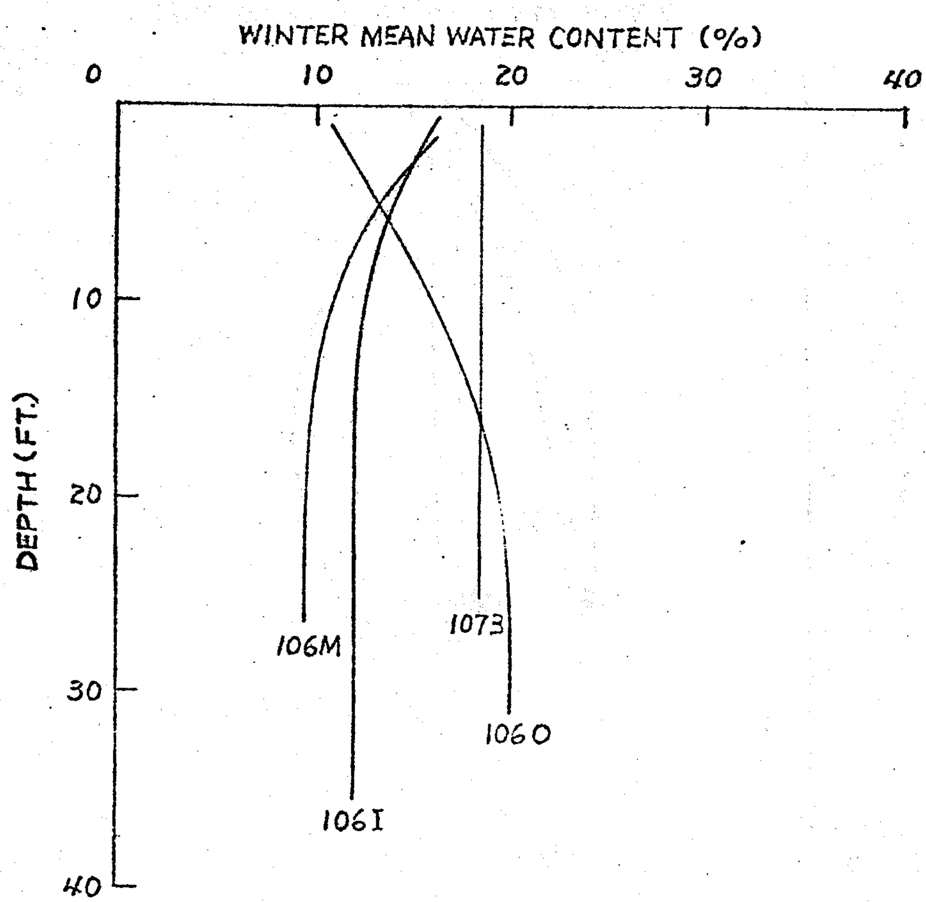


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Figure 5.15 Winter mean water content vs. depth for the SC soils in the Northern Region

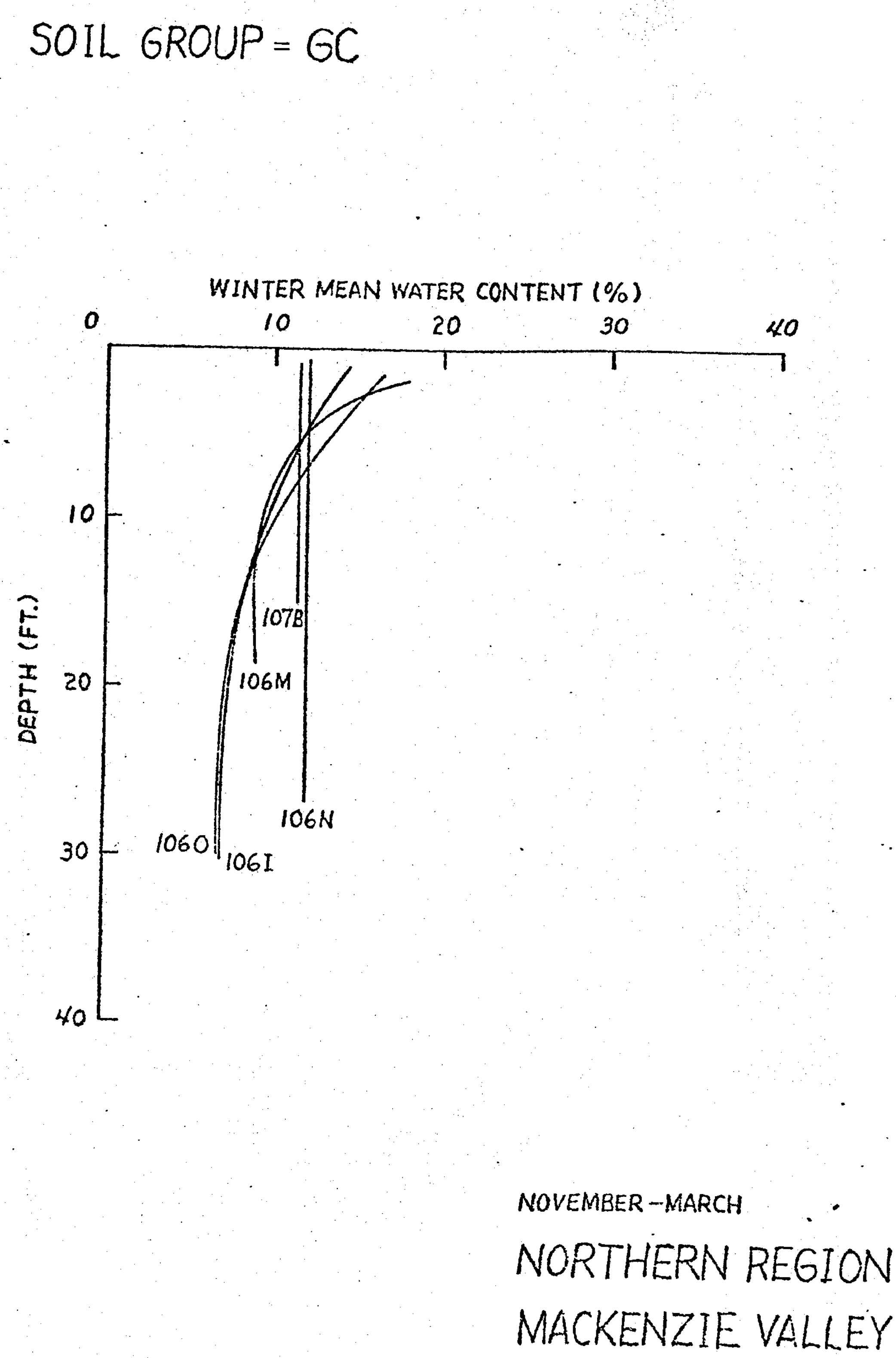


Figure 5.16 Winter mean water content vs. depth for the GC soils in the Northern Region

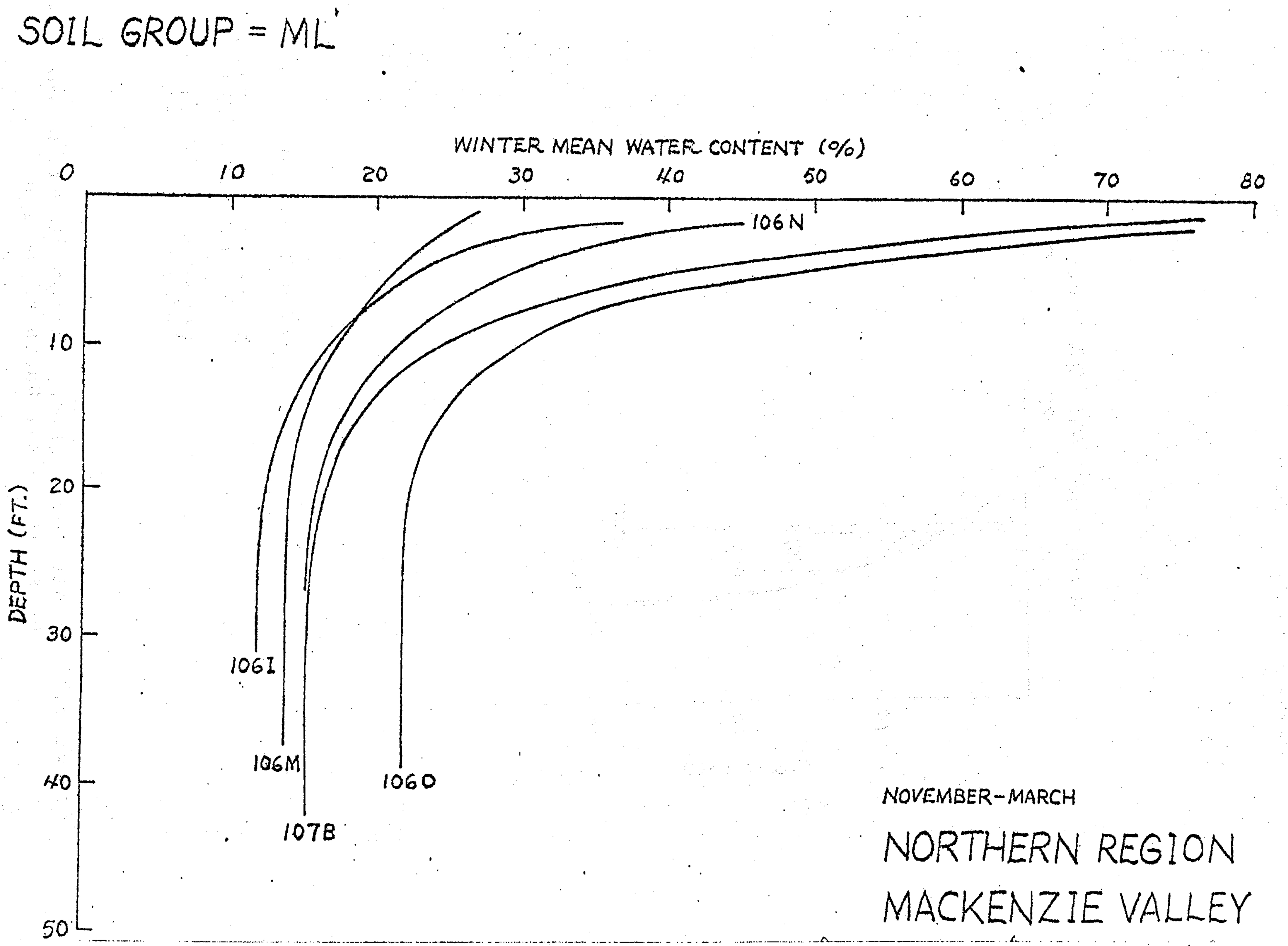
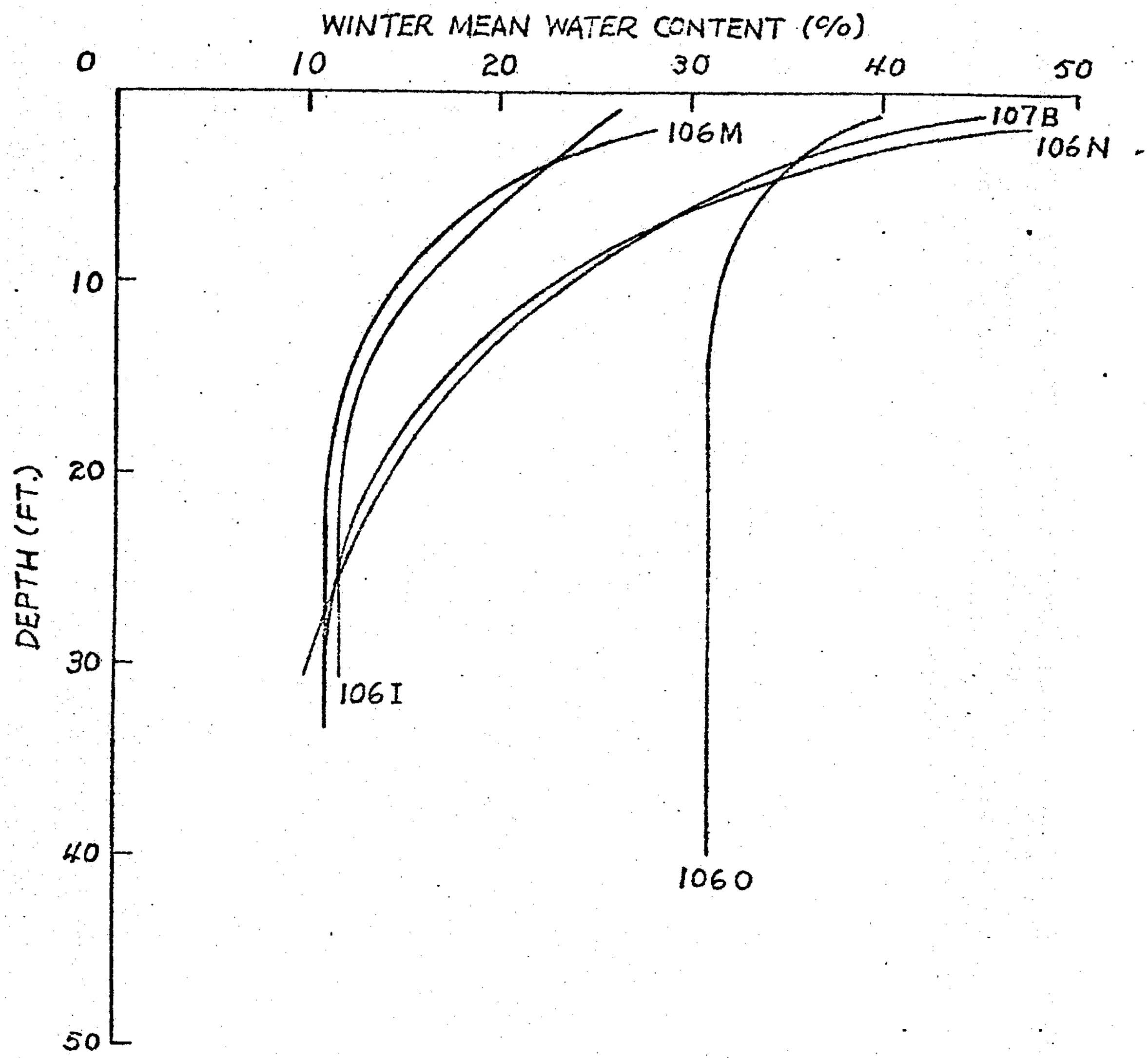


Figure 5.17 Winter mean water content vs. depth for the ML soils in the Northern Region

SOIL GROUP = CL



NOVEMBER–MARCH

NORTHERN REGION

MACKENZIE VALLEY

Figure 5.18 Winter mean water content vs. depth for the CL soils in the Northern Region

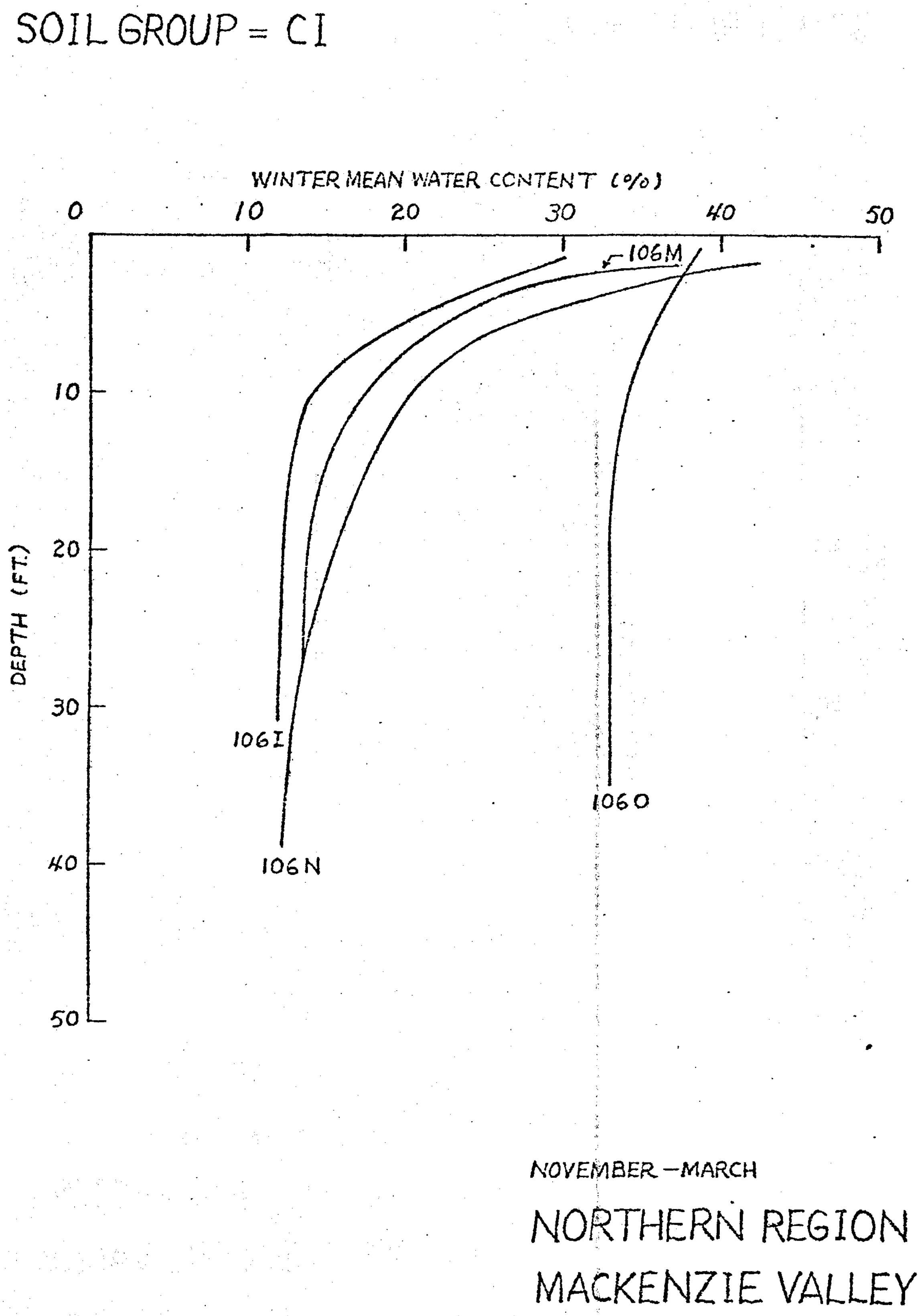


Figure 5.19 Winter mean water content vs. depth for the CI soils in the Northern Region

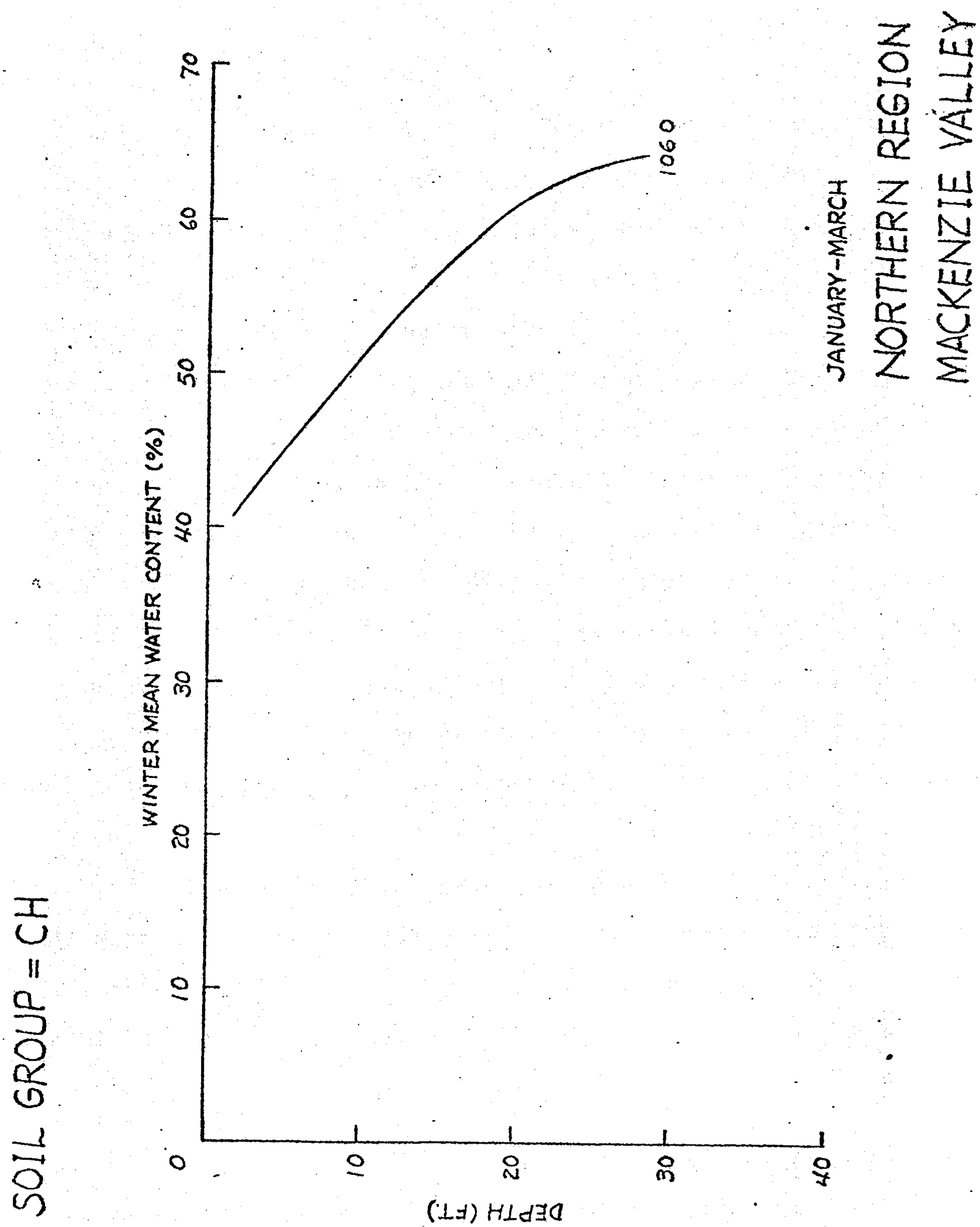


Figure 5.20 Winter mean water content vs. depth for the CH soils in the Northern Region

fine grained soils. Excluding data from the Travaillant Lake area, the winter mean water contents at depths below 20 feet vary from 12-16% for ML soils, 10-12% for CL soils and 12%-14% for CI soils. In Travaillant Lake, the winter mean water contents of the fine grained soils at depths below 20 feet are very high, 22% for ML soils, 31% for CL soils, 33% for CI soils and greater than 60% for CH soils. The winter mean water content of the CH soils in Travaillant Lake is found to increase with depth. The variation of winter mean water contents between the ML, CL and CI soils is small, except in the upper 6 feet where the ML soils have higher winter mean water contents than the CL and CI soils. With the exception of the Travaillant Lake area, the variation of the winter mean water contents of the fine grained soils from one area to another in the northern region is generally small, except in the upper 8 feet. No trend of increase or decrease of the winter mean water content from south to north is noticeable in this region. In the upper 2 feet, the winter mean water contents of the fine grained soils in the northern region seem to be higher than those in the central region, while below a depth of 20 feet, the winter mean water contents in the northern region are lower than those in the central region.

Organic Soils and Peat

The winter mean water contents of the organic soils and peat in the northern region are extremely high, with values varying between 12% and 987% for organic soils and 10% and 931% for peat.

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5.2.4 Area IV - Mackenzie Delta (NTS 107C)

The winter mean water contents of the coarse grained soils in the Mackenzie Delta are low (<20%). The winter mean water contents of the GW, GP and SM soils are constant with depth while those of the SW and SP soils increase with depth (Figure 5.21). The ML soils is the only fine grained soil recorded in this area and the winter mean water contents of the ML soils show an exponential rise towards the surface, from 27% at a depth of 20 feet to 46% near the surface. Very few data are available for organic soils and peat. The few that are available show that the winter mean water contents of the organic soils and peat probably are high, with values varying between 24% and 300%.

In the seabed offshore in the shallow water of the Mackenzie Delta, the winter mean water content of the fine grained soils is very different from that of surficial soils. Below seabed, the winter mean water contents of the fine grained soils and the SM soils are constant with depth, 29.5% for ML soils, 31% for CL soils, 31.5% for CI soils and 25% for SM soils (Figure 5.22). A study of the winter ground ice distribution in Mackenzie Delta shows that virtually all surficial soils in Mackenzie Delta are frozen in winter whereas less than half of the soils below seabed are frozen (Section 5.1.4). With less than half of the soils frozen, the winter mean water contents of the fine grained soils are constant with depth. The winter mean water contents of the ML soils below

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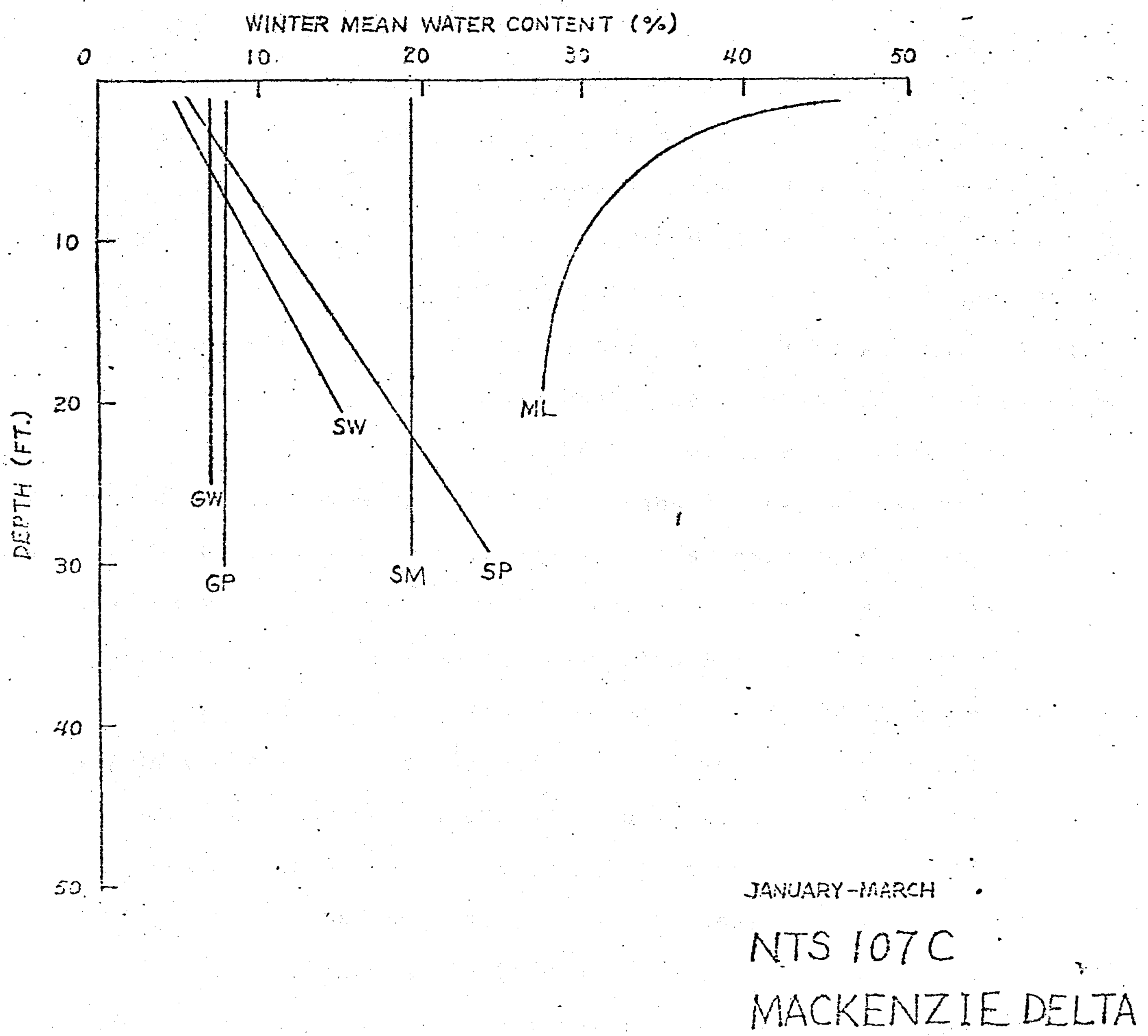

Figure 5.21 Winter mean water content vs. depth for soil groups in Mackenzie Delta

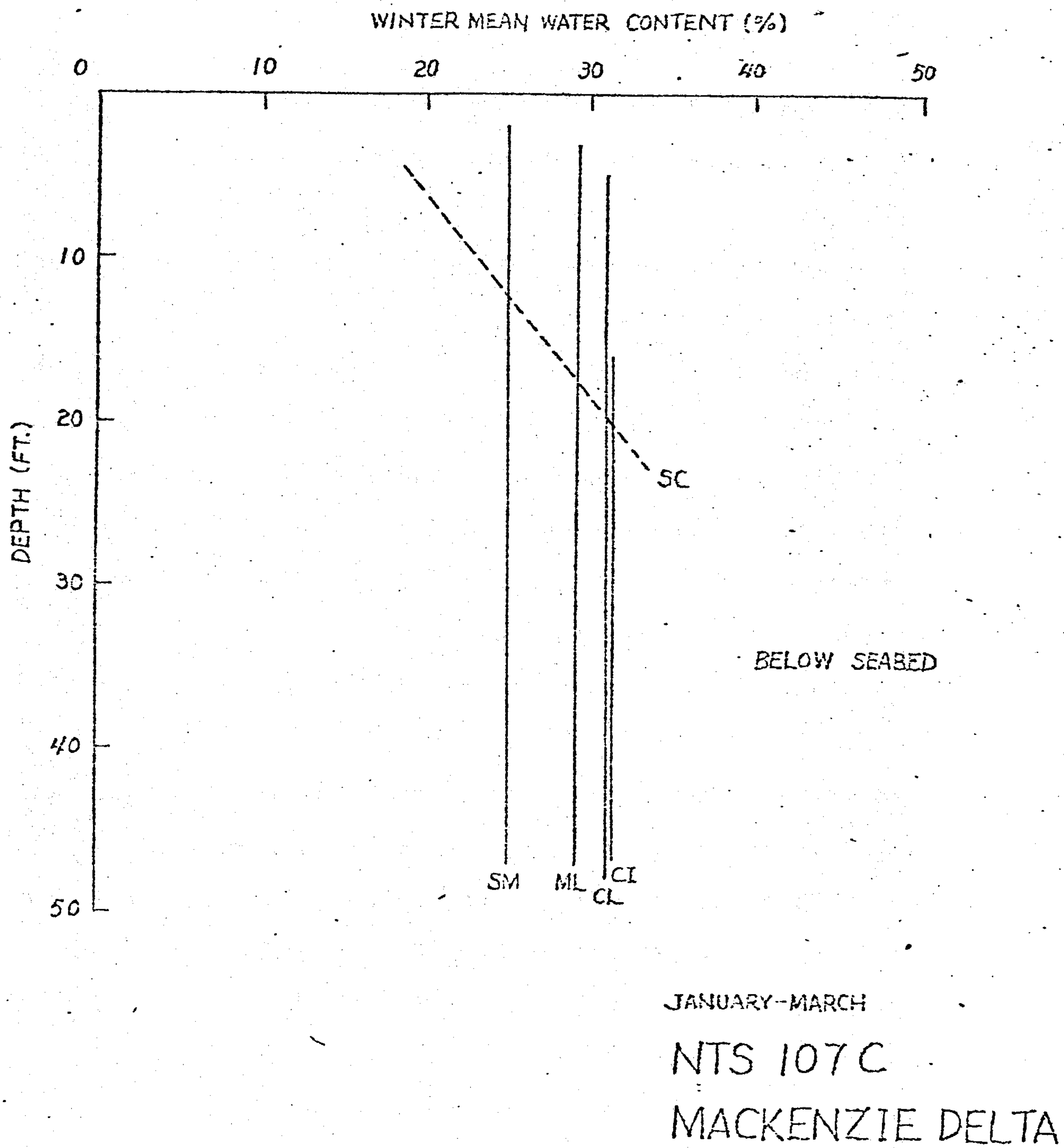

Figure 5.22 Winter mean water content vs. depth for soil groups below seabed in Mackenzie Delta

seabed are found to be lower than those of the surficial ML soils while the winter mean water content of the SM soils below seabed is higher than that of the surficial SM soils.

5.2.5 Summary and conclusions

(1) The winter mean water contents of the coarse grained soils are low.

(2) For most coarse grained soils, the winter mean water contents are constant with depth.

(3) The winter mean water contents of the coarse grained soils increase as the amount of fines increases; sands are found to have higher winter mean water contents than gravels.

(4) With a considerable amount of fines, the winter mean water content curves of some coarse grained soils show an exponential rise towards the surface.

(5) The winter mean water contents of the fine grained soils are higher than those of the coarse grained soils.

(6) The winter mean water content curves of the fine grained soils show an exponential rise towards the surface. At depths below about 20 feet, the winter mean water contents of the fine grained soils are relatively constant with depth. The exceptions are the CI soils in the southern region and the CH soils in Travaillant Lake; in these cases, the winter mean water contents are found to increase with depth.

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(7) The winter mean water contents of the organic soils and peat are extremely high.

(8) The variation of the winter mean water contents of the coarse grained soils from one NTS area to another in a region is small. However, a trend of increase of the winter mean water content from south to north is apparent.

(9) The winter mean water contents of the fine grained soils in the central region are generally higher than those in the southern region, and the winter mean water contents in the northern region seem to be higher than those in the central region in the upper 2 feet but lower at depths below 20 feet.

(10) For the fine grained soils in Norman Wells, alluvial soils always show greater winter mean water content values for a given depth as compared to glaciolacustrine soils. Glaciolacustrine soils always have higher winter mean water contents than morainal soils.

(11) Irregular behaviour and high values of winter mean water contents are observed in the soils in Travaillant Lake, probably due to the widespread of organic deposits in that area.

(12) There appears to be some correlation between the winter mean water content and ground ice distribution of the fine grained soils. When most of the fine grained soils are frozen, the winter mean water content curves show an exponential rise towards the surface. Whereas, with less than half of the fine grained soils frozen, the winter mean water contents increase with depth.

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5.3 Mean Ice Content

Relatively few ice content data are available in the Mackenzie Valley. The few that are available show that the winter mean ice content varies substantially at various depth. Particularly noteworthy is that in many cases the data show a high degree of scatter. The mean values of the winter ice content at various depth of some soil groups in some NTS areas are shown in Appendix VI with their ranges and standard deviations. Table 5.5 summarizes the winter mean ice contents of some soils groups in some NTS areas. Due to the lack of data, these mean values should not be taken as the true mean, but as a guideline to estimate the winter ice content. From Table 5.5, it is reasonable to conclude that the fine grained soils have higher winter mean ice contents than the coarse grained soils and the organic soils have higher mean ice content than the fine grained soils.

An attempt is made to plot the winter mean ice content against depth for the fine grained soils in Norman Wells (Figure 5.23). The winter mean ice content curves show a limiting value at depth greater than 30 feet. Above this depth, the curves show an exponential rise in the winter mean ice content towards the surface, while beyond this depth, the winter mean ice contents are relatively constant. These curves are similar to the winter mean water content curves of the fine grained soils. Unfortunately, the lack of data

NTS AREAS	WINTER MEAN ICE CONTENT (%)										
	SOIL GROUP										
	GM	GC	SP	SM	ML	CL	CI	CH	OL	OH	Pt
950						5.5					
96C				11.8	20.5	19.8	18.7	19.9	48.6	33.4	34.7
96E	13.9	18.4	6.2	11.8	15.5	22.4	17.9	15.5	30.8	48.5	41.6
106H					29.7	27.3	32.5			50.7	48.5
106I				12.5	15.8	21.2	22.2		21.3		36.3
106N							45.5				
1060					22.3	25.5			18.1		19.0
107B					17.7	18.0			25.0		19.0

Table 5.5 The winter mean ice contents of some soil groups in some NTS areas.

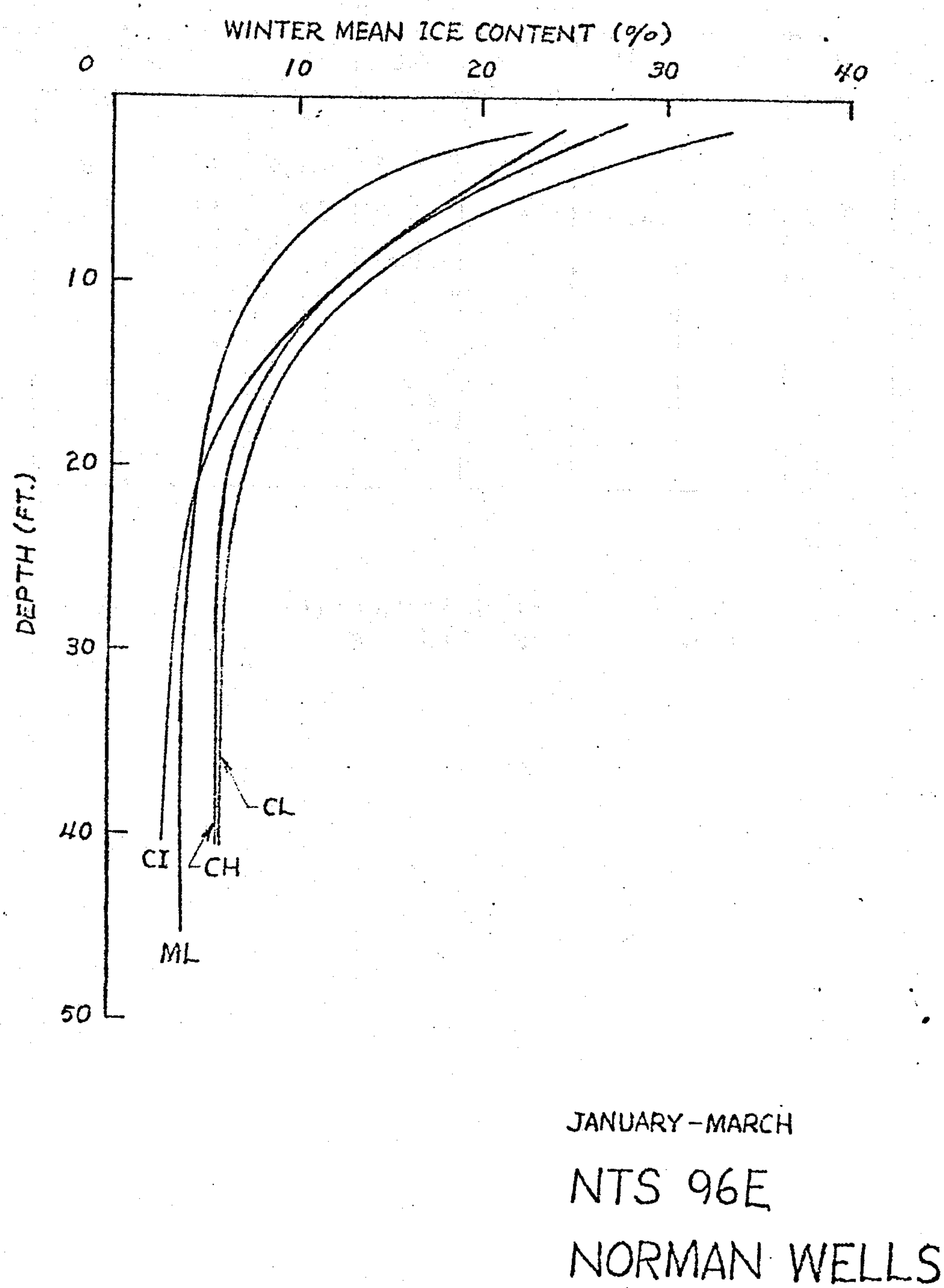

Figure 5.23 Winter mean ice content vs. depth for fine grained soil groups in Norman Wells

does not permit any further analysis of the winter mean ice content and depth relationship. However, limited data (Appendix VI) indicate that the winter mean ice content appears to be higher near the surface than at a greater depth.

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6. Conclusions

(1) In general, for the coarse grained soils, fine grained soils, organic soils, and peat, the amount of frozen soils and the amount of soils containing visible ice increase from south to north in the Mackenzie Valley, and then decrease dramatically offshore in the seabed of Beaufort Sea.

(2) For the gravels and sands, the amount of visible ice increases as the amount of fines increases.

(3) Frozen soils and visible ice are encountered more often in the organic soils and peat than in the fine grained soils; and more often in the fine grained soils than in the coarse grained soils.

(4) The winter mean water contents of the coarse grained soils are low, but increase as the amount of fines increases.

(5) For most coarse grained soils, the winter mean water contents are constant with depth. However, with a considerable amount of fines, the winter mean water content curves of some coarse grained soils show an exponential rise towards the surface.

(6) The winter mean water contents of the fine grained soils are higher than those of the coarse grained soils.

(7) The winter mean water content curves of the fine grained soils show an exponential rise towards the surface, while at depth below about 20 feet, the winter mean water contents of the fine grained soils are relatively constant with depth.

...69

(8) The winter mean water contents of the organic soils and the peat are extremely high.

(9) There appears to be some correlation between the winter mean water content and ground ice distribution of the fine grained soils. When most of the fine grained soils are frozen, the winter mean water content curves shown an exponential rise towards the surface. Whereas, with less than half of the fine grained soils frozen, the winter mean water contents increase with depth.

(10) The fine grained soils have higher winter mean ice contents than the coarse grained soils, and the organic soils have higher mean ice content than the fine grained soils.

(11) The winter mean ice content appears to be higher near the surface than at a greater depth.

8. References

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Pihlainen, J.A. and G.H. Johnston
1963: Guide to a field description of permafrost for engineering purposes; NRC of Can. Tech. Memo. 79, 24 p.

Proudfoot, D.A. and Lawrence, D.E.
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APPENDIX 1

* SOURCES OF INFORMATION *

Consultant/Agency	Area of Geotechnical Expertise	Purpose	Year of Publication	Approx. No. of Holes
Dept of Public Works	Ft.Simpson to Mackenzie Crossing (Miles 295 - 343.6)	Mackenzie Hwy Geotech Inves.	1972, 1973	346
Acres (for DPW)	Mackenzie Crossing to Mt. Gaudet (Miles 346 - 450)	——— " ———	1973	1040
Underwood, McClellan (for DPW)	Mt. Gaudet to Big Smith Creek (Miles 450 - 545)	——— " ———	1973	1015
Hardy & Associates (for DPW)	Big Smith Creek to Bosworth Cr. (Miles 545 - 632)	——— " ———	1973	1041
Brooker & Associates (for DPW)	Bosworth Creek to Hare Indian R. (Miles 632 - 724)	——— " ———	1973	1292
Pemcan "72" (for Dept of Ind.Aff. & North Dev.)	Ft. Simpson to Ft. Good Hope (up to 10 miles away from prop. highway alignment)	Granular Resources Inventory	1973	657
Ripley Klohn & Leonoff (for D.I.A.N.D.)	Tuktoyaktuk Penn.,Richards Island Mackenzie River delta, south to Ft. McPherson & Arctic Red River	——— " ———	1973	360
Geological Survey of Canada	Norman Wells Area	Permafrost regression study	1973	17
Ripley Klohn & Leonoff (for Cdn Bechtel)('69)	Mackenzie Valley Pipeline Route (Prudhoe Bay to Alta border) (both routes)	Pipeline investigation (terrain conditions)	1970	211

Consultant/Agency	Area of Geotechnical Expertise	Purpose	Year of Publication	Approx. No. of Holes
Ripley Klohn & Leonoff (for Mackenzie Valley Pipeline Research Ltd.) ('70)	——— " ———	——— " ———	1971	198
Northwest Project Study Group (done by Hardy & Assoc.)	Canol Road, Norman Wells	Permafrost regression study	1971, 1972	77
Gas Arctic System Study Group	Northern Canada Power Comm. route Inuvik to Parsons Lake, N.W.T.	Terrain & permafrost investigation. Holes drilled for a power line.	1972	129
D.P.W.	Dempster Hwy Mile 330 - 365	Soil survey	1972	390
D.P.W.	Mackenzie Hwy 931 - 964	——— " ———	1972	350
Blackwell & Watson (for Mackenzie Valley Pipeline Research)	Hanna River to Tuktoyaktuk	Regional reconnaissance-level subsurface info for a warm-oil pipeline feasibility study.	1972	164
Alberta Gas Trunk Lines (by Templeton Engineering)	Norman Wells, Ft. Simpson, N.W.T.	Permafrost regression	1970	42

DATA BANK UP-DATE 1975

Consultant/Agency	Area of Geotechnical Expertise	Purpose	Year of Publication	Approx. No. of Holes
D.P.W.	Fort Good Hope to Dempster and Mackenzie Hwy Junction (925 - 936)	Mackenzie Highway Geotechnical Investigation	1975	≃ 3233
G.S.C. (Kurfurst & Heginbottom)	Various sites	Ground Ice Variability	1975	80
CAGSL by NESCL & Hardy	Fort Simpson	Frost effects	1975	38
CAGSL by NESCL & Hardy	Major River crossings along pipe line route	Geotechnical		27
Gulf	Parsons Lake	Granular Materials	1975	282
D.P.W.	Major River Crossings Mackenzie Highway Mile 725 - 936	Geotechnical	1975	73
D.P.W.	Mackenzie Highway Mile 902 - 936	Geotechnical	1975	318
CAGSL(by NESCL)	Travaillant Lake	Geotech for route and compressor sites	1975	50
CAGSL by NESCL & Hardy	Mackenzie Delta	Geotech crossing Delta alteration	1975	109
Sunoco (for Arctic Geotechnical Group)	Beaufort Sea	Geotechnical	1975	124
CAGSL (by NESCL)		Frost Effects	1975	≃100

APPENDIX II

MACKENZIE VALLEY GEOTECHNICAL DATA BANK

The Mackenzie Valley Geotechnical Data Bank is output on a Computer Output Microfilm (COM) unit. The basic unit of information is one bore hole report per micro-fiche frame (page). There is a maximum of 70 frames of information contained on one 6" by 4" micro-fiche (at 24 times reduction). Micro-fiche output permits indexing to a particular group of reports by sorted NTS map sheet number and UTM coordinate references which appear in large print at the top of each micro-fiche.

The first line of large characters at the top of the micro-fiche consist of a) a three digit sequence number (it must be noted that due to production problems micro-fiche numbers 2-3 are not included), b) the micro-fiche title "MACKENZIE VALLEY DATA BANK" and c) a six digit UTM easting. The second line of titling consists of a) a NTS map sheet number indicating which 1:250,000 map sheet the information is from, b)"FICHE NO." and a two digit number indicating the sequence within the set of micro-fiche from a particular NTS map area, c) "ZONE" and a two digit UTM zone number of the bore holes contained on the micro-fiche and d) a seven digit UTM northing.

The bore hole records are sorted in such a way that within each NTS map sheet area the records are arranged in order of ascending UTM zone, decending UTM northing, ascending UTM easting and ascending DATA-NO of the bore hole record. This method of sorting orders the records as if they were starting in the upper left hand corner and ending in the lower right hand corner. The UTM eastings and northings that appear in the large characters of the micro-fiche title are the UTM co-ordinate of the first frame (upper left hand corner of the micro-fiche. Scince all the bore holes are sorted the rest of the bore holes that are recorded on the micro-fiche will be located to the south and east of the first frame. When the UTM index co-ordinates are used in conjunction with the transparent NTS overlay location maps, the bore hole reports of a particular area of interest may easily be located.

A new micro-fiche is started when ever the NTS map area changes. When this happens the "FICHE NO." is reset to 1 and incremented each time a full micro-fiche of information from the same NTS map area is completed.

The Mackenzie Valley Geotechnical Report is largely a self-explanatory document. In the Header portion of the report, where possible, the internal codes of the Data Bank have been translated into meaningful English words. The only codes remaining are those for temperature and land zone classification, both of these make reference to map areas. Also if the area around the bore hole has been burnt or cleared and the year of the disturbance is unknown a "X" is placed in the variable space. In the Horizon portion of the report, description space was limited, consequentially the raw codes were used and the numbers printed without there associated units. If the variables associated with the titles are blank this indicates that the value was not recorded. The exception being the "GRAIN SIZE" group. This group is made up of "GR" (gravel, "SN" (sand), "SL" (silt), CL (clay) and "OR" (organic content). If a "-1" appears under the column heading this indicates that no value was recorded, if the variable is blank it indicates that two or more values were combined and the percentage value being placed under the coarser size fraction. Also, if there is a "+" or "-" sign in the Liquid Limit column, this indicates that the liquid limit of the sample is greater or less than the moisture content.

The Following section describes the codes and associated units found in the horizon records.

Horizon Record Codes

1) DEPTH-SAMP. - feet below the ground surface.

2) SOIL TYPE - refers to the soil, rock or other material classification. The Modified Unified Classification is used for soils and mnemonics for all other material description. Where the code appears in a 5 character hyphenated form this refers to a combination of 2 soil types of the Modified Unified Classification chart). Where the code appears as a 4 character mnemonic it refers to the following additional codes.

CODE	NOUN
ARKE	Arkose
ARTE	Artificial
BRCC	Breccia
BTTM	Bottom
CBNT	Carbonate
CGLM	Conglomerate
CHRT	Chert
COAL	Coal
DLMT	Dolomite
FILL	Fill
GARB	Garbage
GPSM	Gypsum
GRWK	Greywacke
ICEE	Ice
IGRC	Igneous Rock
LIQD	Liquid
LMSN	Limestone
MARL	Marl
MDSN	Mudstone
MOSS	Moss
MRBL	Marble
QRTZ	Quartz
RBLE	Rubble
ROCK	Rock
SHLE	Shale
SLSN	Siltstone
SLTE	Slate
SMRC	Sedimentary rock
SNDS	Sandstone
TILL	Till
UNSP	Unspecified
VGTN	Vegetation
VOID	Void
WATER	Water
WOOD	Wood

3) GRAIN SIZE - the 5 elementary items that belong to this group are, GR, SN, SL, CL and OR all are expressed as percents. Also as previously noted a - 1 indicates that no value

was recorded, a blank space indicates that two or more of the individual items have been combined and the value was recorded under the coarser fraction.

4) SIZE - contains the maximum particle size in the sample recorded to the nearest tenth of an inch.

5) SAND PASSING- contains the percentage of sand passing the number 4, 10, 40, and 200 sieve. If the field is blank there was no value recorded.

6) MC - the natural moisture content expressed as a percent of the dry weight.

7) ATTERBERG - contains the moisture content, plastic limit, liquid limit, and the index of plasticity.

a) PL - the plastic limit appearing as a qualitative indication (see codes), or as a value.

CODE	INDICATOR
N	Non plastic
NS	Non to Slightly Plastic
S	Slightly plastic
SM	Slight to medium plasticity
M	Medium plasticity
MH	Medium to highly plastic
H	Highly plastic

b) LL - the liquid limit

c) IP - the index of plasticity appearing as a qualitative indicator (see codes), or as a value

CODE	INDICATOR
H	High
MH	Medium to high
M	Medium
LM	Low to medium
L	Low

8) BULK DENS - contains the natural (NTL), dry (DRY), and frozen (FZN) densities of the soil measured in lbs/ft^3.

9) PROC-COMP - this group contains the Proctor Compaction values.

a) M/D - is the maximum density measured in lbs/ft^3.

b) O/M - is the optimum moisture content expressed as a percentage.

10) SPEC GRAV - the specific gravity of the soil sample.

11) PEN RES - the penetration resistance of the soil. The value being the number of blows from a 140 lb. weight dropped from 30" per foot of penetration.

12) PERM FRST - contains the NRC classification of perma-frost contained in the sample.

CODE	PERMA-FROST
X	Material not frozen
F	Material frozen - type unkown
FX	Material partially frozen - type unknown
N	Ice not visible
NF	Ice not visible - poorly bonded
NB	Ice not visible - well bonded
NBN	Ice not visible - well bonded, no excess
NBE	Ice not visible - well bonded, excess ice
V	Visible ice
VX	Visible ice - indiv. ice crystals or inclusions
VC	Visible ice - ice coating on particles
VR	Visible ice - random or irregular orientation
VS	Visible ice - stratified or orientated ice
ICE	Ice
SPACE	Perma-frost not recorded

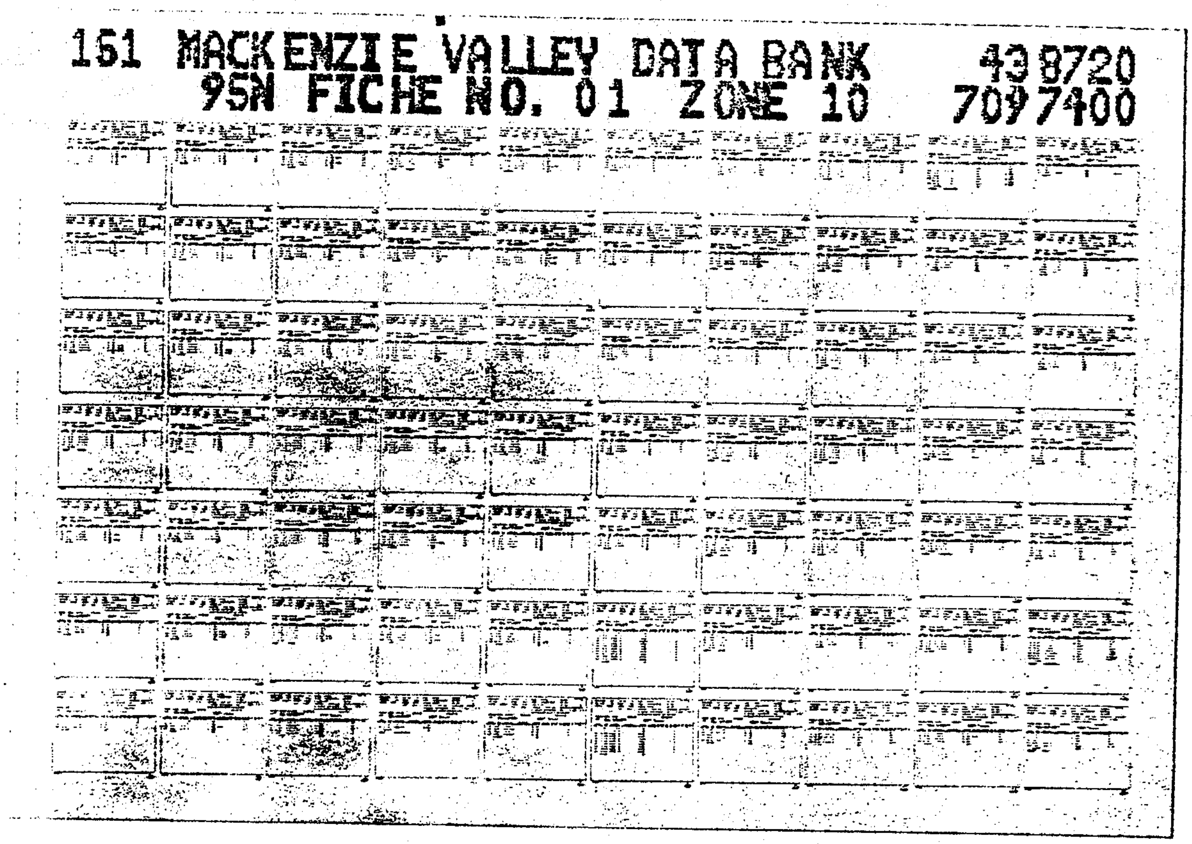
13) ICE - an estimate of the percentage of visible ice.

14) SAT - the percentage of void space occupied by water.

15) EXS MST - the excess moisture expressed as a percentage of the total volume

16) S/M - a code indicating the type of undisturbed sample taken

CODE	SAMPLE METHOD
0	No undisturbed sample taken
1	Split-spoon sample
2	Shelby Tube sample
3	Rock core or Barrel sample
4	Method unspecified (for undisturbed samples only)


161 MACKENZIE VALLEY DATA BANK 438720
95N FICHE NO. 01 ZONE 10 7097400

MICRO-FICHE

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03363	0273	21	2	0520		M		0		8	3	J	00	06

S-DP	HOR-DP	MA-B	GR	SX	SI	CL	OX	MS	N4	N10	WN	LL	PL	PFX	ICE	WX	SM
0020	0010	CI	-1	-1	-1	-1	-1				099	000	M	ICE	80		0
0040	0030	CI	-1	-1	-1	-1	-1				073	000	M	VX	60		0
0060	0050	CI	-1	-1	-1	-1	-1				026	000	M	VX	15		0
0100	0070	CI	-1	-1	-1	-1	-1				013	000	M	NBN			0
0140	0070	CI	-1	-1	-1	-1	-1				010	000	M	NBN			0
0200	0160	CI	-1	-1	-1	-1	-1				008	000	M	NF			0

DATA-NO	M/Y	MET	R	ELEV	TEXT	GN	MOPH	AN	OR	N	LZ	TZ	THW	LEVEL
03364	0273	21	2	0520		M		0		8	3	J	00	09

S-DP	HOR-DP	MA-B	GR	SX	SI	CL	OX	MS	N4	N10	WN	LL	PL	PFX	ICE	WX	SM
0020	0015	CI	-1	-1	-1	-1	-1				099	000	N	ICE	99		0
0040	0025	SM	-1	-1	-1	-1	-1				020	000	N	VX	10		0
0060	0040	SM	-1	-1	-1	-1	-1				020	000	N	NBN			0
0080	0070	SM	-1	-1	-1	-1	-1				016	000	N	VX	05		0
0100	0095	SM	-1	-1	-1	-1	-1				012	000	N	NF			0
0120	0095	SM	-1	-1	-1	-1	-1				013	000	N	NF			0
0140	0130	CI	-1	-1	-1	-1	-1				012	000	M	VX	05		0
0180	0140	SM	-1	-1	-1	-1	-1				011	000	N	NBN			0
0200	0140	SM	-1	-1	-1	-1	-1				007	000	N	NBN			0

SEMI-FORMATTED REPORT

Appendix III
The Unified Soil Classification System

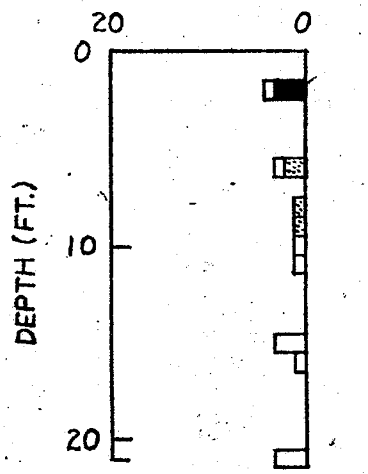
Table 8-1 The Unified Soil Classification System

Major divisions			Group symbol	Typical names	Classification criteria for coarse-grained soils	
Coarse-grained soils (more than half of material is larger than #200)	Gravels (more than half of coarse fraction is larger than #4 sieve size)	Gravels with fines (appreciable amount of fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	$C_u = D_{60}/D_{10} > 4$ $C_c = 1 < D_{30}^2/D_{10} \times D_{60} < 3$	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	Not meeting all gradation requirements for GW	
		Clean gravels (little or no fines)	GM *d* / *u*	Silty gravels, gravel-sand-silt mixtures	Atterburg limits below A line or $I_P < 4$	Above A line with $4 < I_P < 7$ are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterburg limits above A line with $I_P > 7$	
	Sands (more than half of coarse fraction is smaller than #4 sieve size)	Clean sands (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines	$C_u = D_{60}/D_{10} > 6$ $C_c = 1 < D_{30}^2/D_{10} \times D_{60} < 3$	
			SP	Poorly graded sands, gravelly sands, little or no fines	Not meeting all gradation requirements for SW	
		Sands with fines (appreciable amount of fines)	SM *d* / *u*	Silty sands, sand-silt mixtures	Atterburg limits below A line or $I_P < 4$	Limits plotting in hatched zone with $4 \leq I_P \leq 7$ are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures	Atterburg limits above A line with $I_P > 7$	
Fine-grained soils (more than half of material is smaller than #200)	Silts and clays (liquid limit < 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	1. Determine percentages of sand and gravel from grain-size curve. 2. Depending on percentages of fines (fraction smaller than 200 sieve size), coarse-grained soils are classified as follows: Less than 5% – GW, GP, SW, SP, More than 12% – GM, GC, SM, SC 5 to 12% – Borderline cases requiring dual symbols	
			CL < 30 CI 30–50	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	Silts and clays (liquid limit > 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity, organic silts		
	Highly organic soils		Pt	Peat and other highly organic soils		

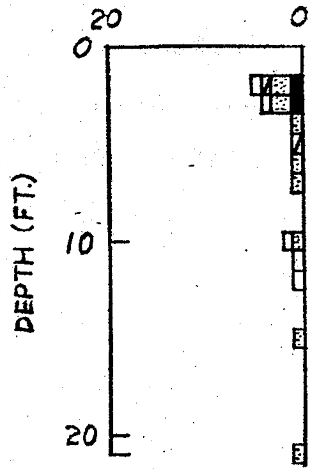
APPENDIX IV

THE CUMULATIVE FREQUENCY PLOTS OF WINTER GROUND ICE

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOIL NOT FROZEN



SOIL GROUP = SW



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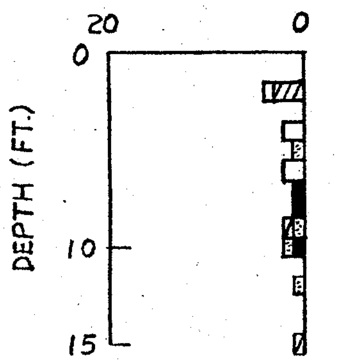

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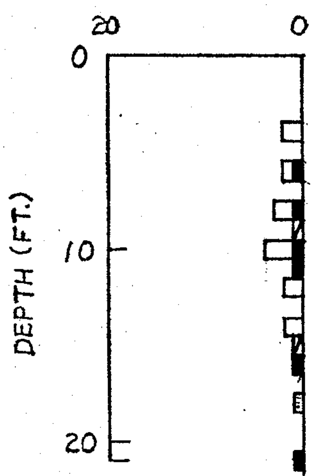
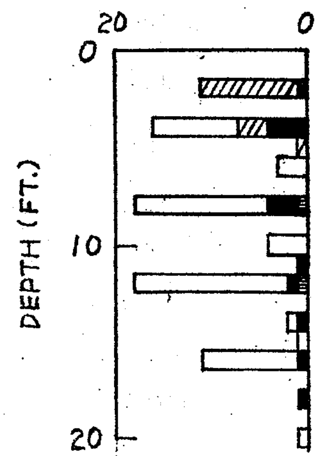
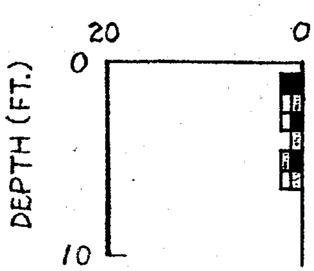


SOIL GROUP = CL



SOIL GROUP = CI



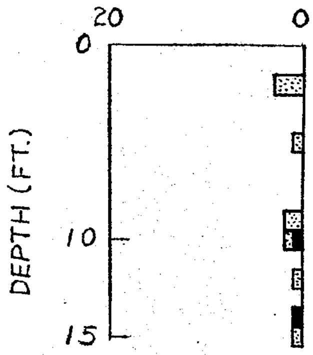
SOIL GROUP = Pt

NOVEMBER-MARCH

NTS 95 H

FORT SIMPSON

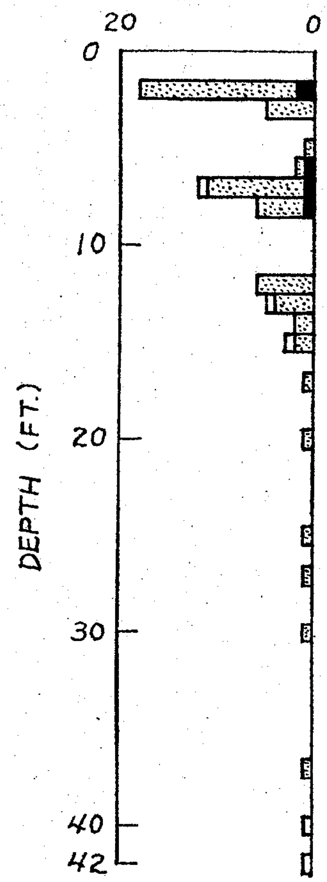
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



SOIL GROUP = GW

JANUARY-MARCH

NTS 95 J
CAMSELL BEND



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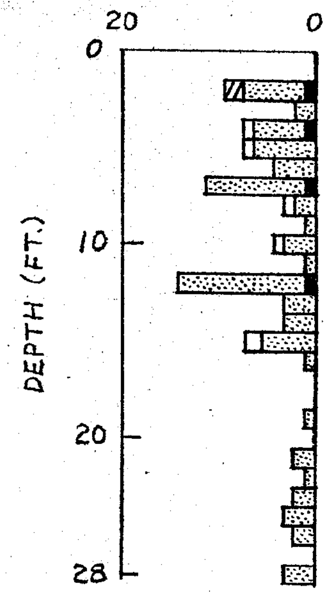
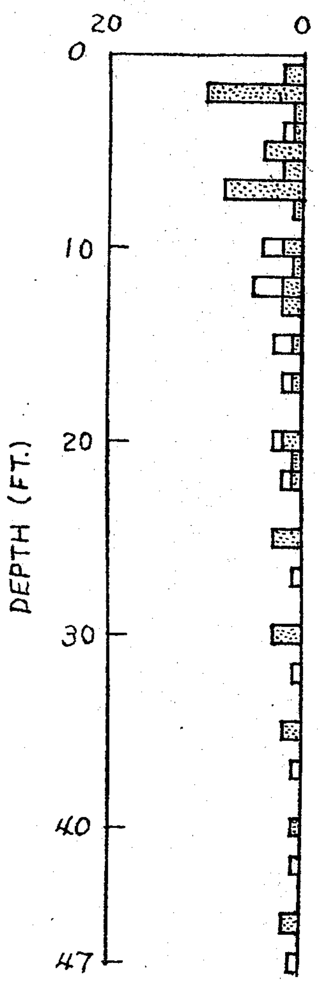
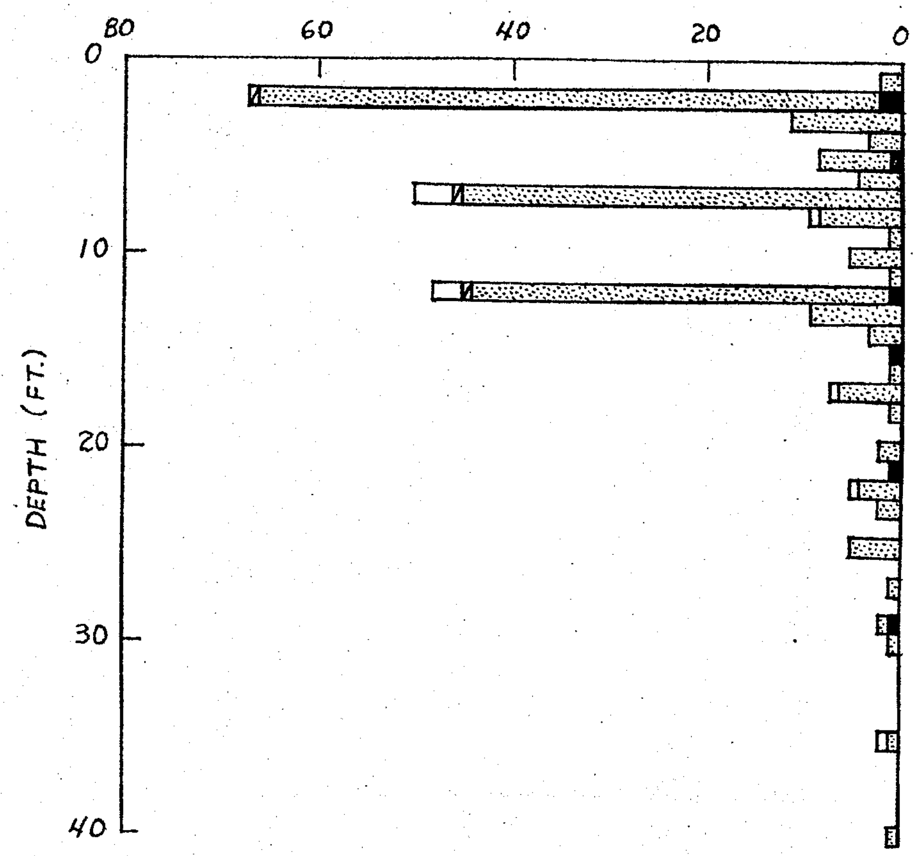


SOIL GROUP = SC



SOIL GROUP = SP



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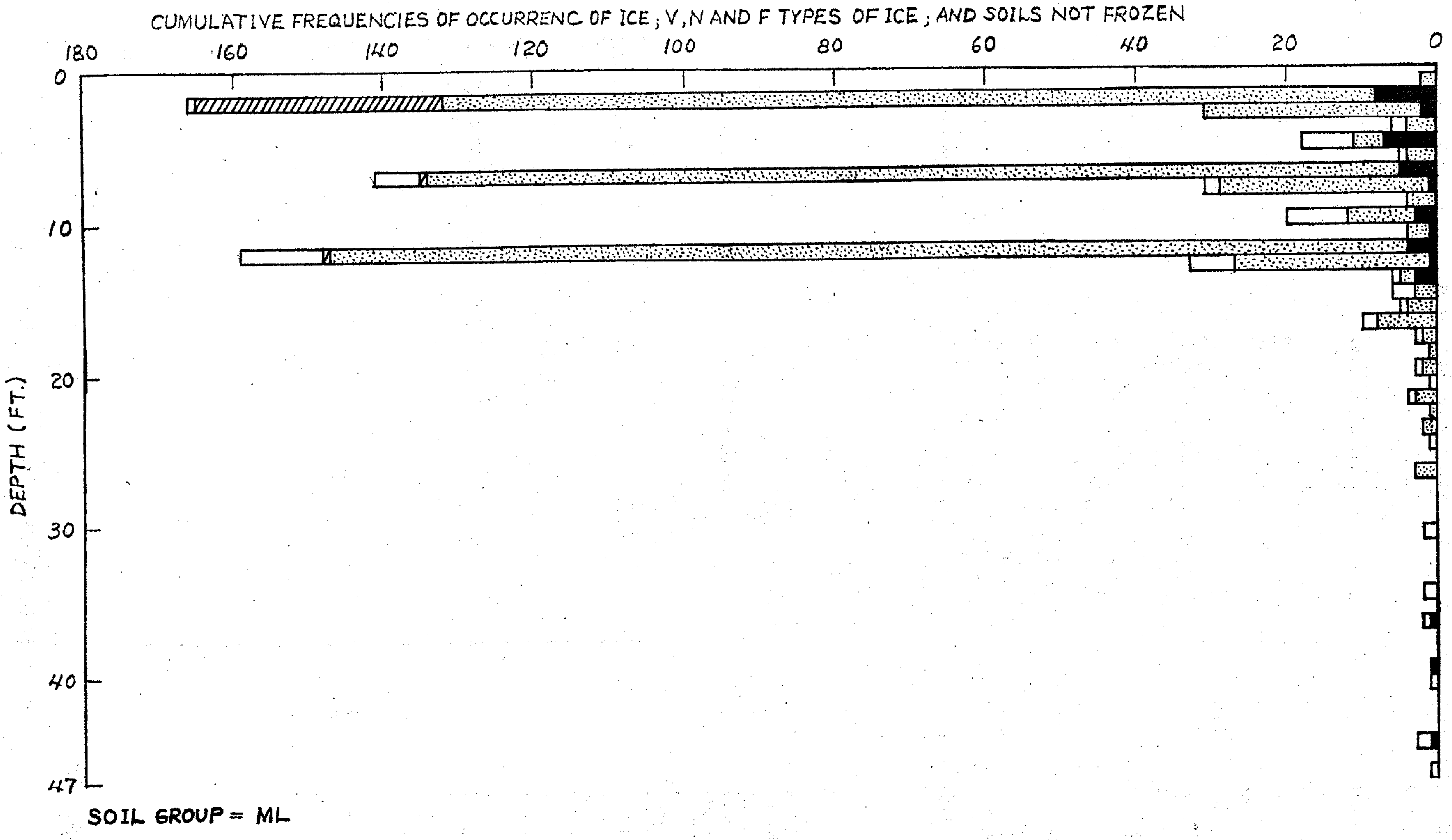
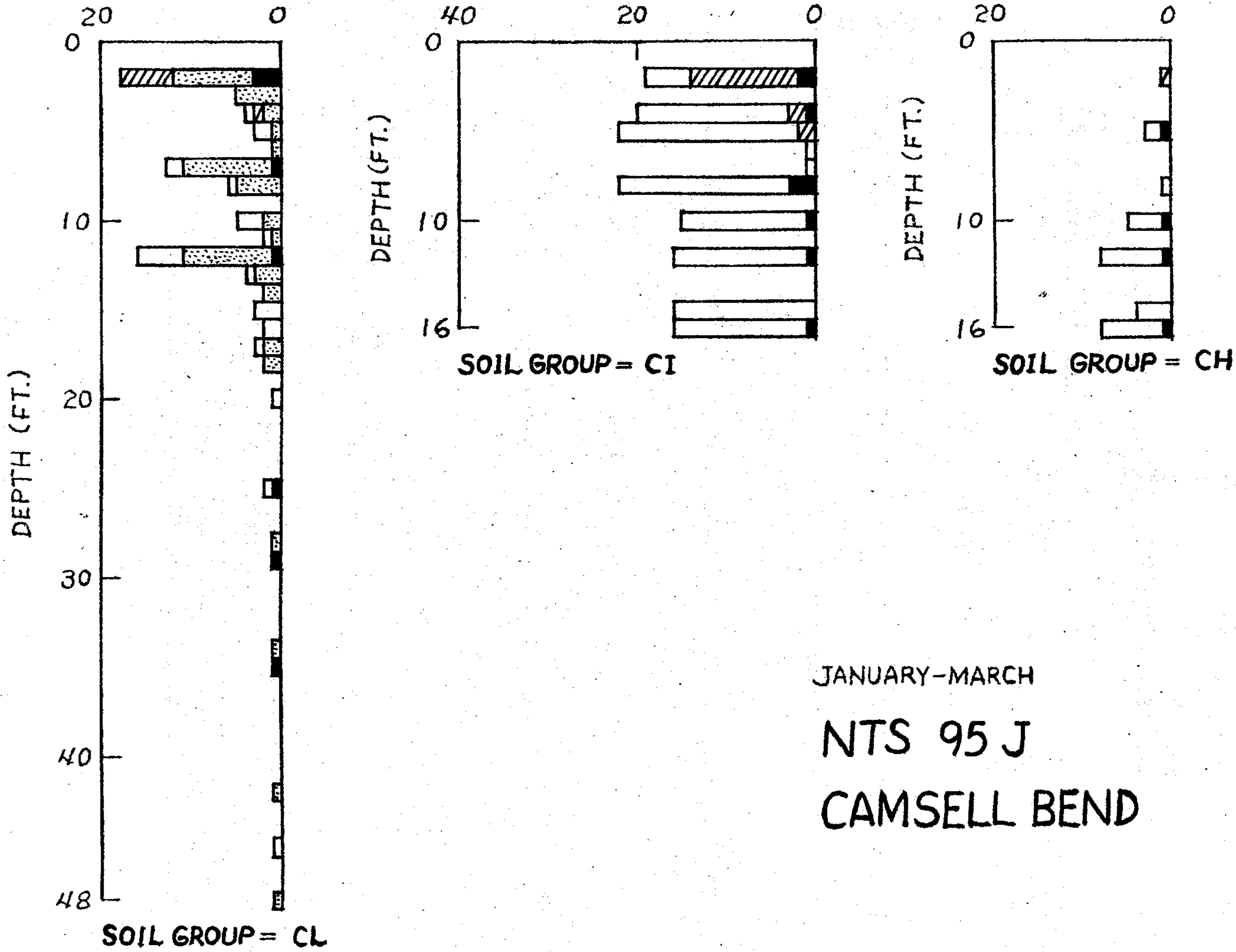


JANUARY-MARCH

NTS 95 J

CAMSELL BEND

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY-MARCH

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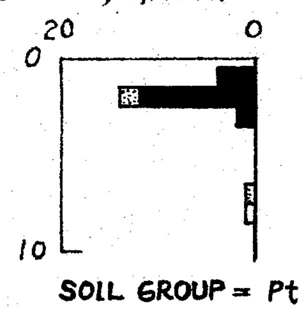
CAMSELL BEND

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V,N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY-MARCH

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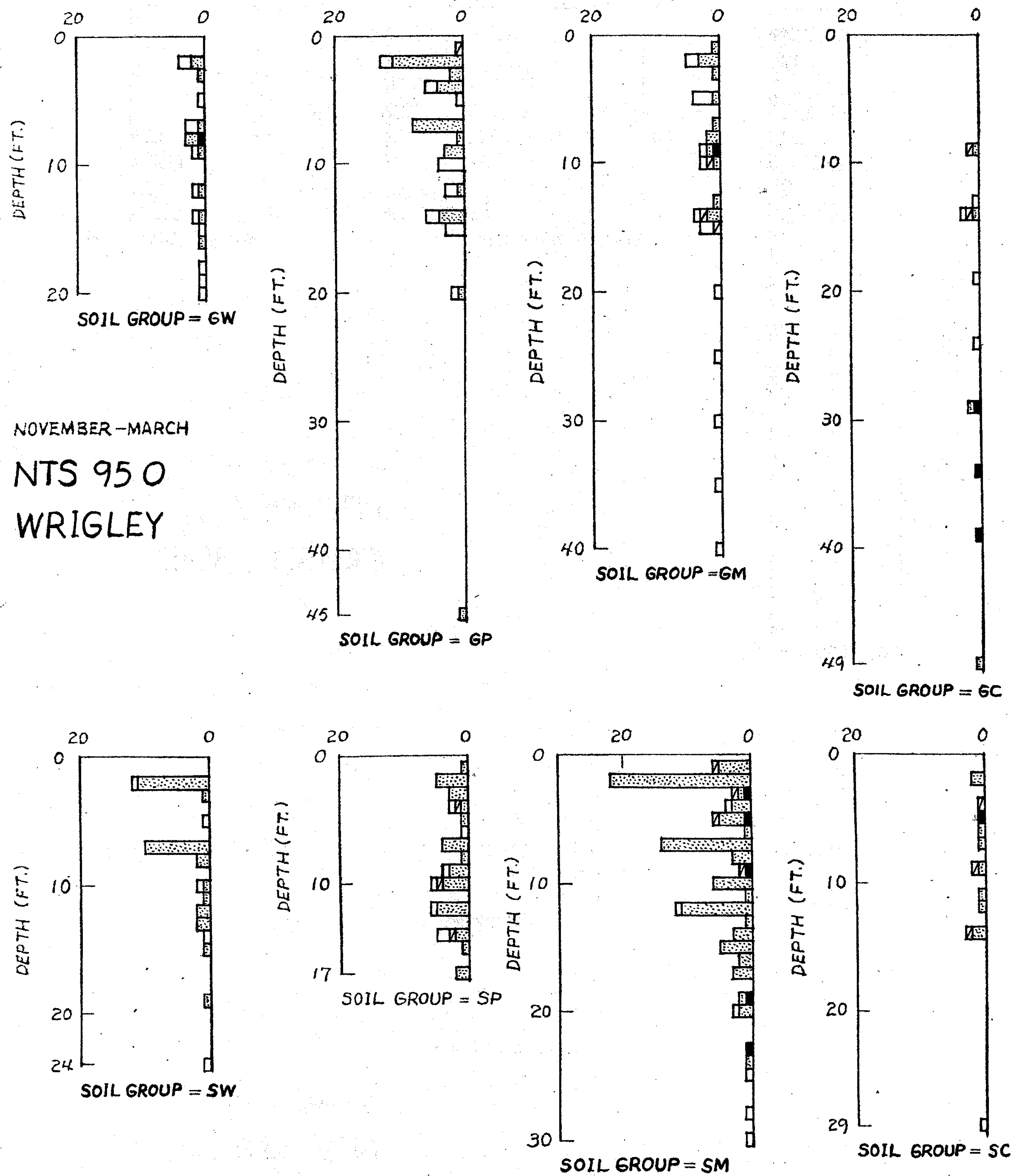
CAMSELL BEND

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



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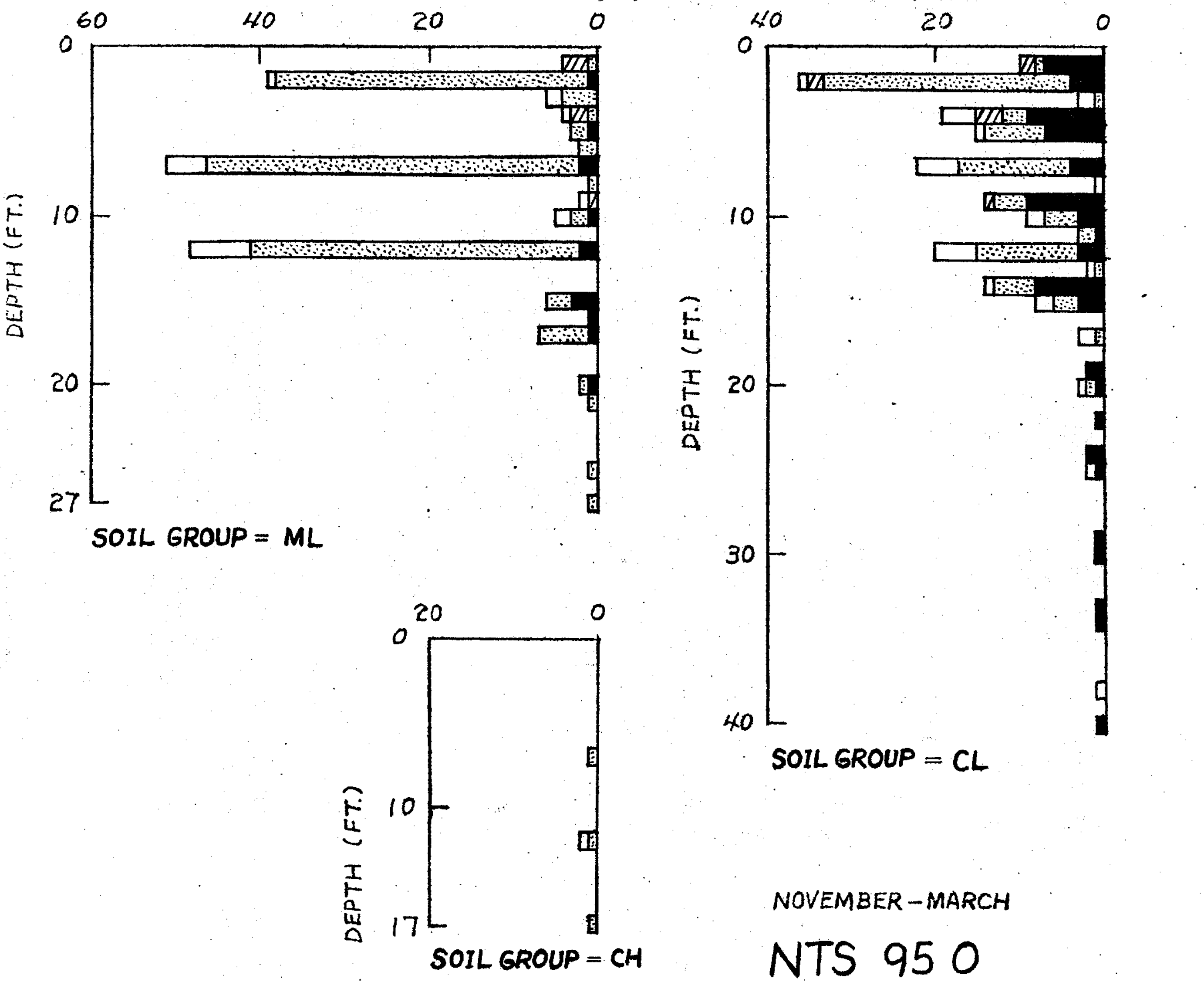
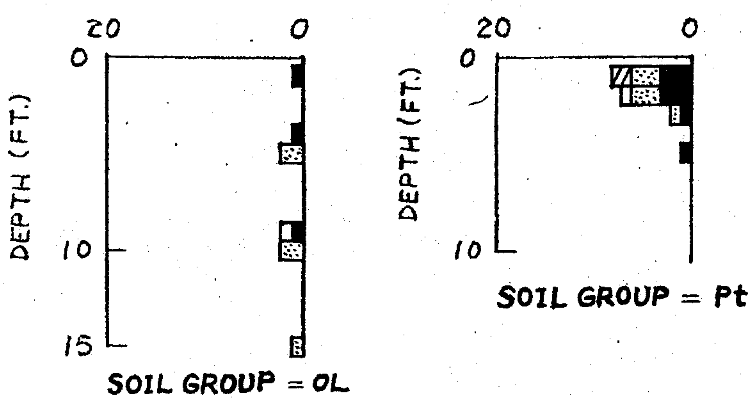


NOVEMBER–MARCH

NTS 95 O

WRIGLEY

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPE OF ICE; AND SOILS NOT FROZEN

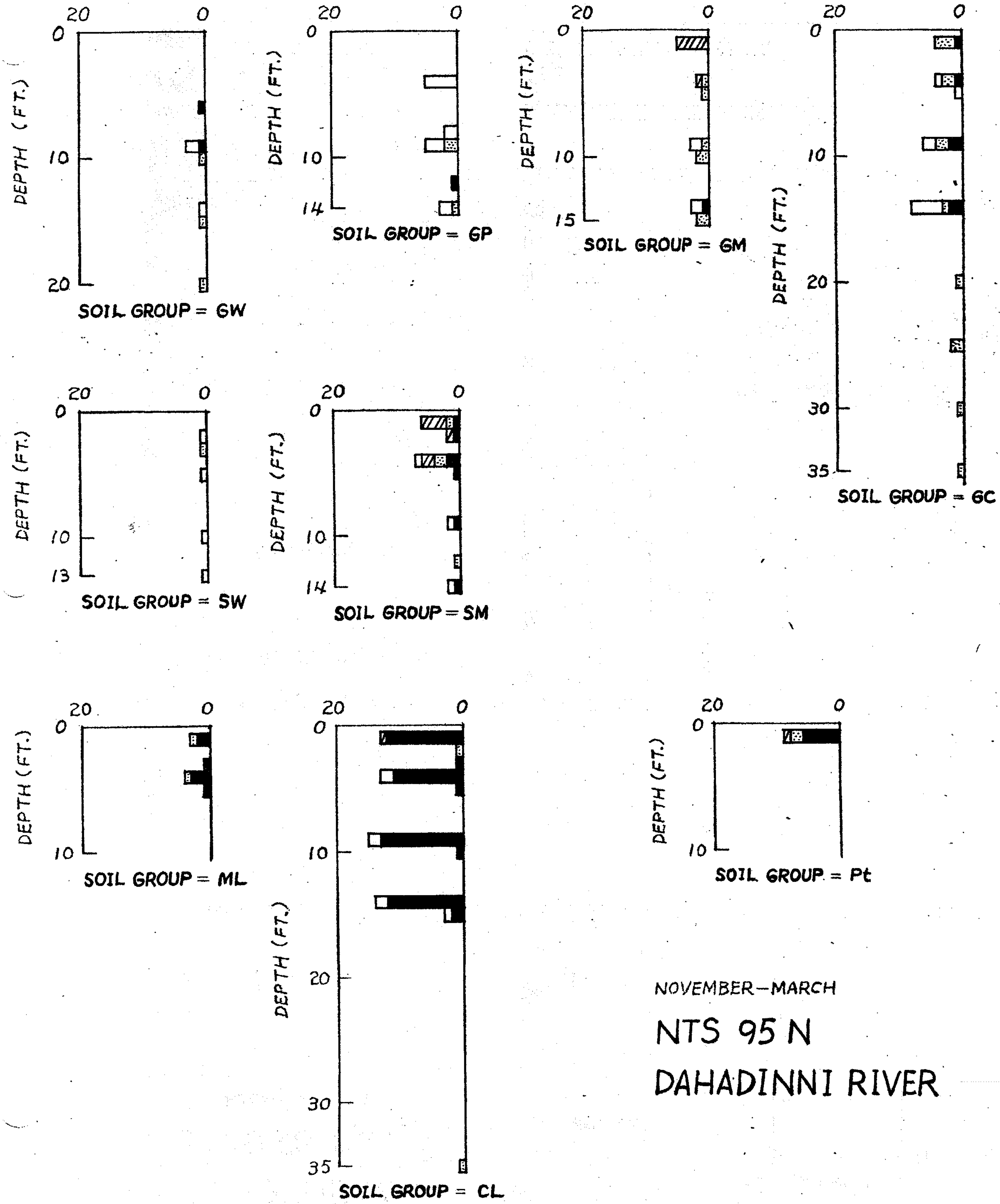


NOVEMBER–MARCH

NTS 95 O

WRIGLEY

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

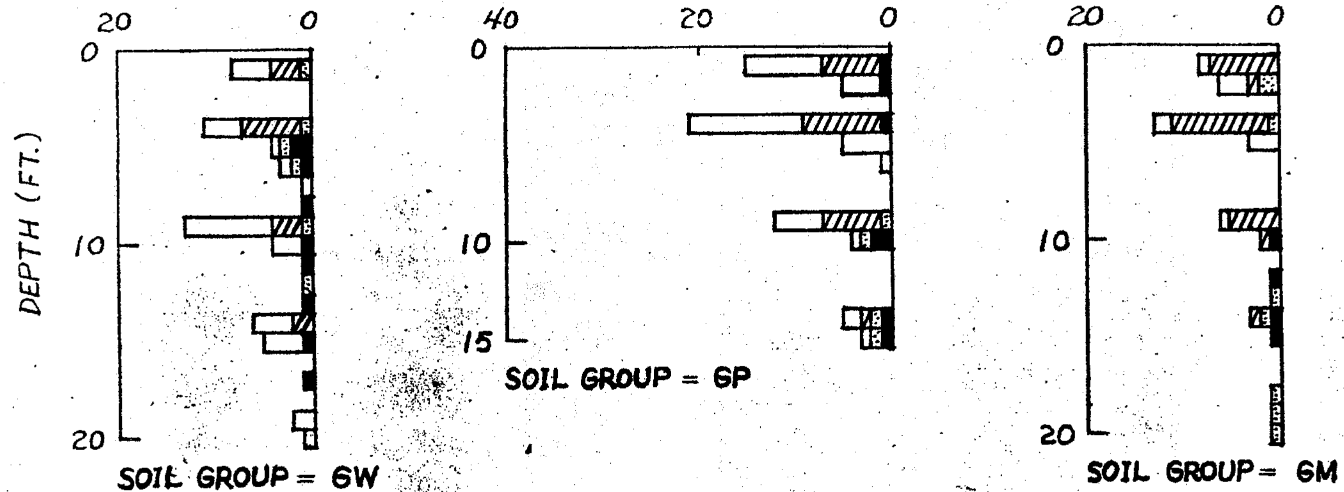


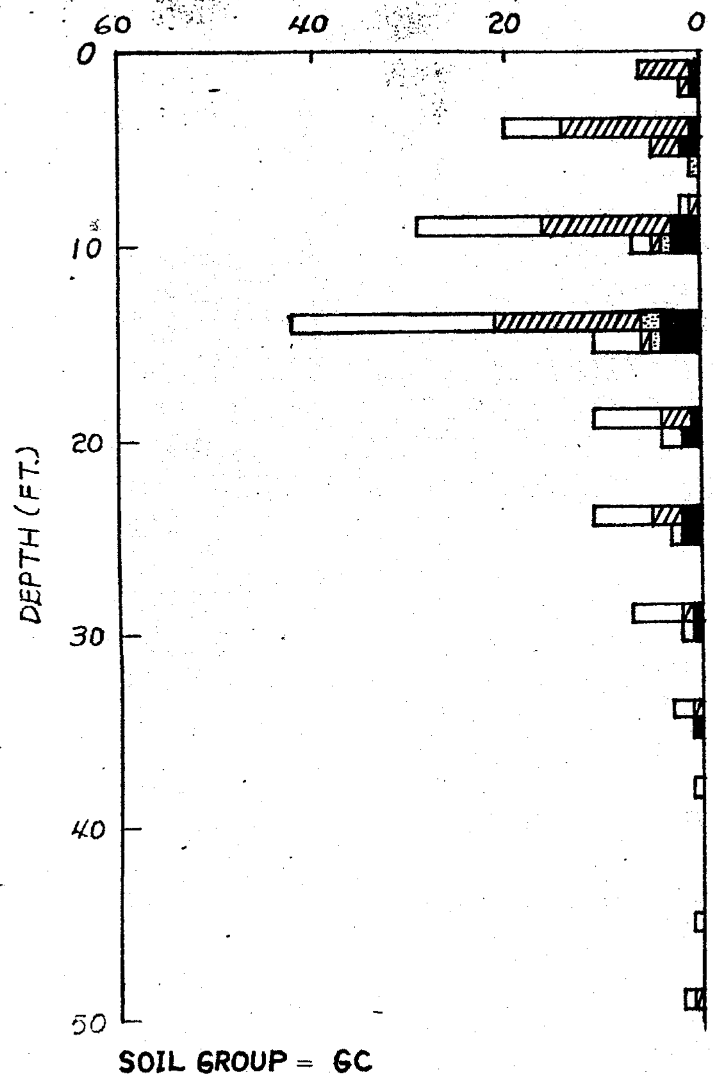
NOVEMBER—MARCH

NTS 95 N

DAHADINNI RIVER

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



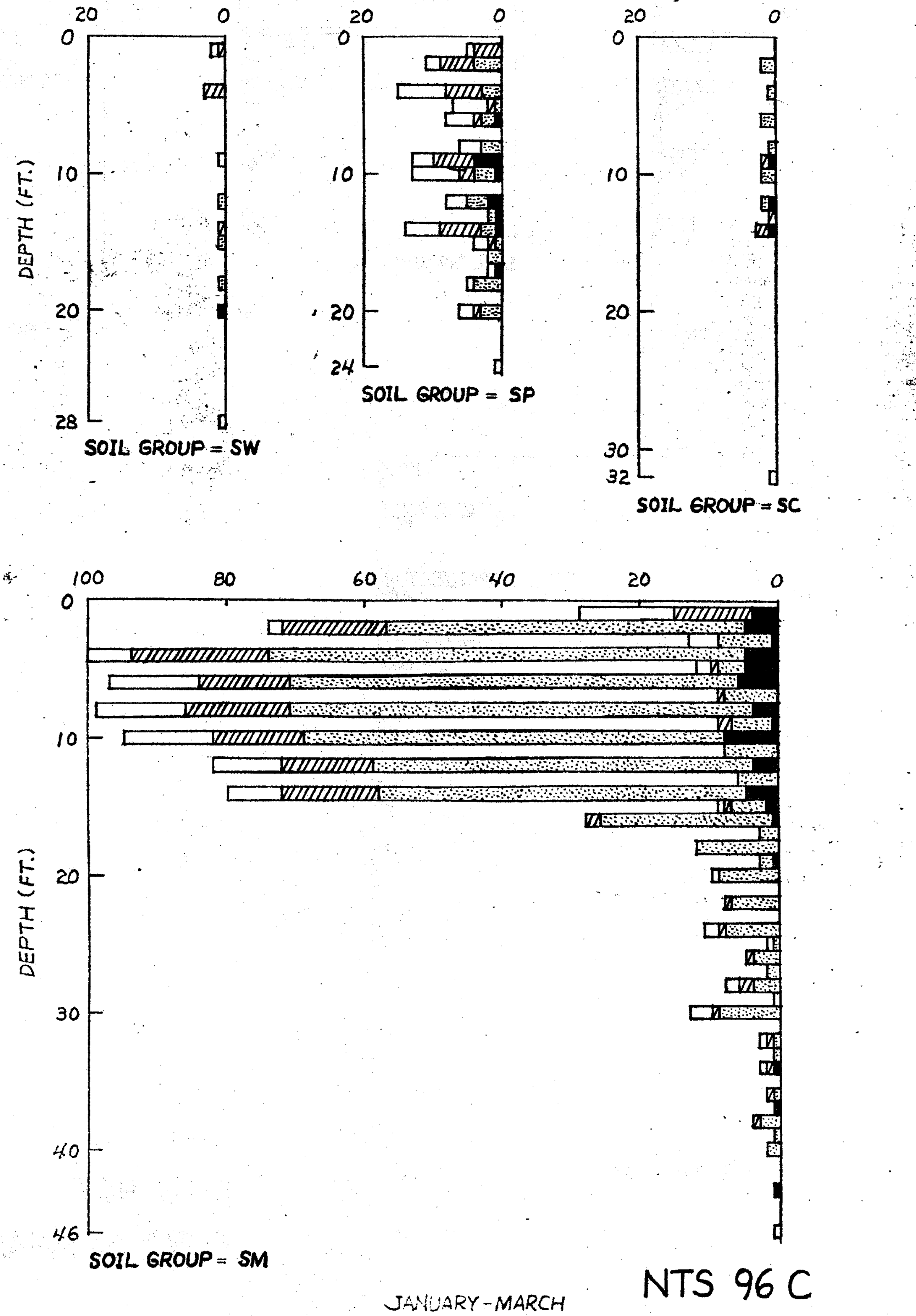


JANUARY–MARCH

NTS 96C

FORT NORMAN

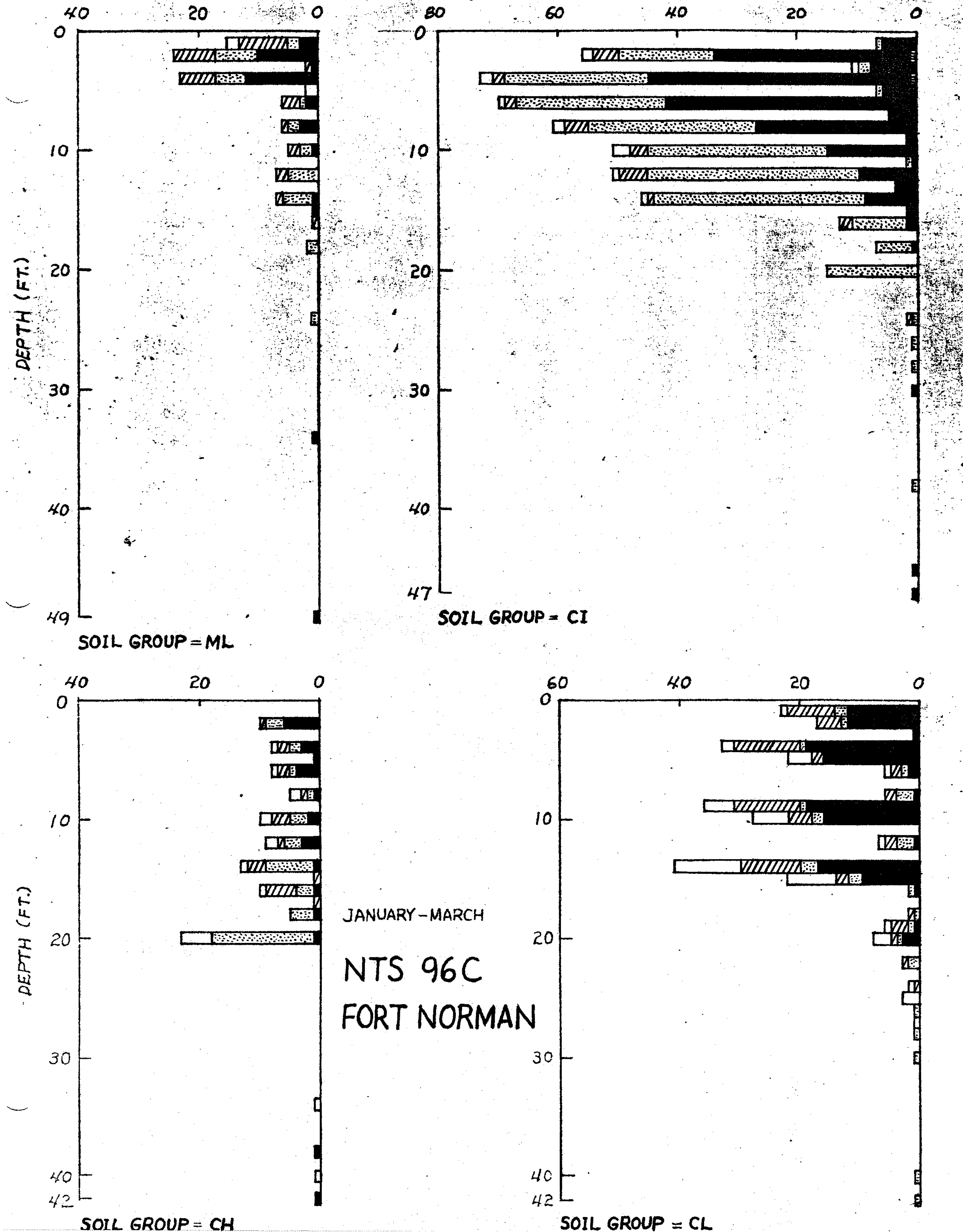
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



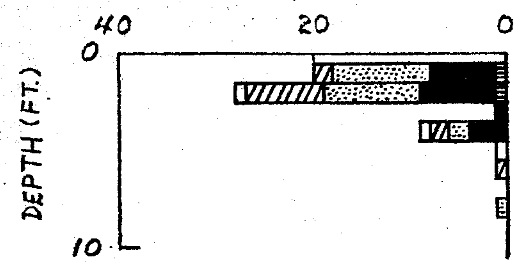
NTS 96 C

FORT NORMAN

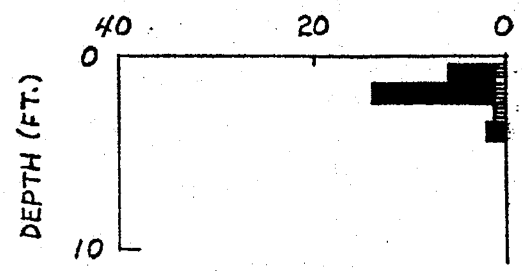
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



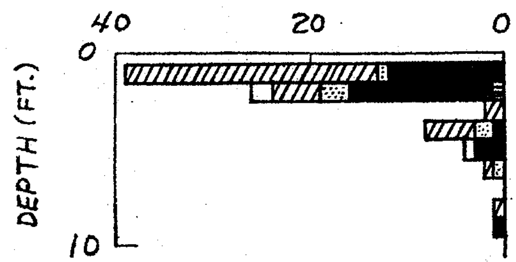
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



SOIL GROUP = OL



SOIL GROUP = OH



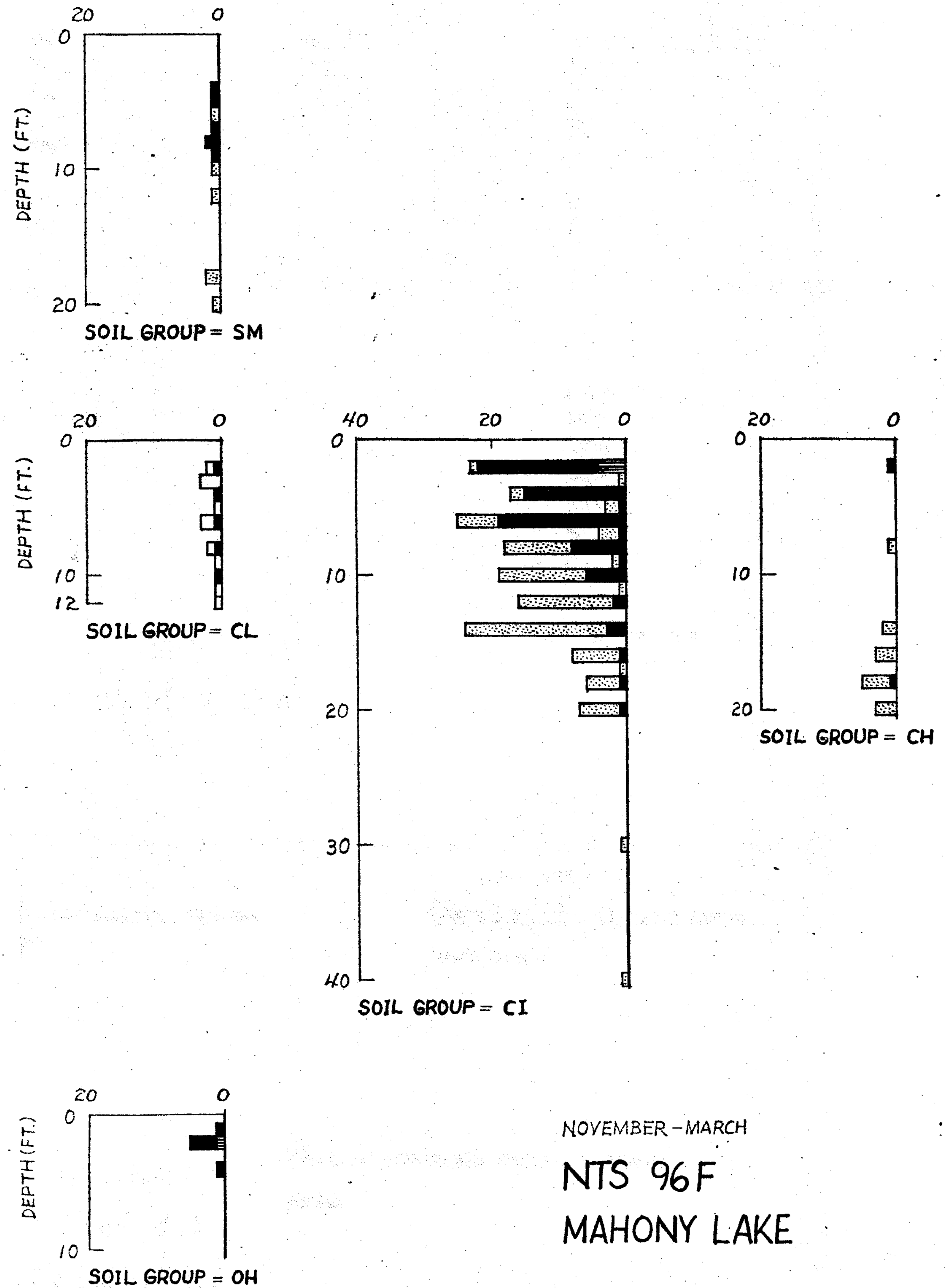
SOIL GROUP = Pt

JANUARY-MARCH

NTS 96C

FORT NORMAN

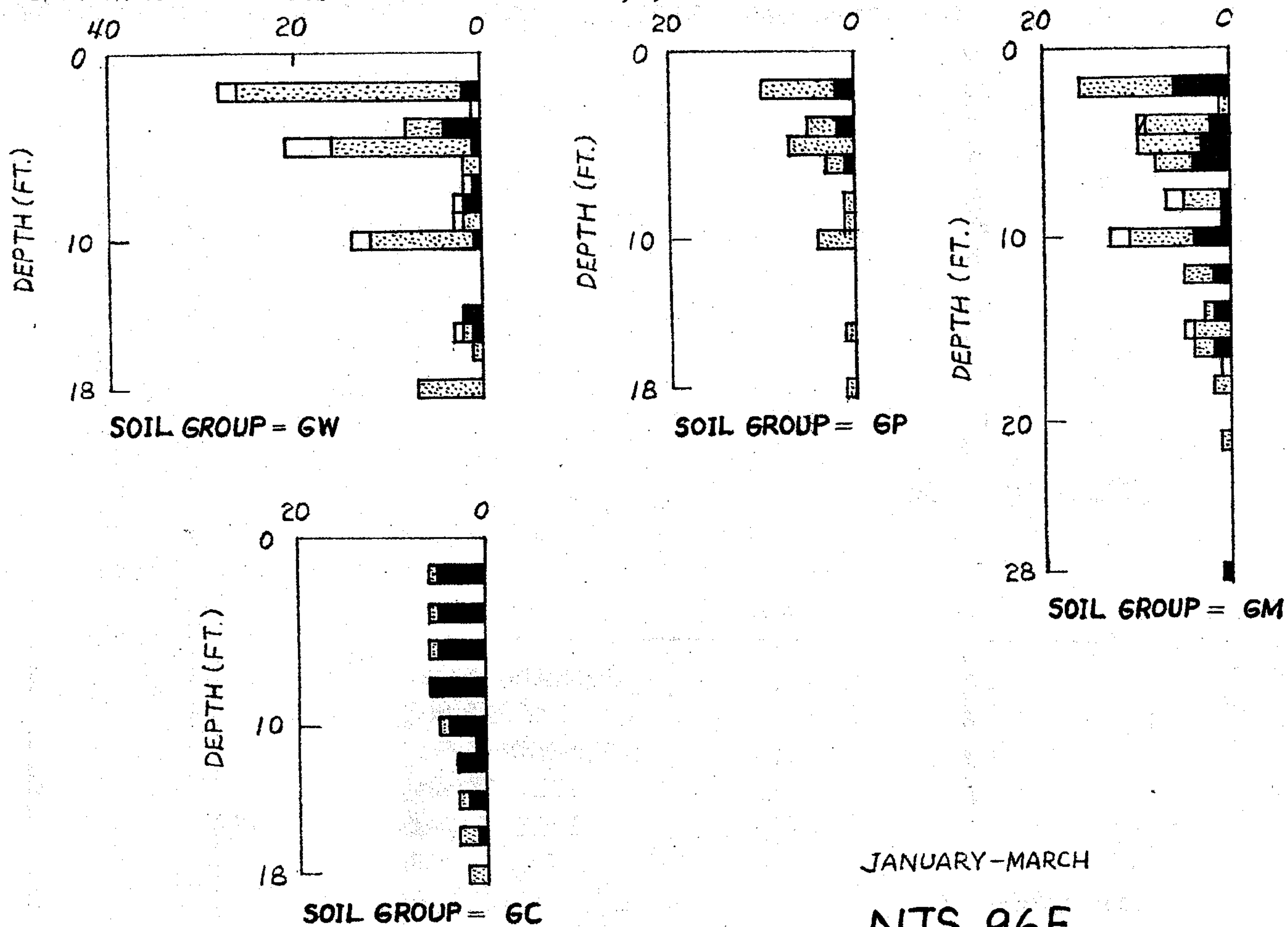
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



NOVEMBER – MARCH

NTS 96F
MAHONY LAKE

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

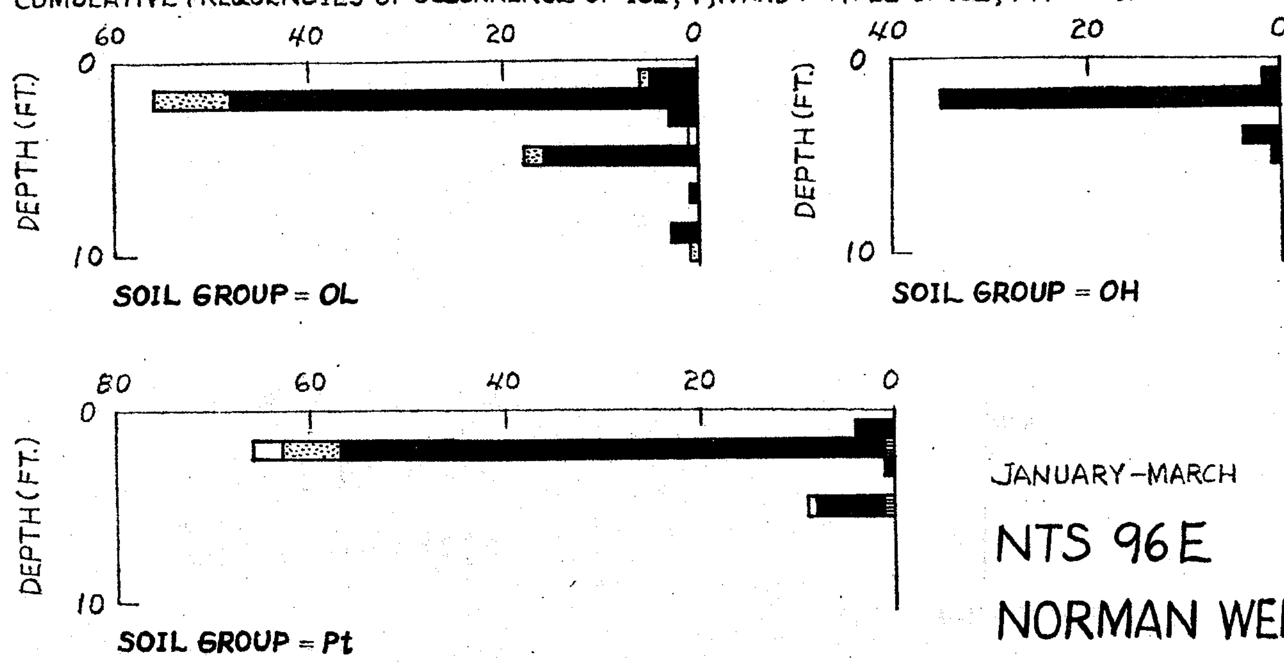


JANUARY-MARCH

NTS 96E

NORMAN WELLS

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

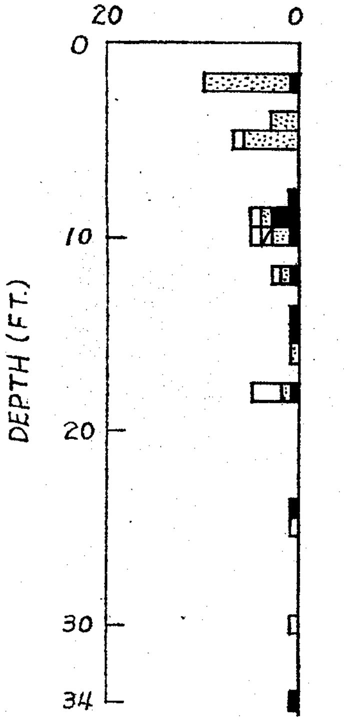


JANUARY-MARCH

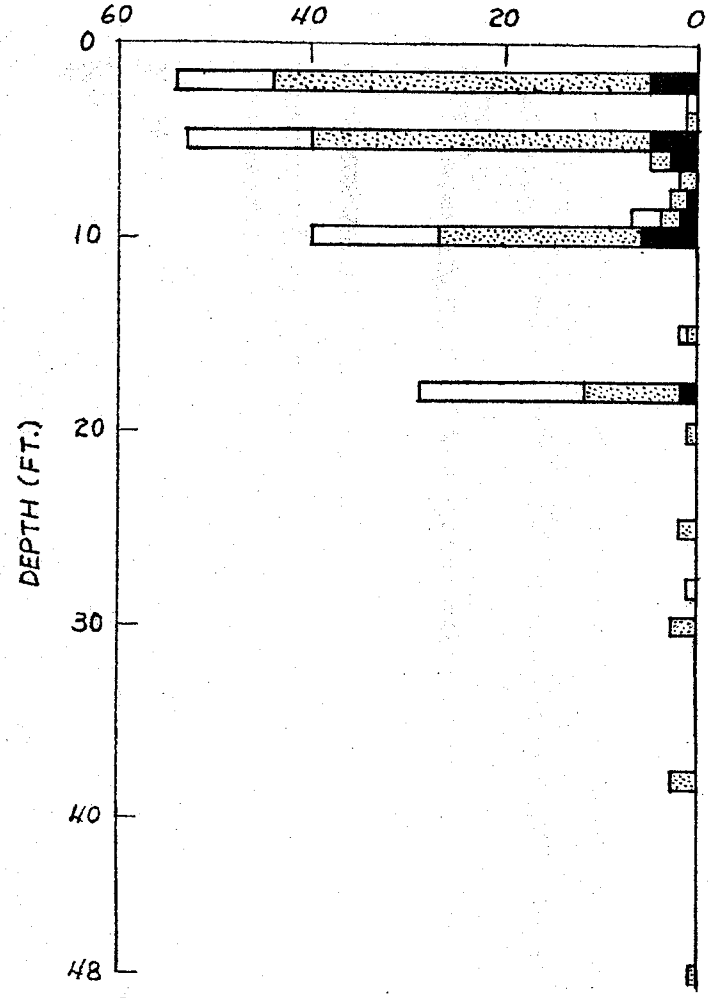
NTS 96E

NORMAN WELLS

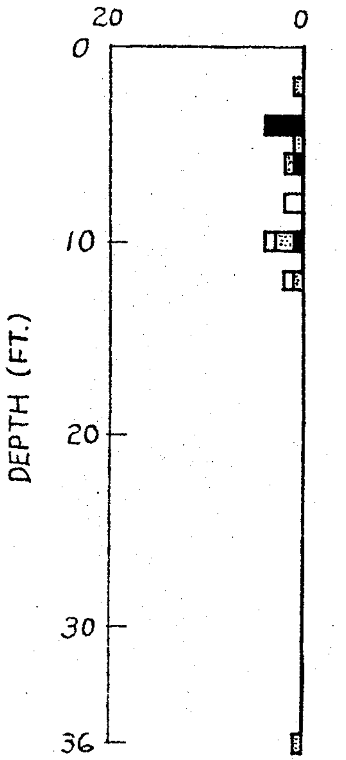
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



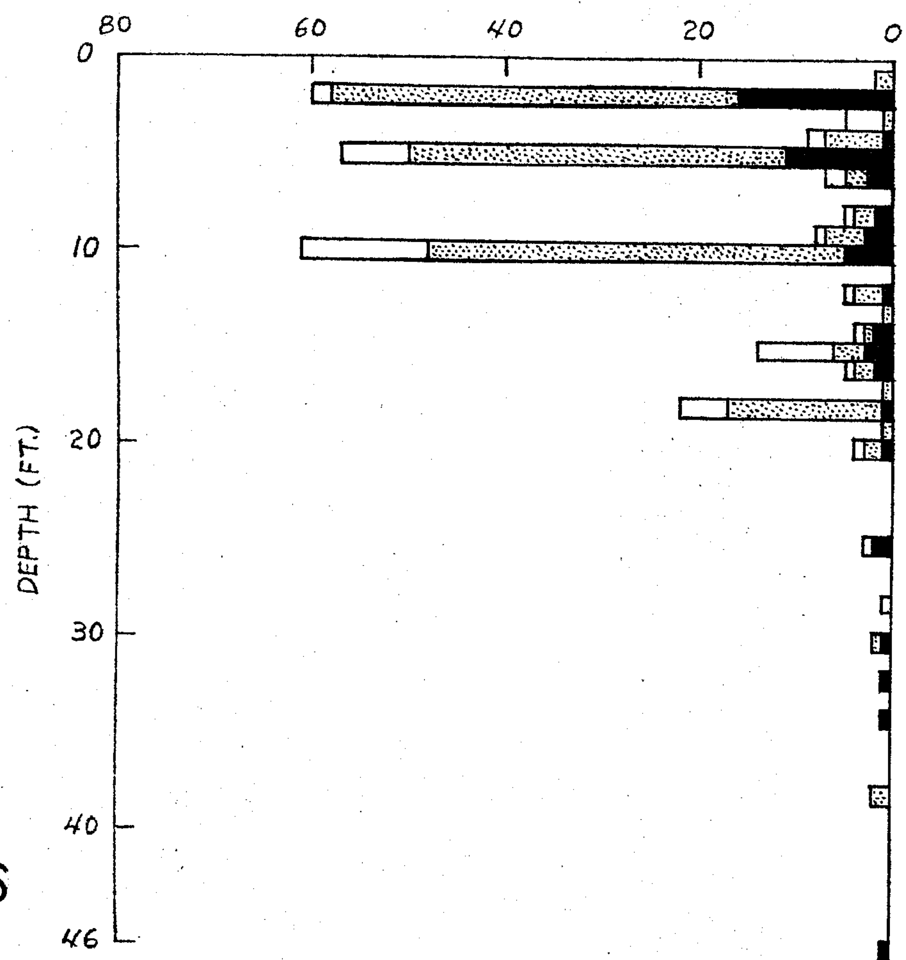
SOIL GROUP = SW



SOIL GROUP = SP



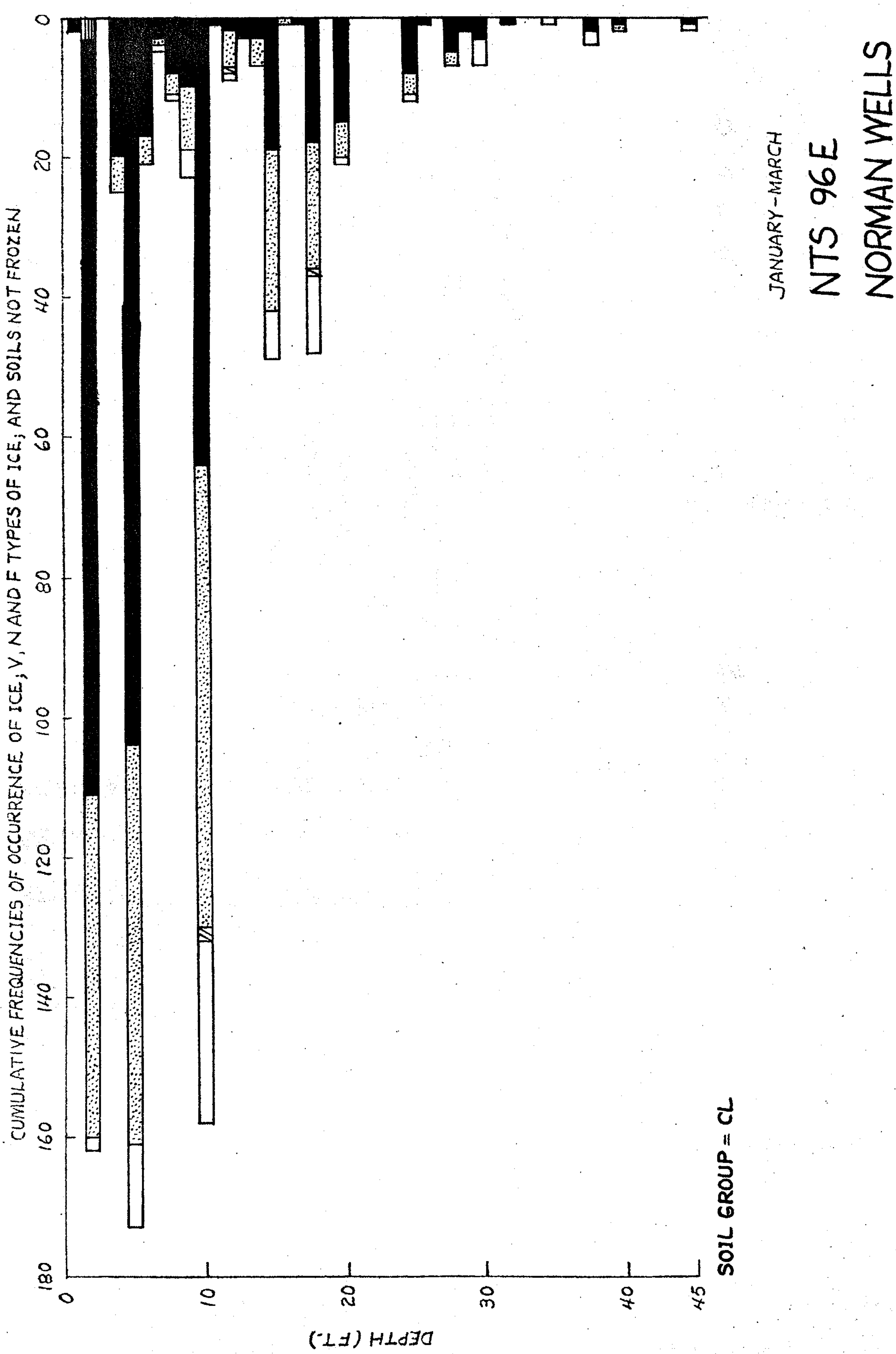
SOIL GROUP = SC



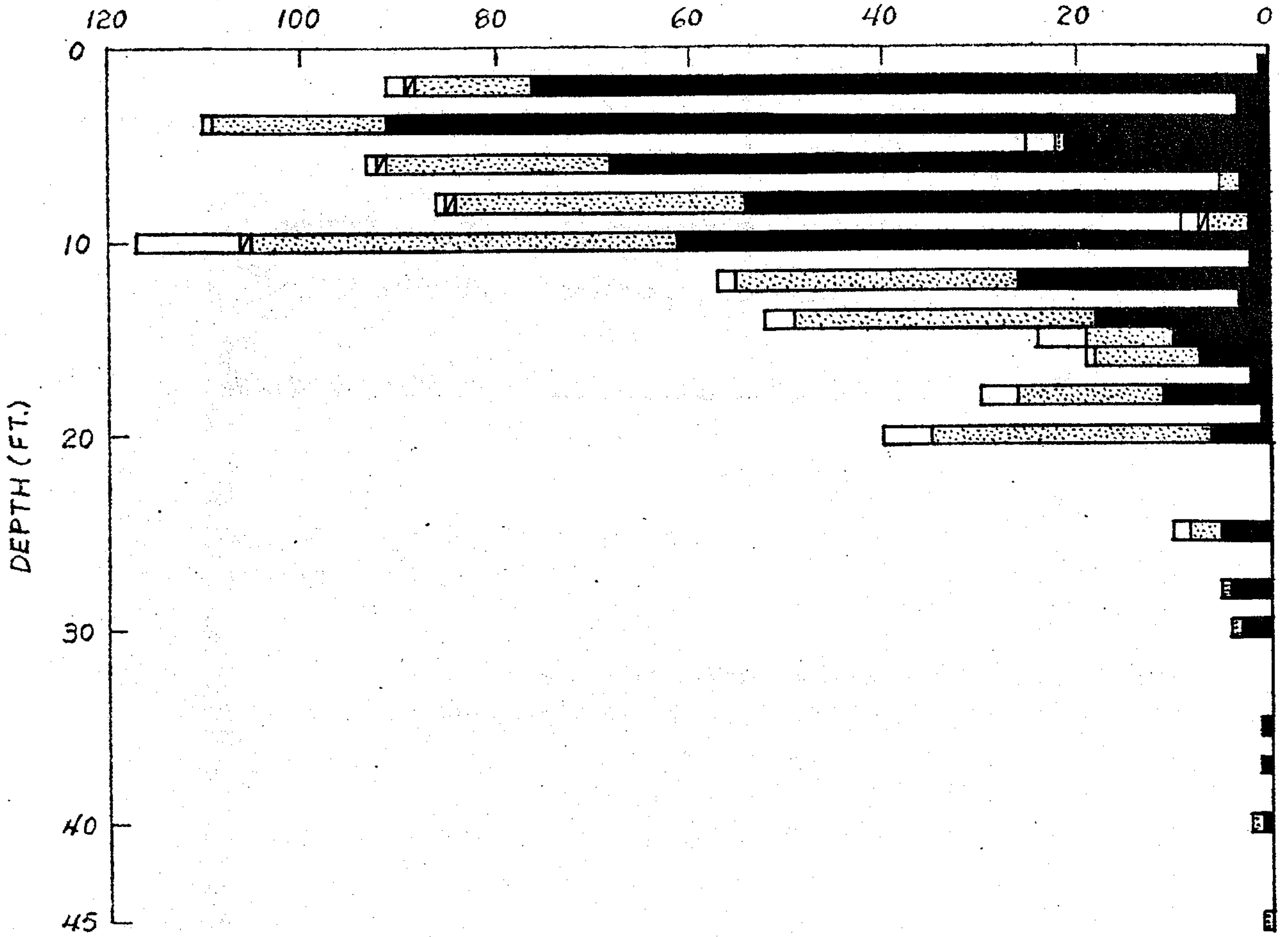
SOIL GROUP = SM

JANUARY–MARCH

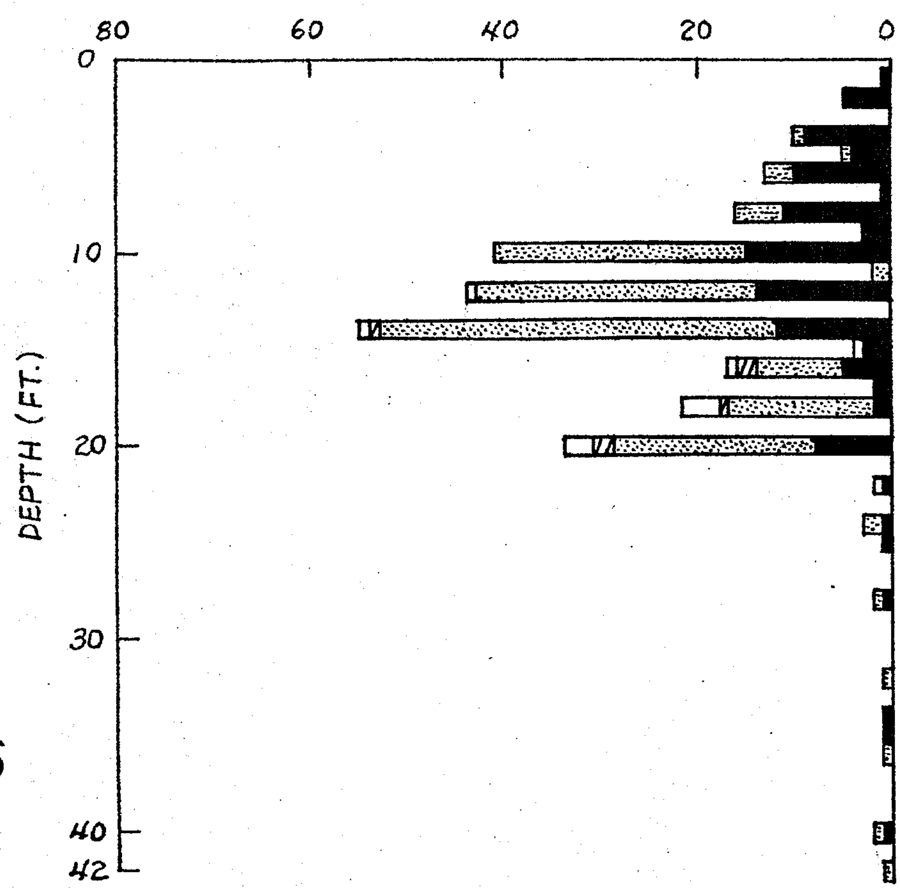
NTS 96E
NORMAN WELLS


CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE, V, N AND F TYPES OF ICE, AND SOILS NOT FROZEN
0
20
40
60
80
100
120
140
160
180
0
10
20
30
40
45
DEPTH (FT.)
SOIL GROUP = CL
JANUARY-MARCH
NTS 96 E
NORMAN WELLS

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



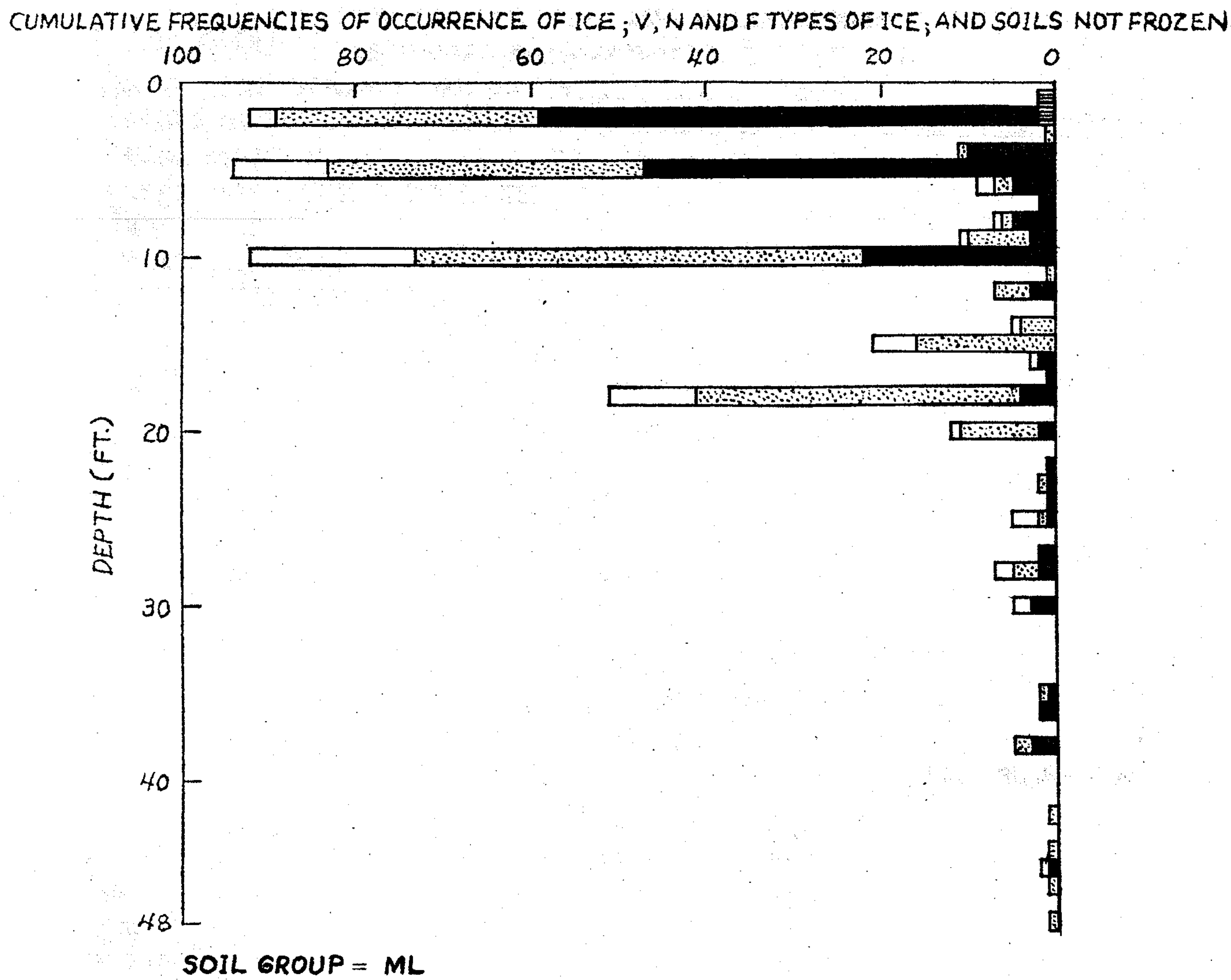
SOIL GROUP = CI



SOIL GROUP = CH

JANUARY - MARCH

NTS 96E
NORMAN WELLS

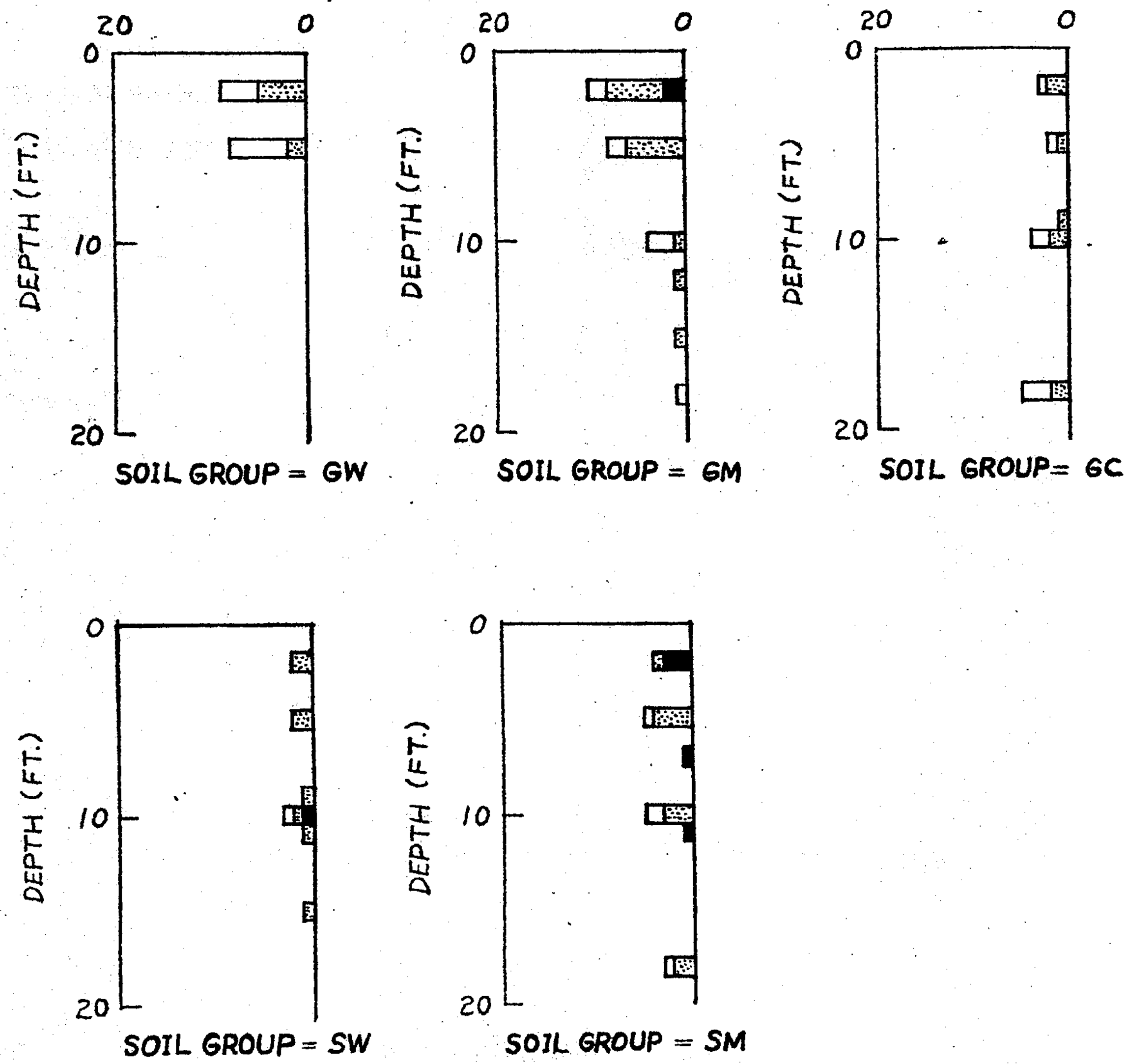


JANUARY–MARCH

NTS 96E

NORMAN WELLS

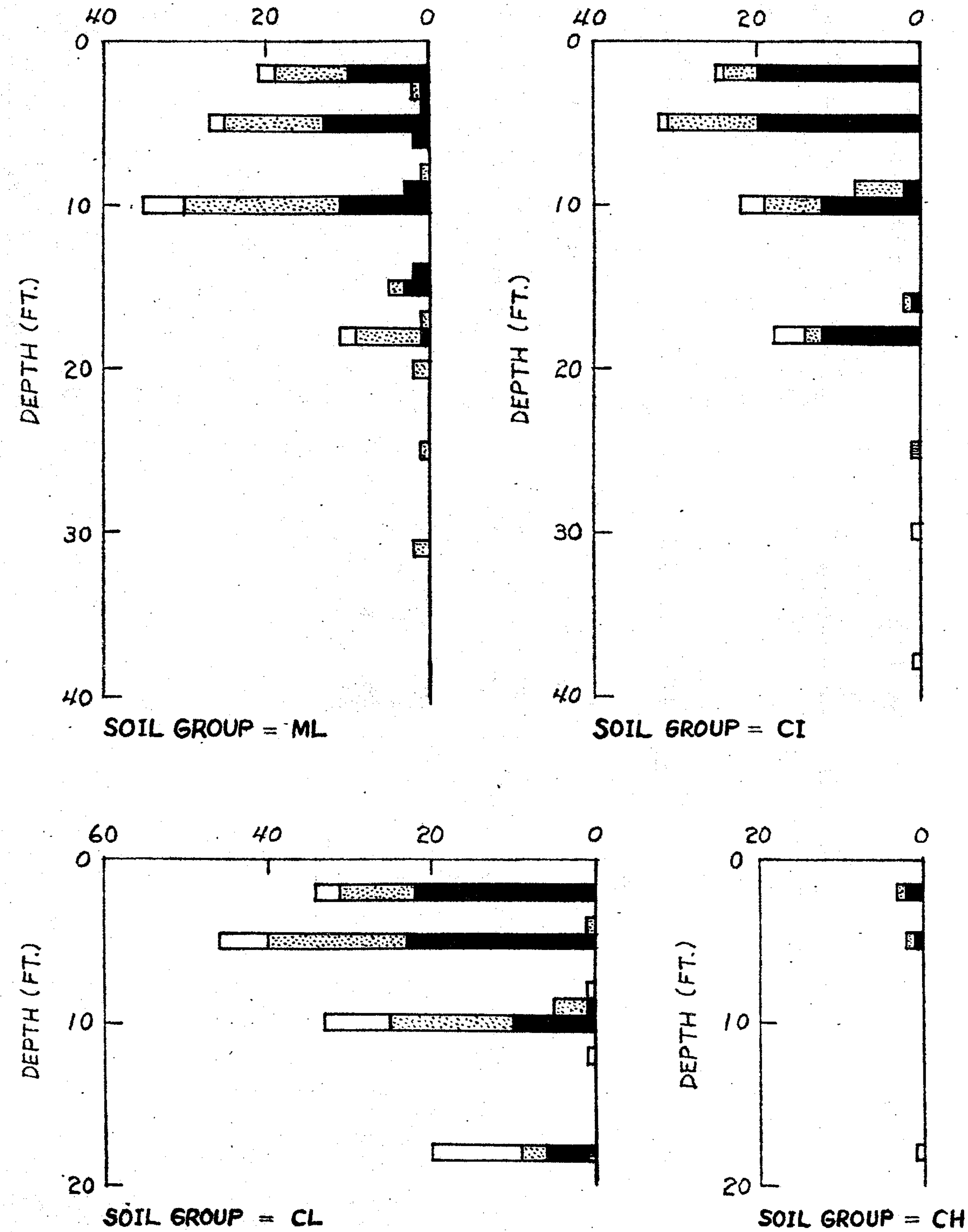
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE ; AND SOILS NOT FROZEN



JANUARY – MARCH

NTS 106 H
SANS SAULT RAPIDS

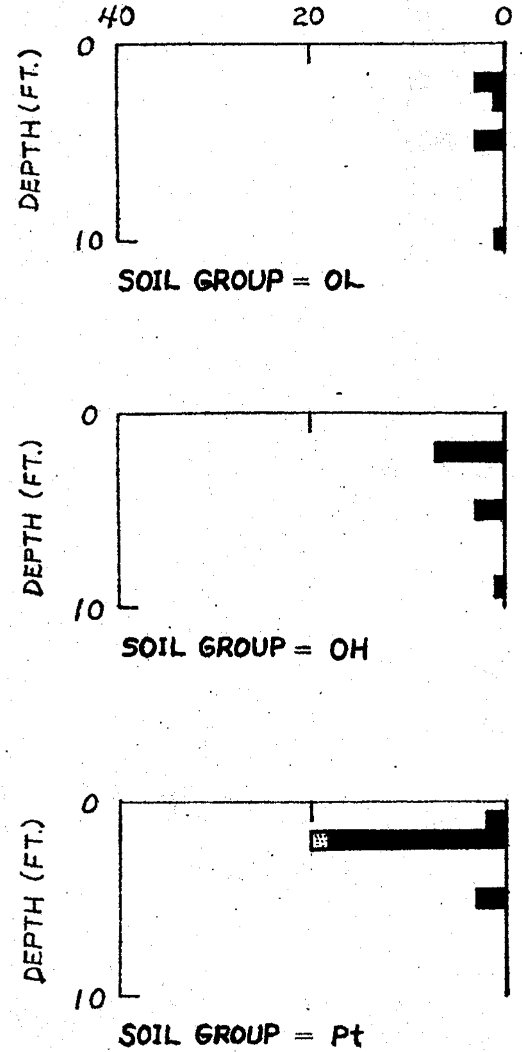
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY – MARCH

NTS 106 H
SANS SAULT RAPIDS

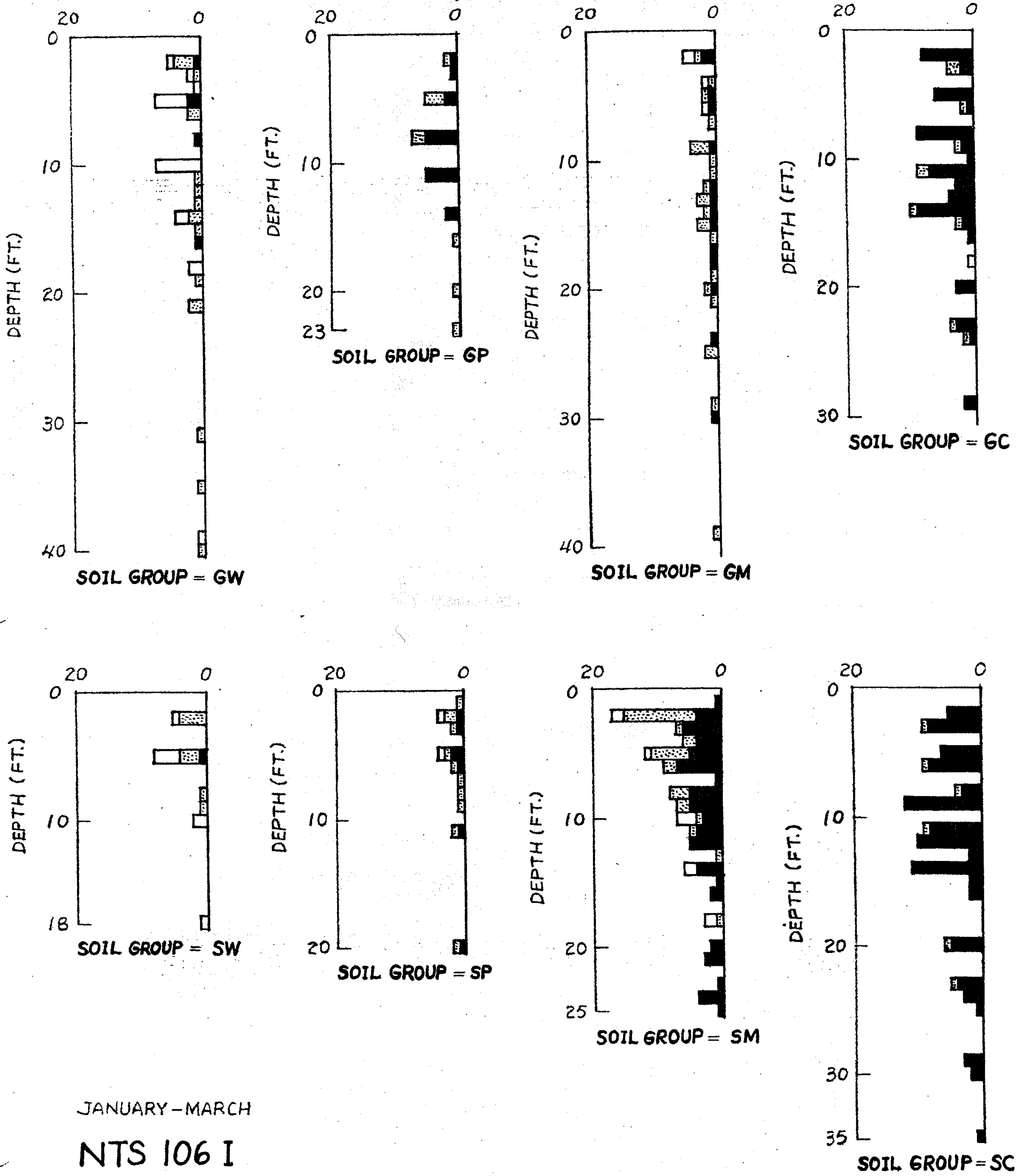
CUMULATIVE FREQUENCES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY – MARCH

NTS 106 H
SANS SAULT RAPIDS

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

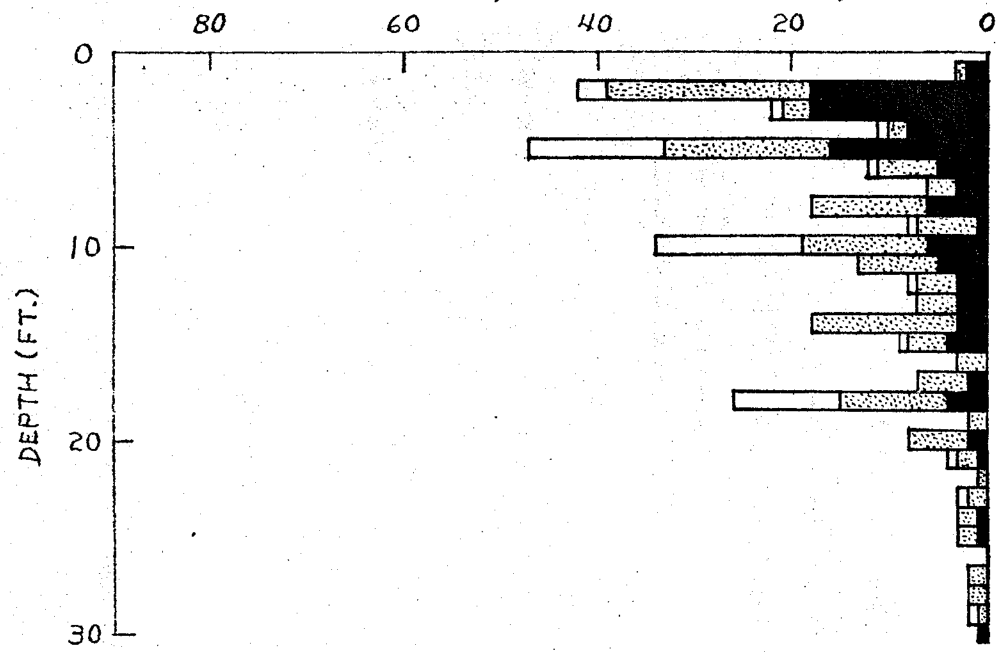


JANUARY–MARCH

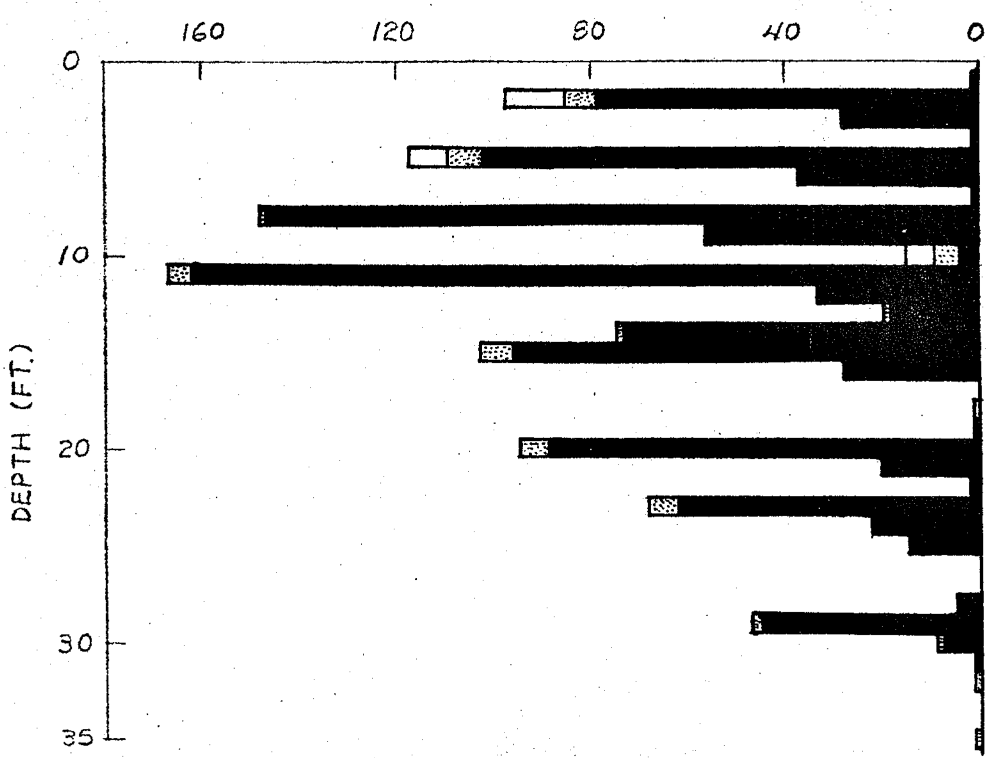
NTS 106 I

FORT GOOD HOPE

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



SOIL GROUP = ML

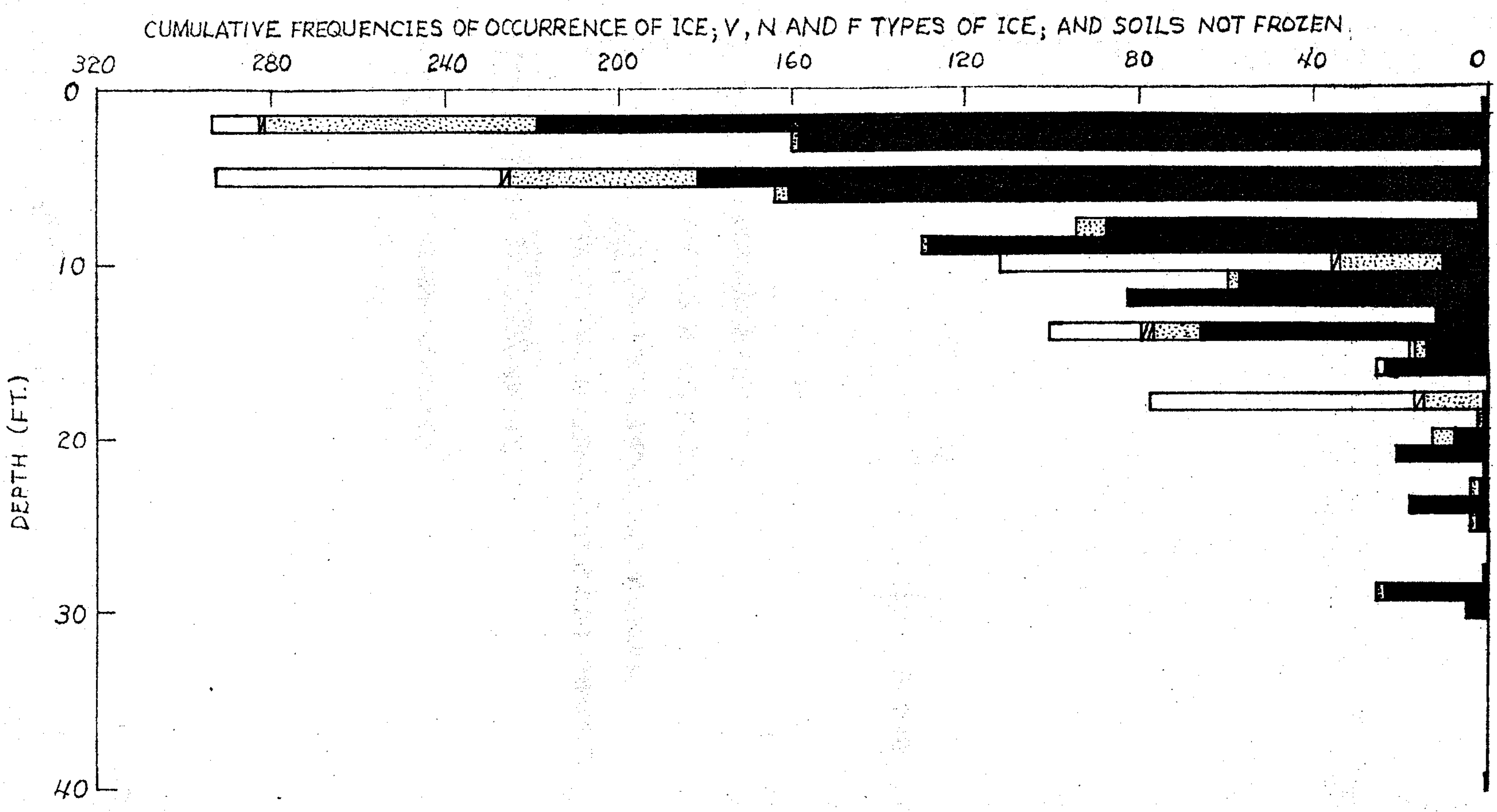


SOIL GROUP = CI

JANUARY - MARCH

NTS 106 I

FORT GOOD HOPE



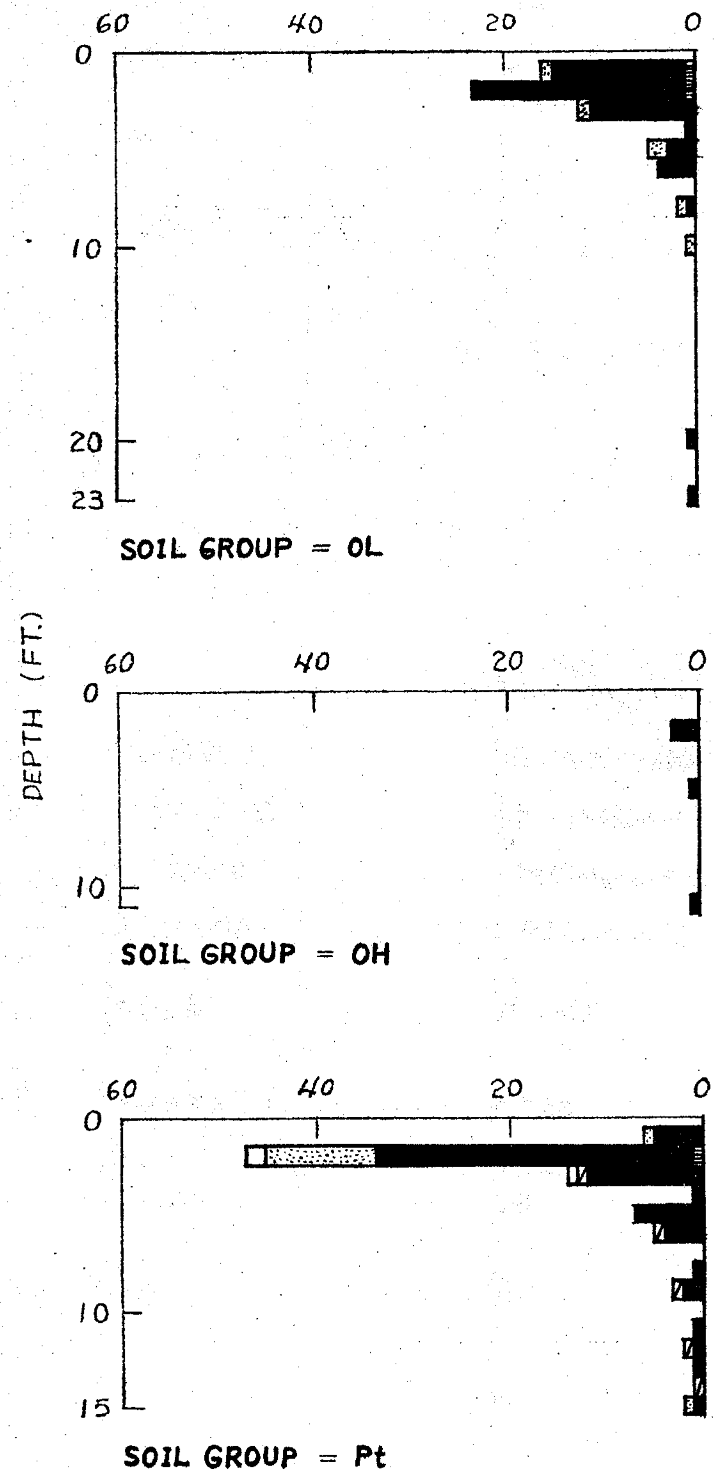
SOIL GROUP = CL

JANUARY - MARCH

NTS 106 I

FORT GOOD HOPE

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

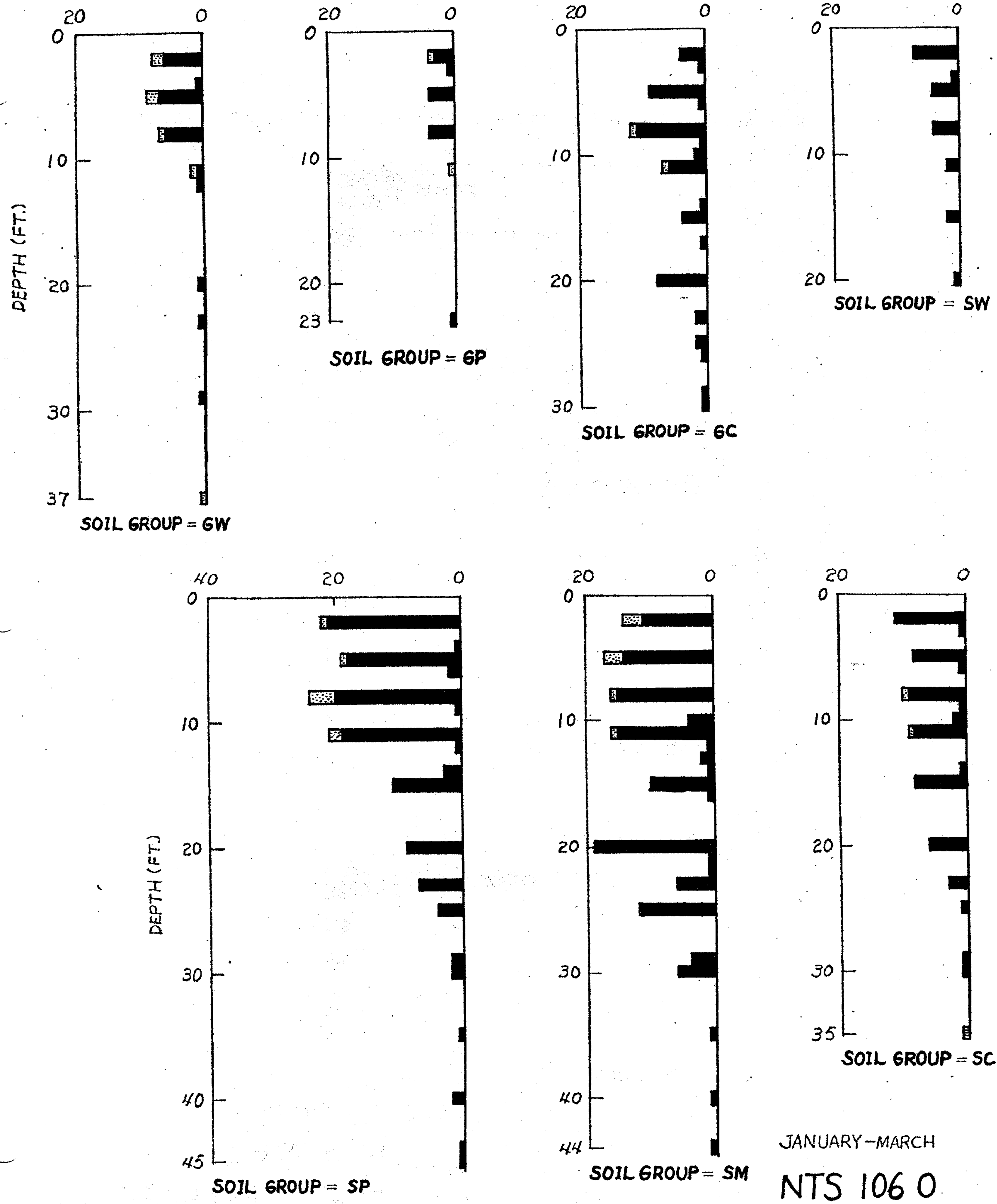


JANUARY – MARCH

NTS 106 I

FORT GOOD HOPE

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

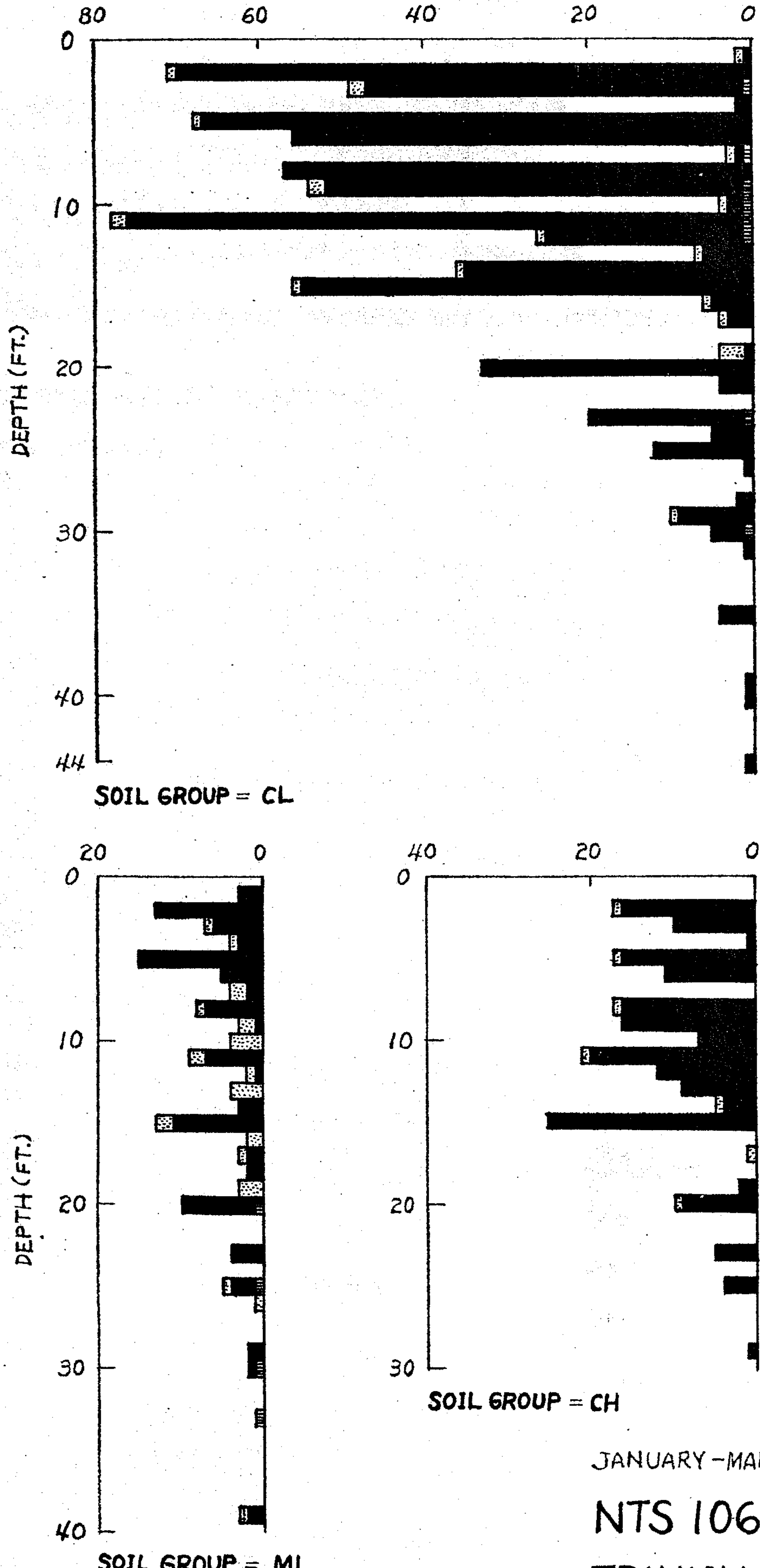


JANUARY–MARCH

NTS 106 O

TRAVAILLANT LA

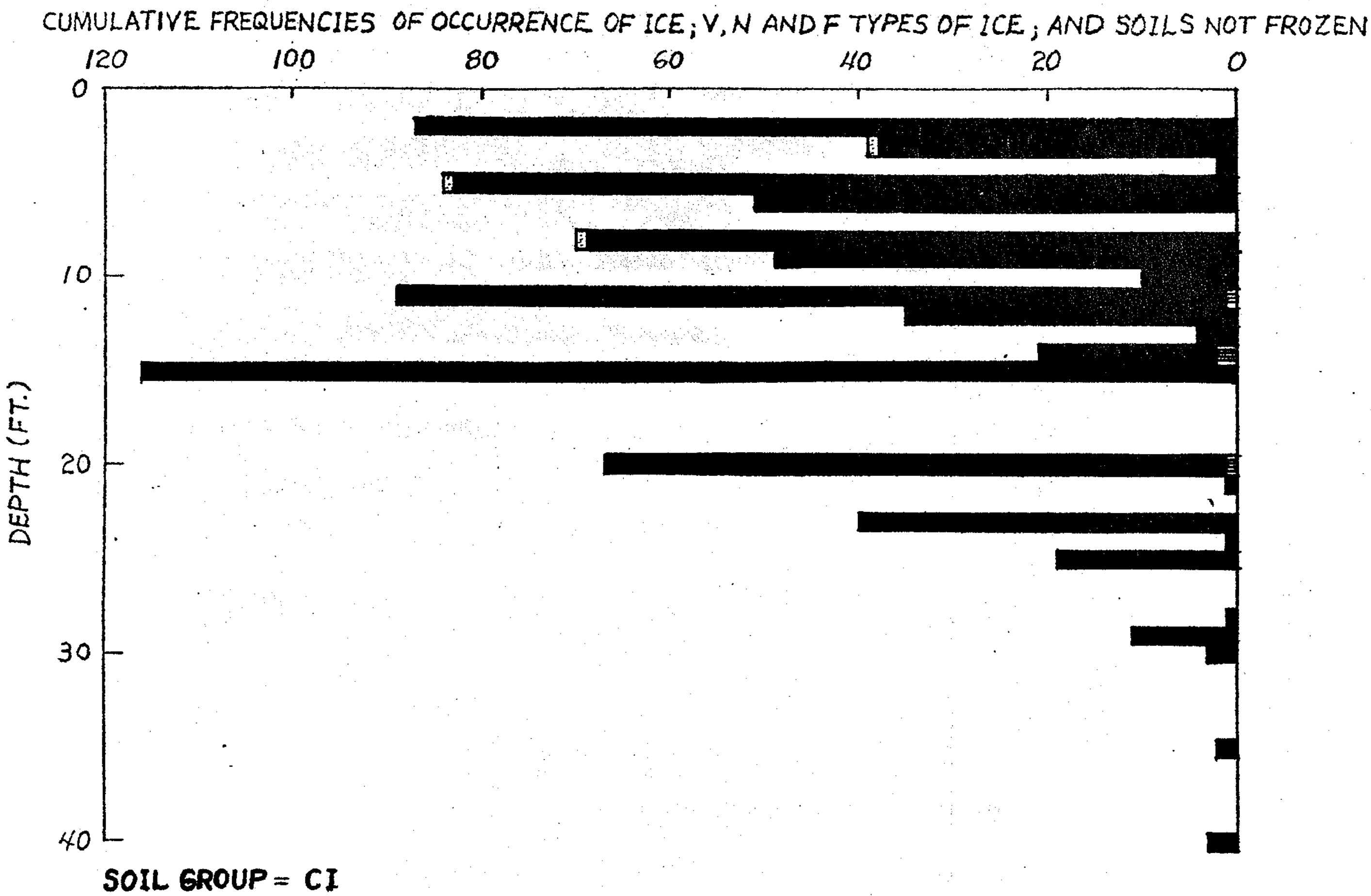
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY - MARCH

NTS 106 O

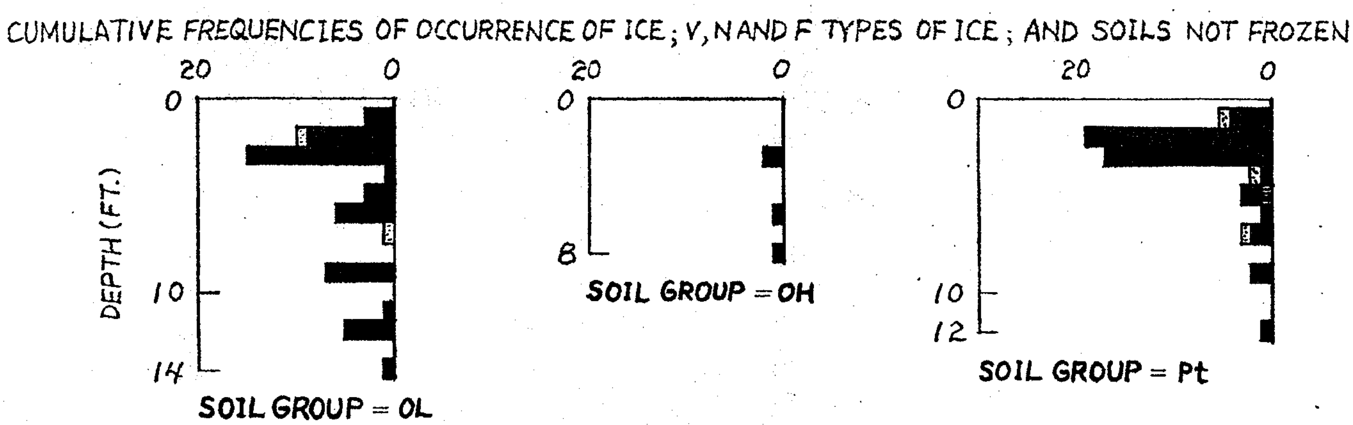
TRAVAILLANT LAKE



JANUARY–MARCH

NTS 106 O

TRAVAILLANT LAKE

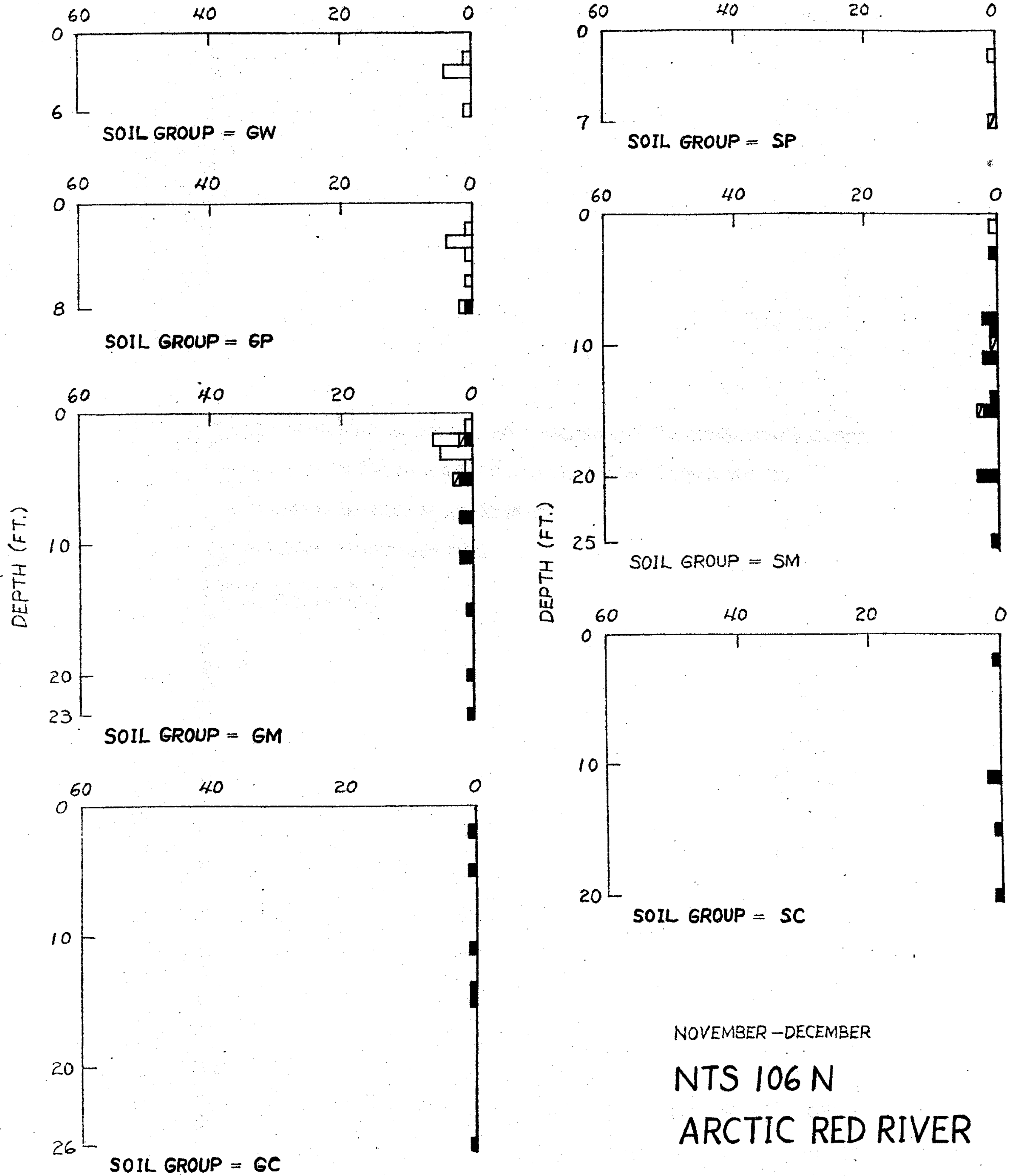


JANUARY–MARCH

NTS 106 O

TRAVAILLANT LAKE

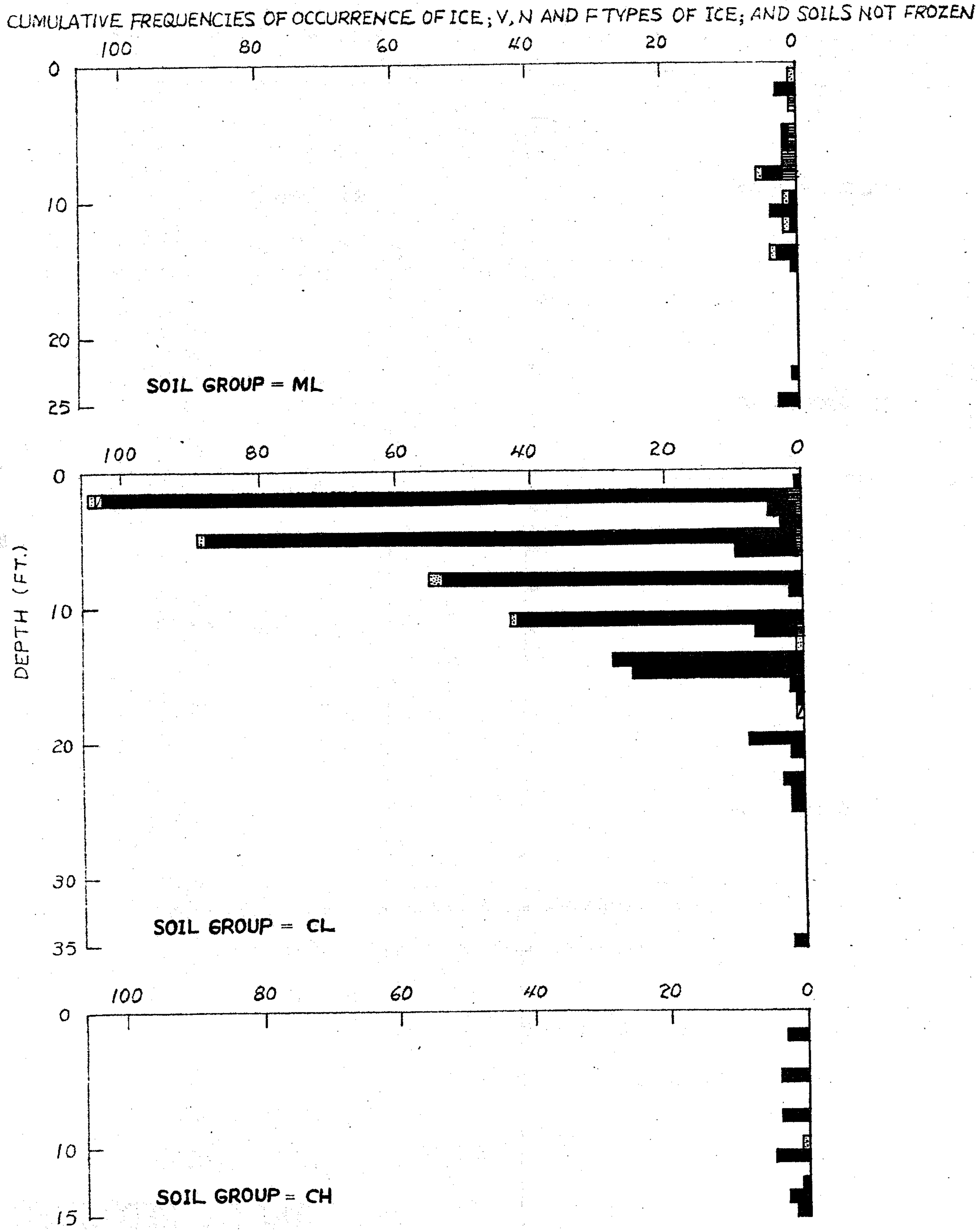
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



NOVEMBER – DECEMBER

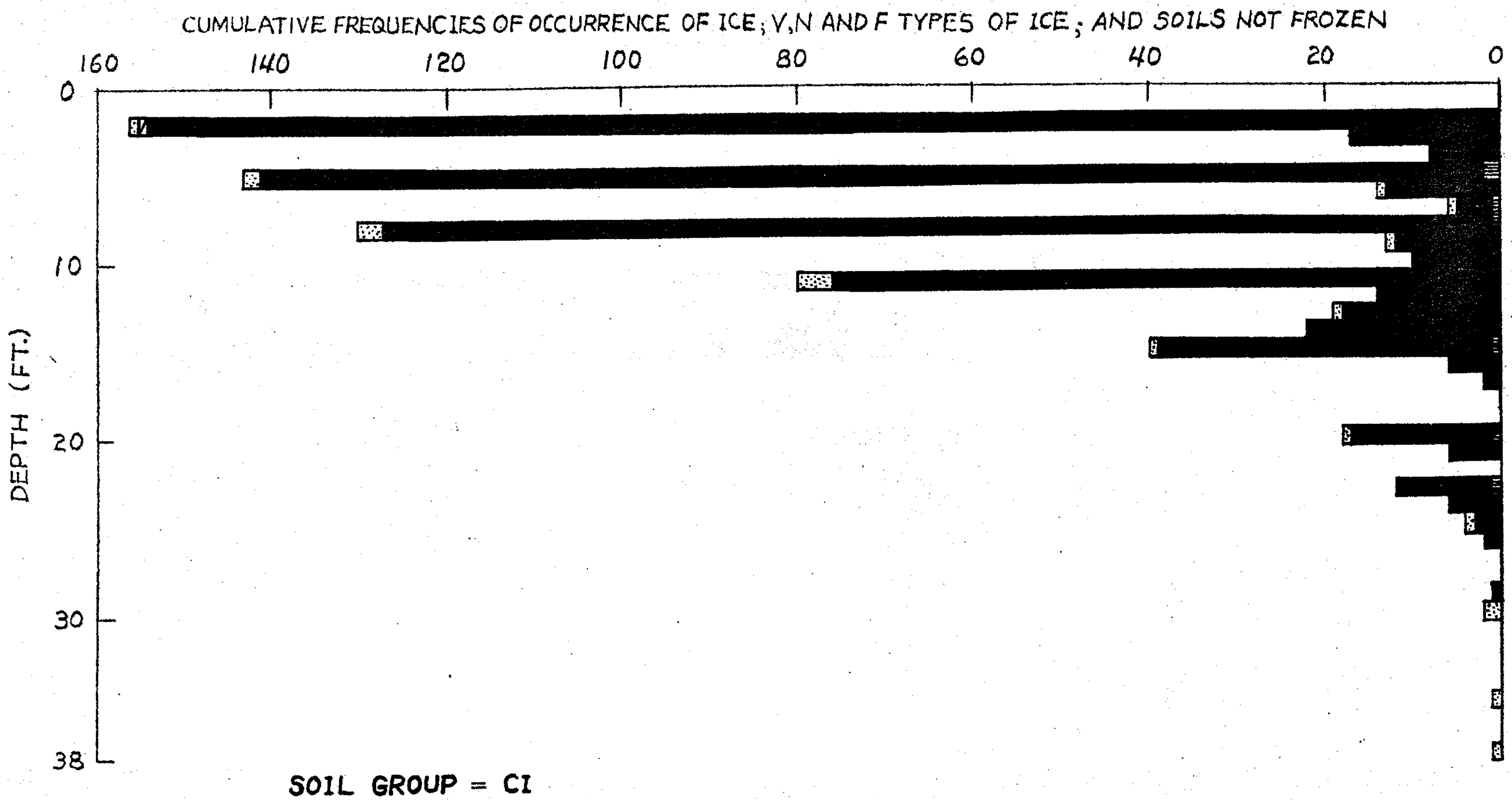
NTS 106 N

ARCTIC RED RIVER



NOVEMBER - DECEMBER

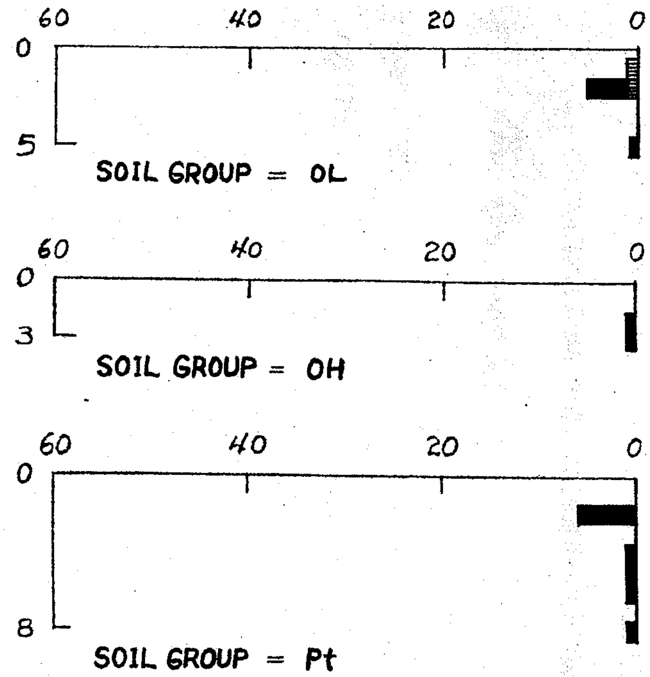
NTS 106 N
ARCTIC RED RIVER



NOVEMBER–DECEMBER

NTS 106 N
ARCTIC RED RIVER

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

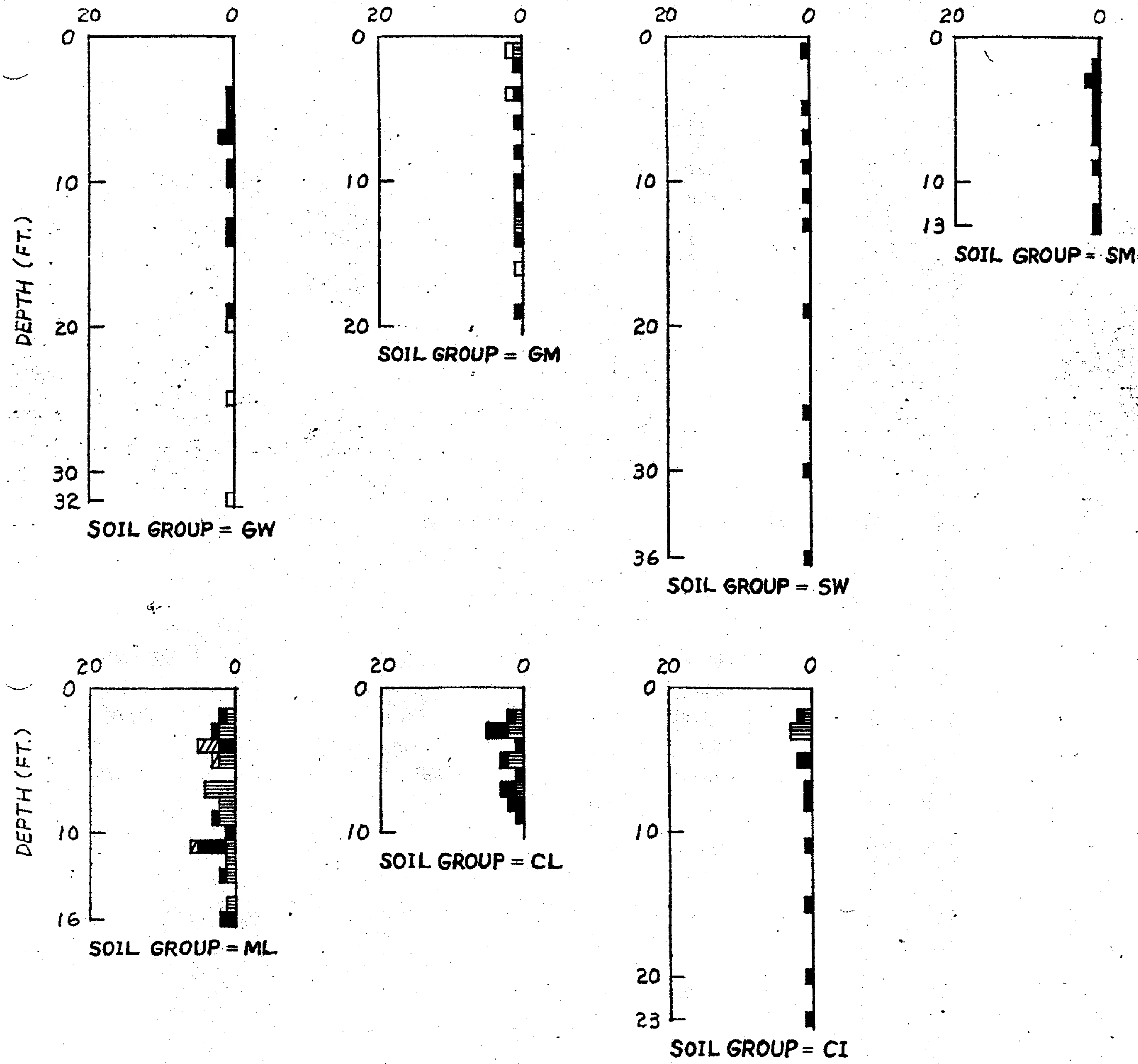


NOVEMBER – DECEMBER

NTS 106 N

ARCTIC RED RIVER

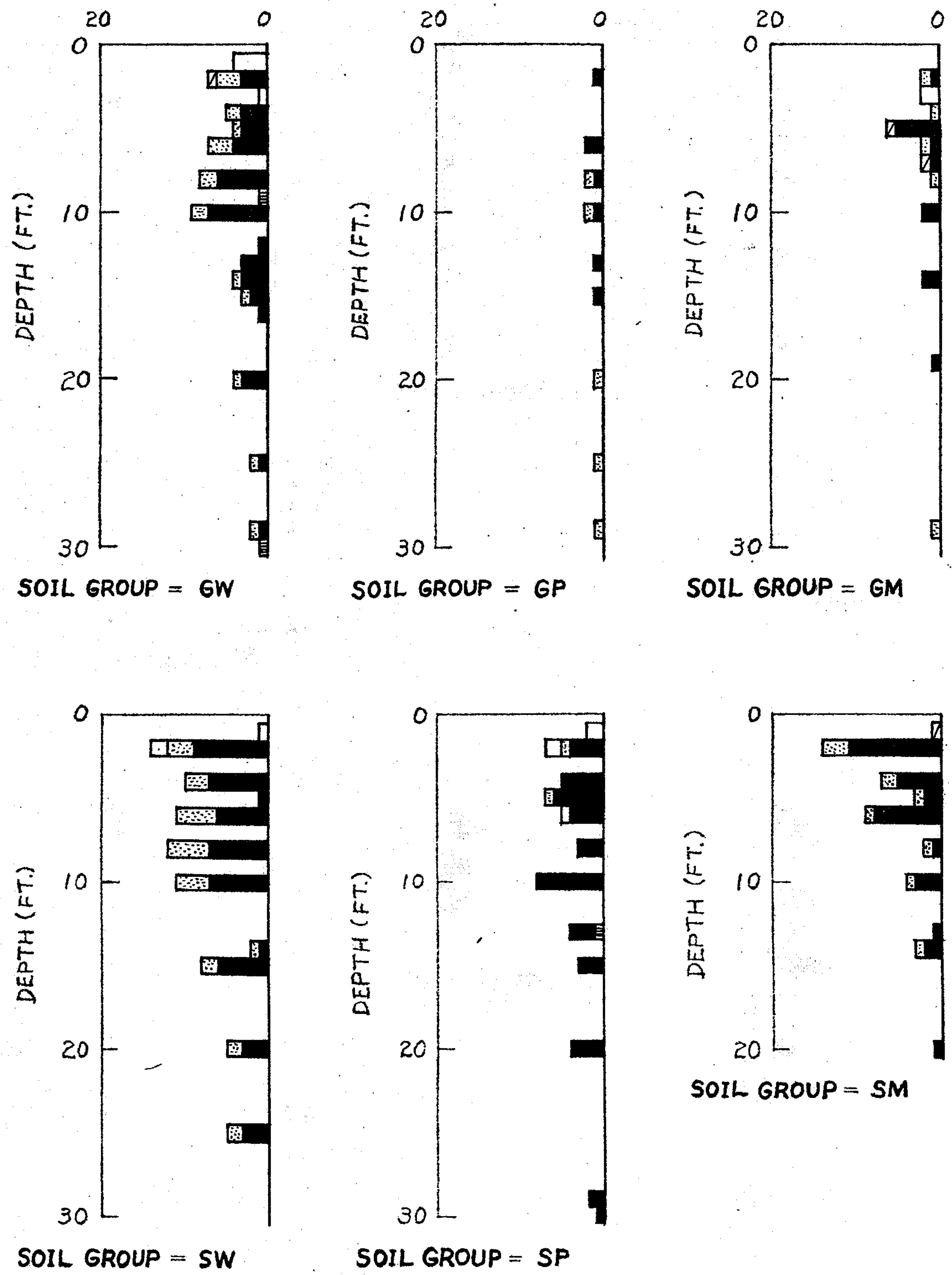
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



NOVEMBER–MARCH

NTS 106 M
FORT MCPHERSON

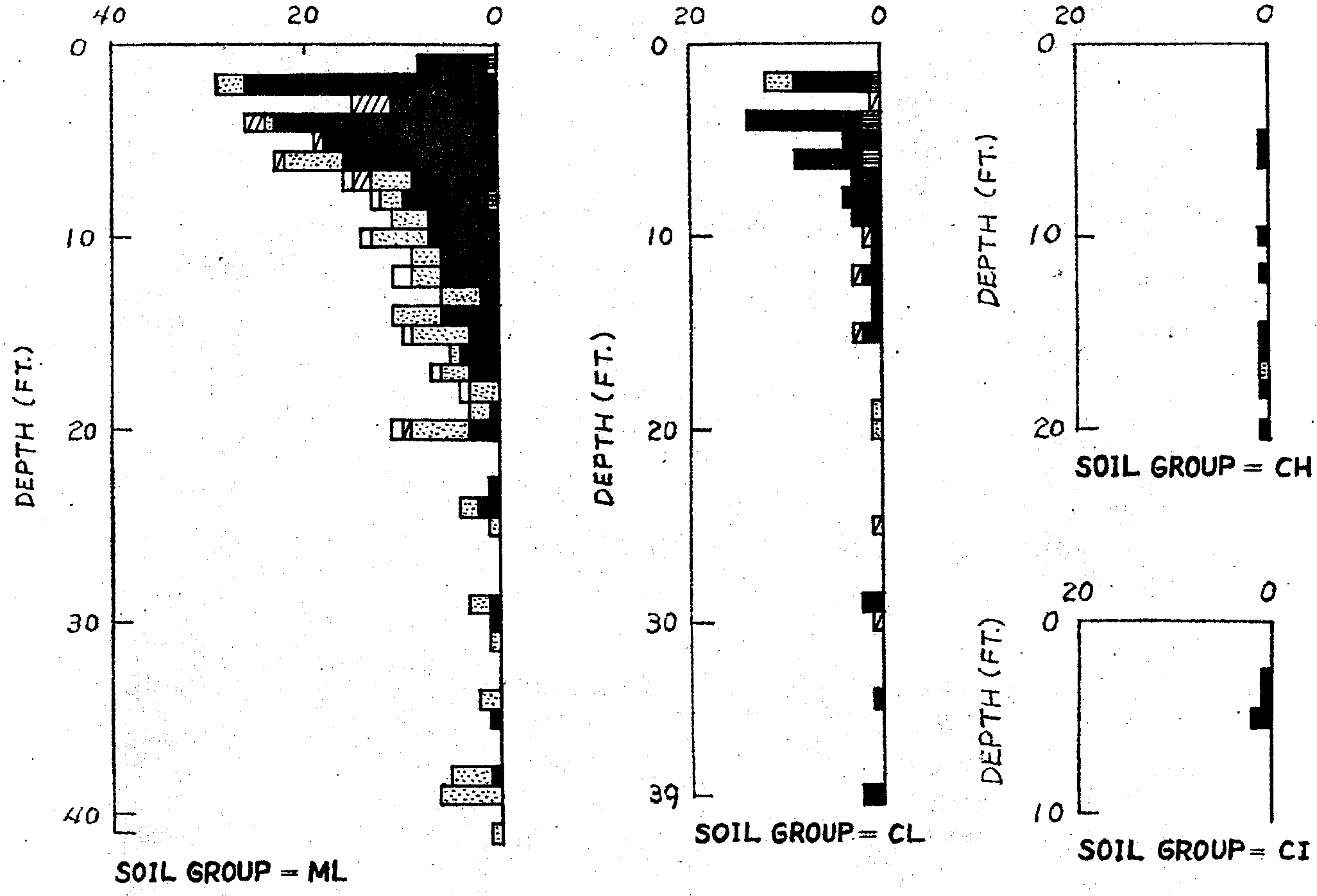
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



NOVEMBER - MARCH

NTS 107 B
AKLAVIK

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

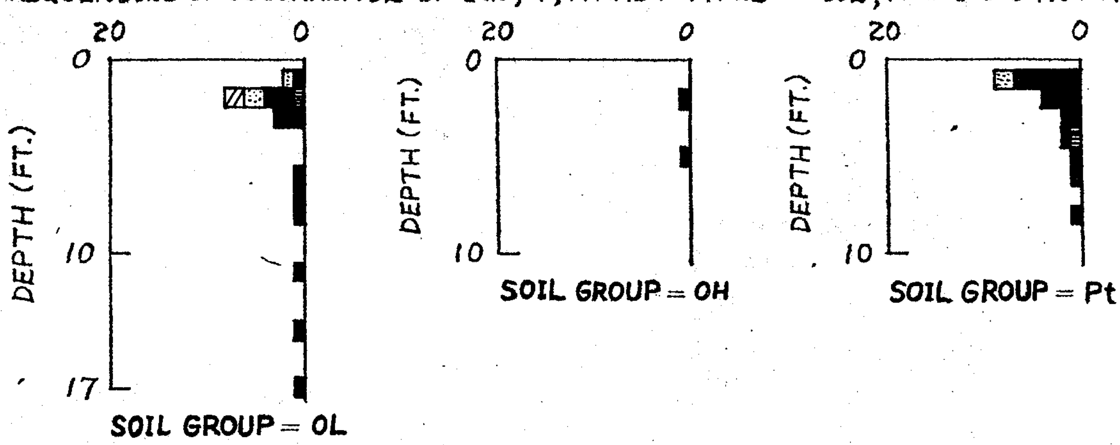


NOVEMBER-MARCH

NTS 107 B

AKLAVIK

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN

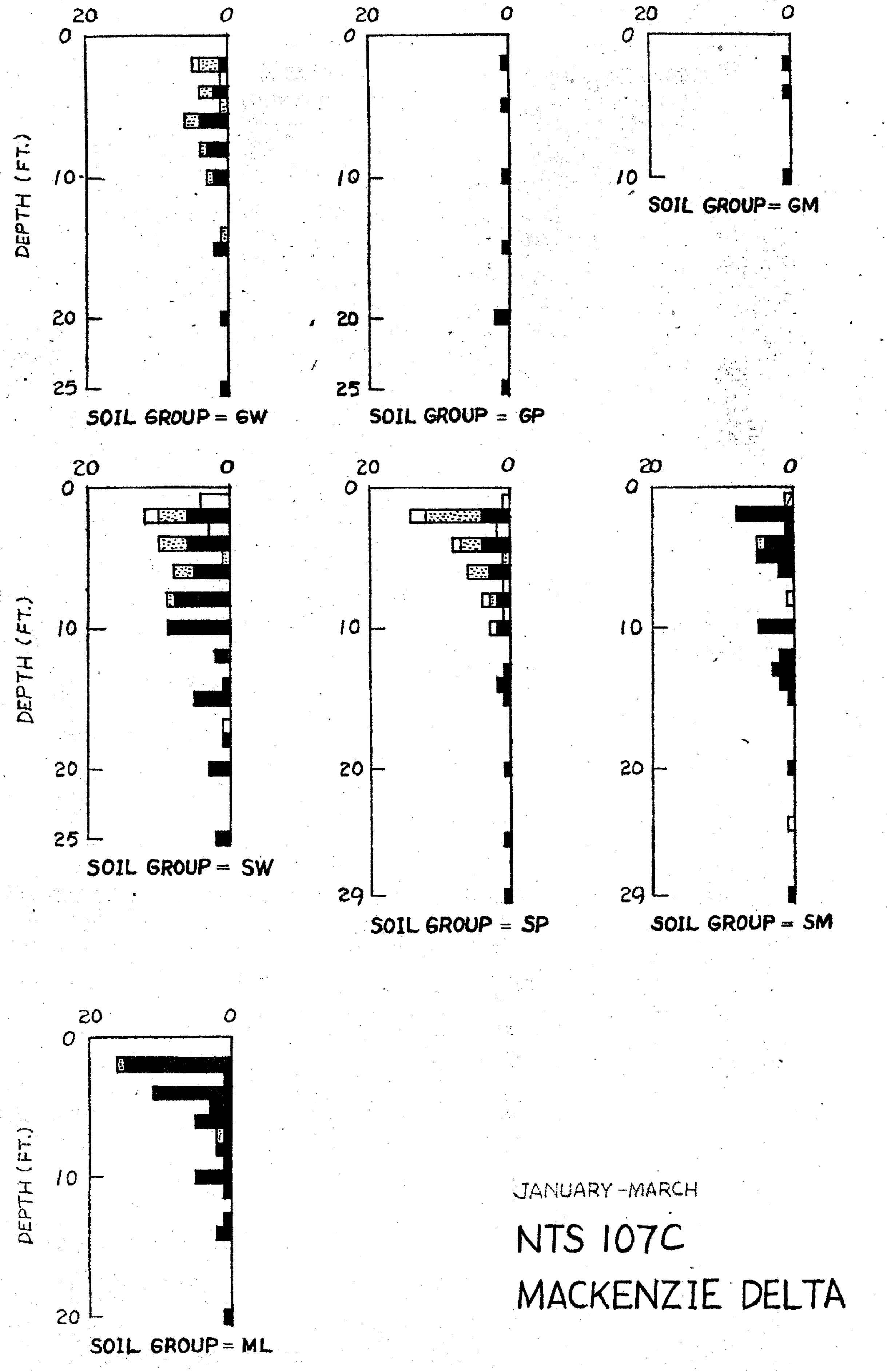


NOVEMBER-MARCH

NTS 107 B

AKLAVIK

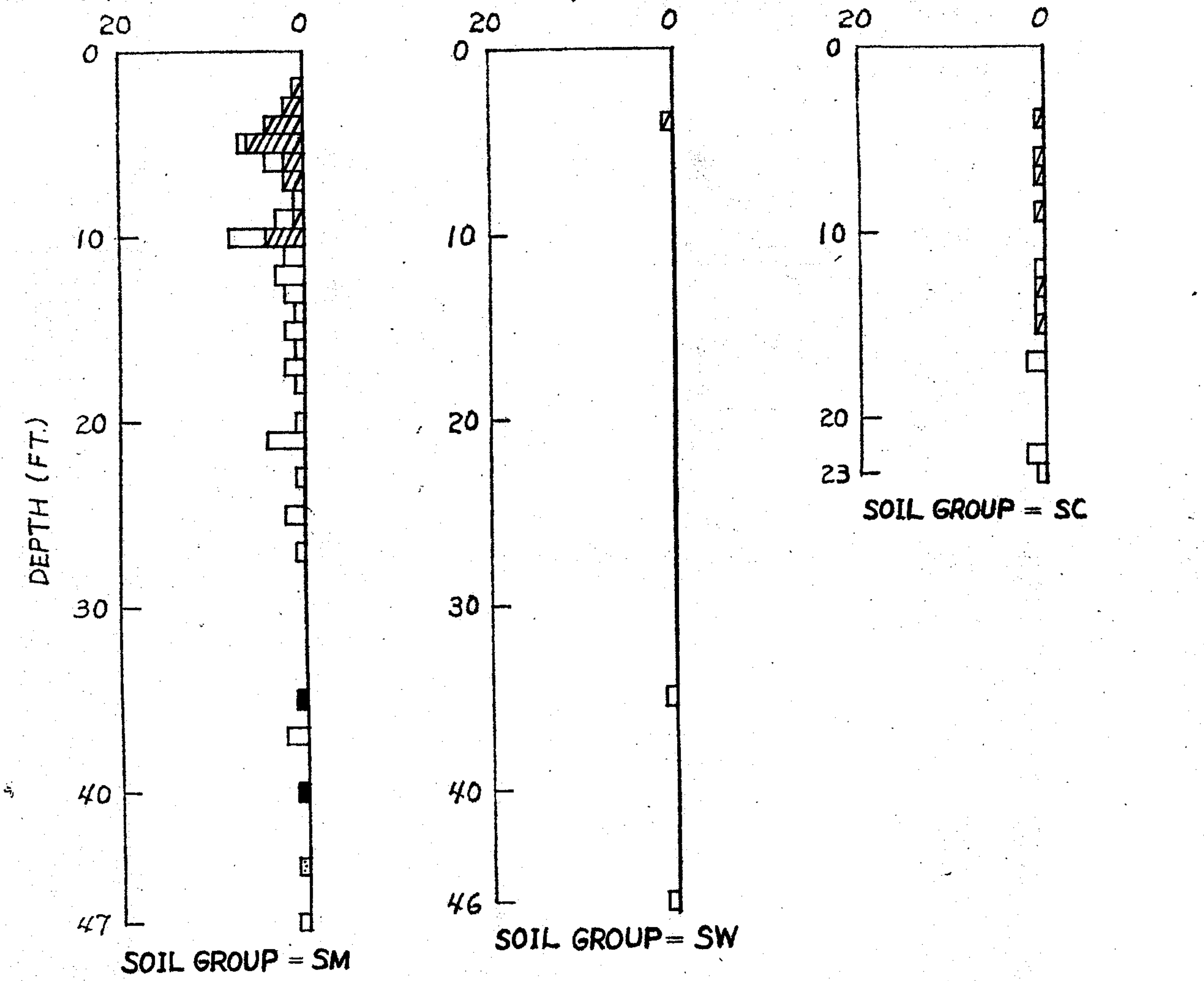
CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY–MARCH

NTS 107C
MACKENZIE DELTA

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



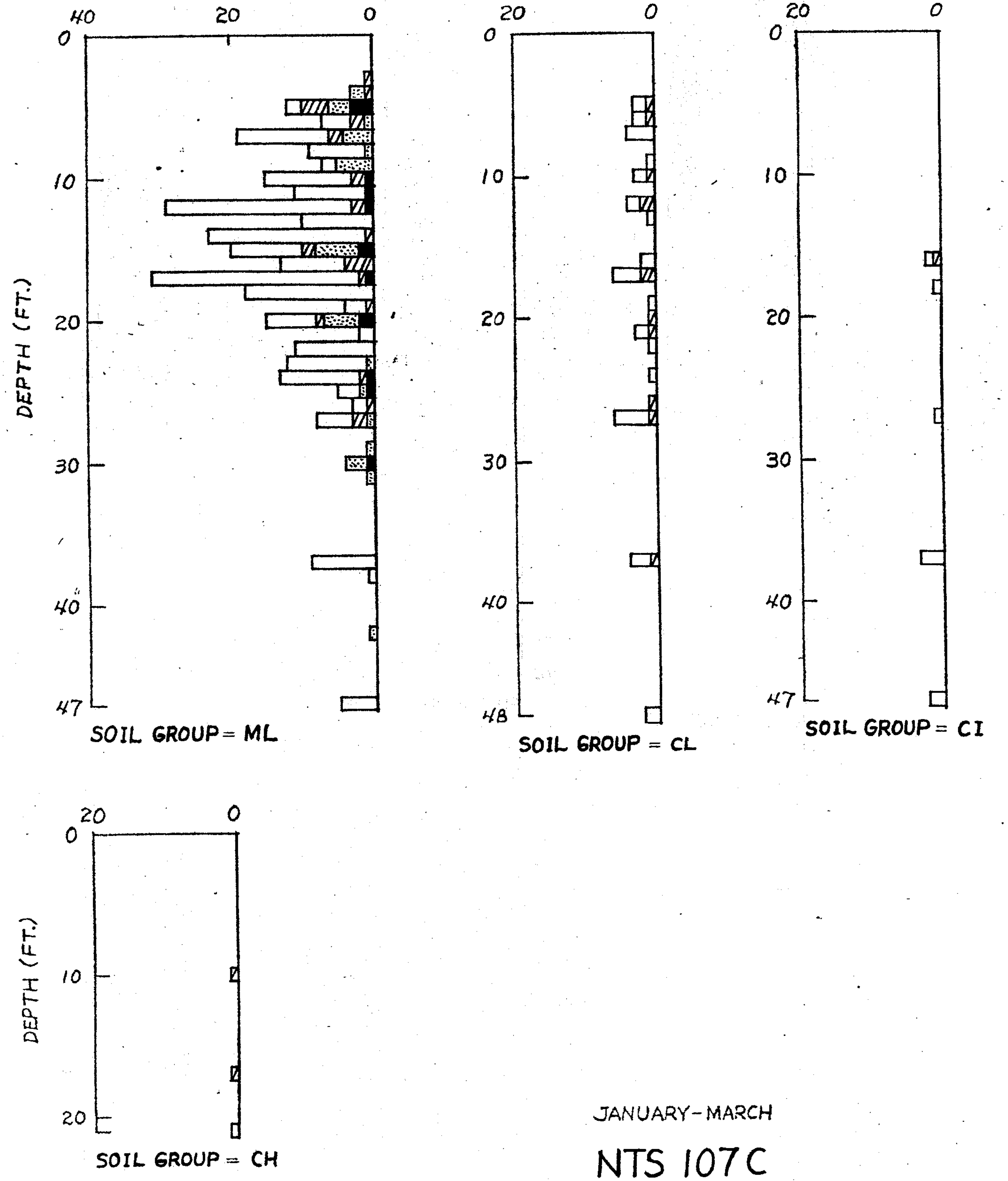
JANUARY-MARCH

NTS 107C

MACKENZIE DELTA

BELOW SEABED

CUMULATIVE FREQUENCIES OF OCCURRENCE OF ICE; V, N AND F TYPES OF ICE; AND SOILS NOT FROZEN



JANUARY-MARCH

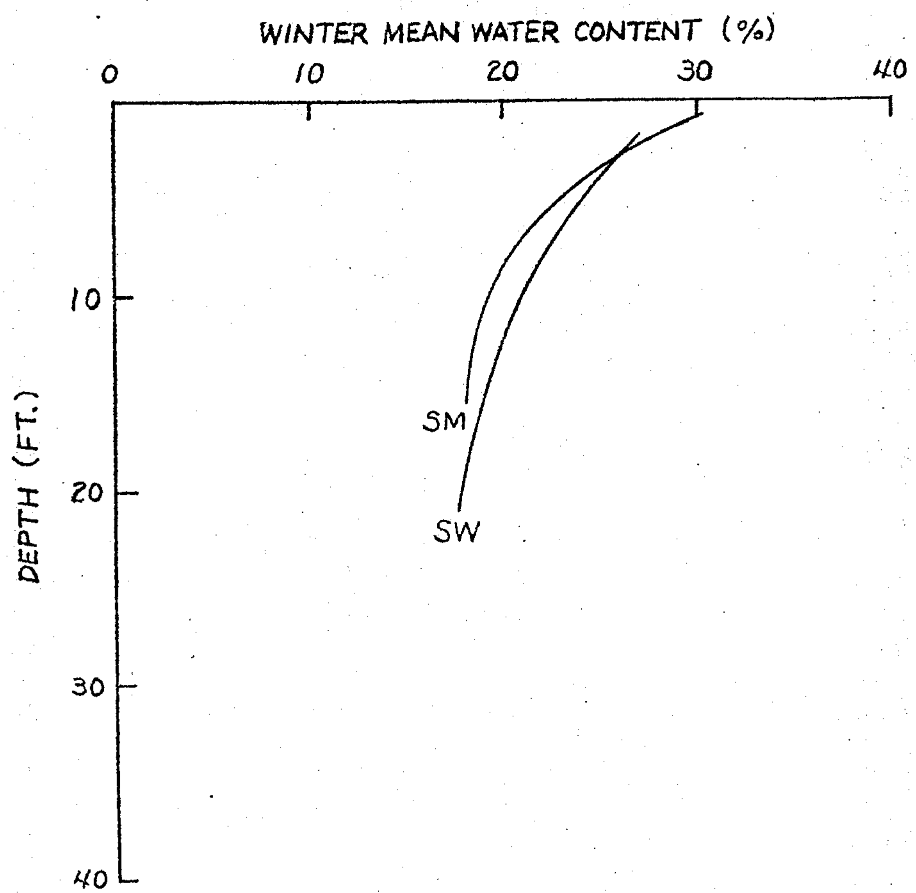
NTS 107C
MACKENZIE DELTA

BELOW SEABED

APPENDIX V

PLOTS OF WINTER MEAN WATER CONTENT VS. DEPTH

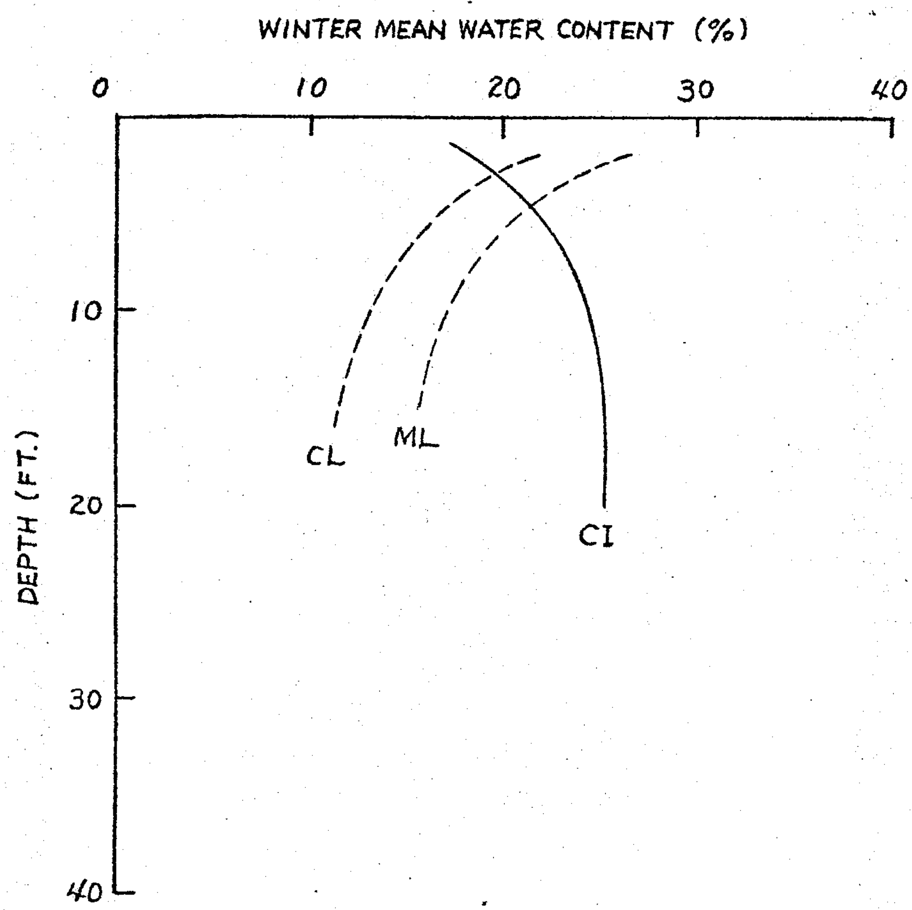
---- Line not well defined



NOVEMBER - MARCH

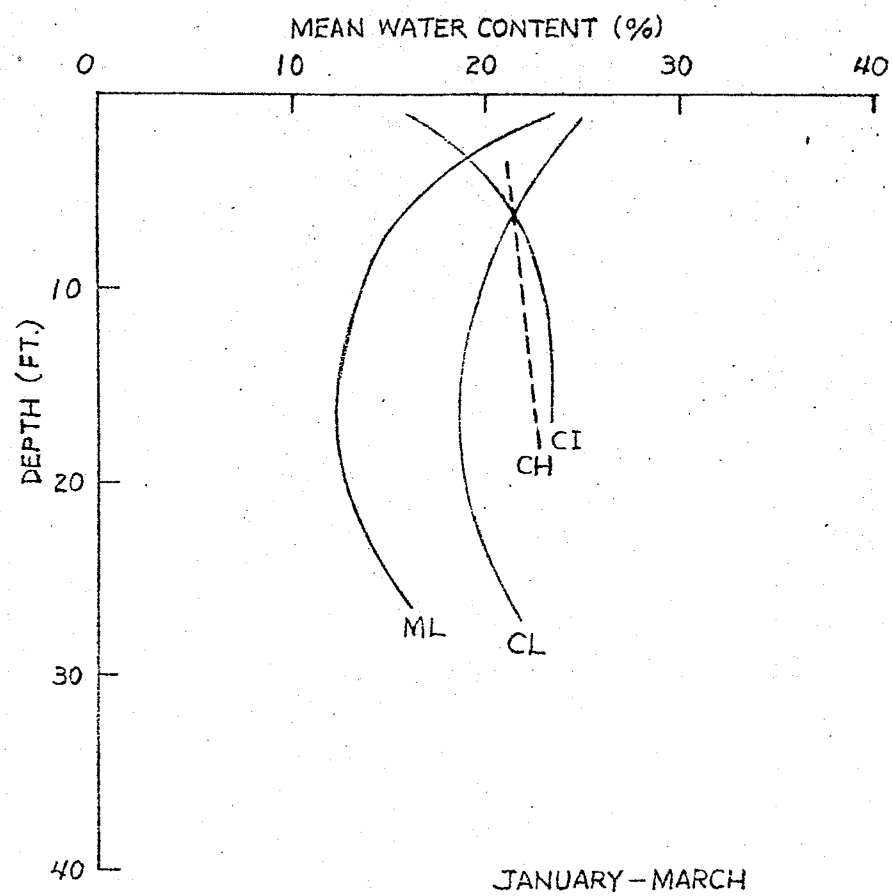
NTS 95 H

FORT SIMPSON

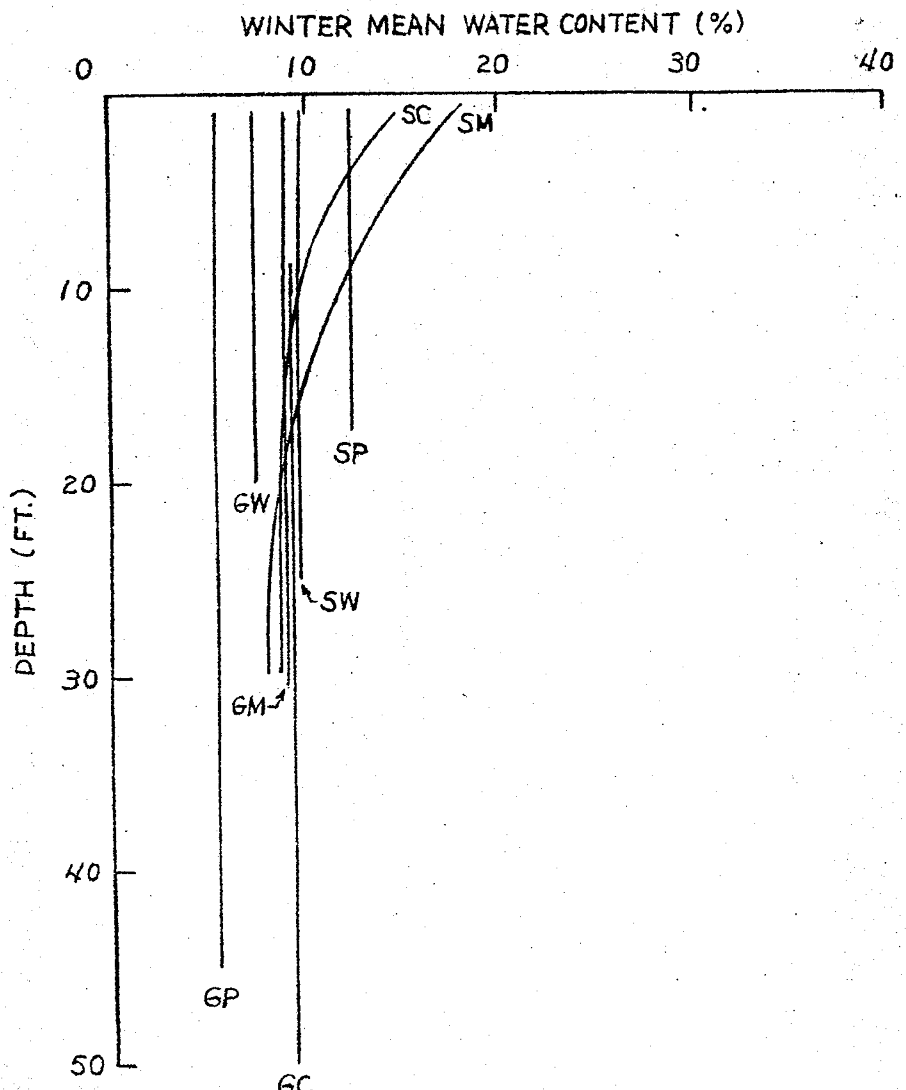


NOVEMBER–MARCH

NTS 95 H
FORT SIMPSON



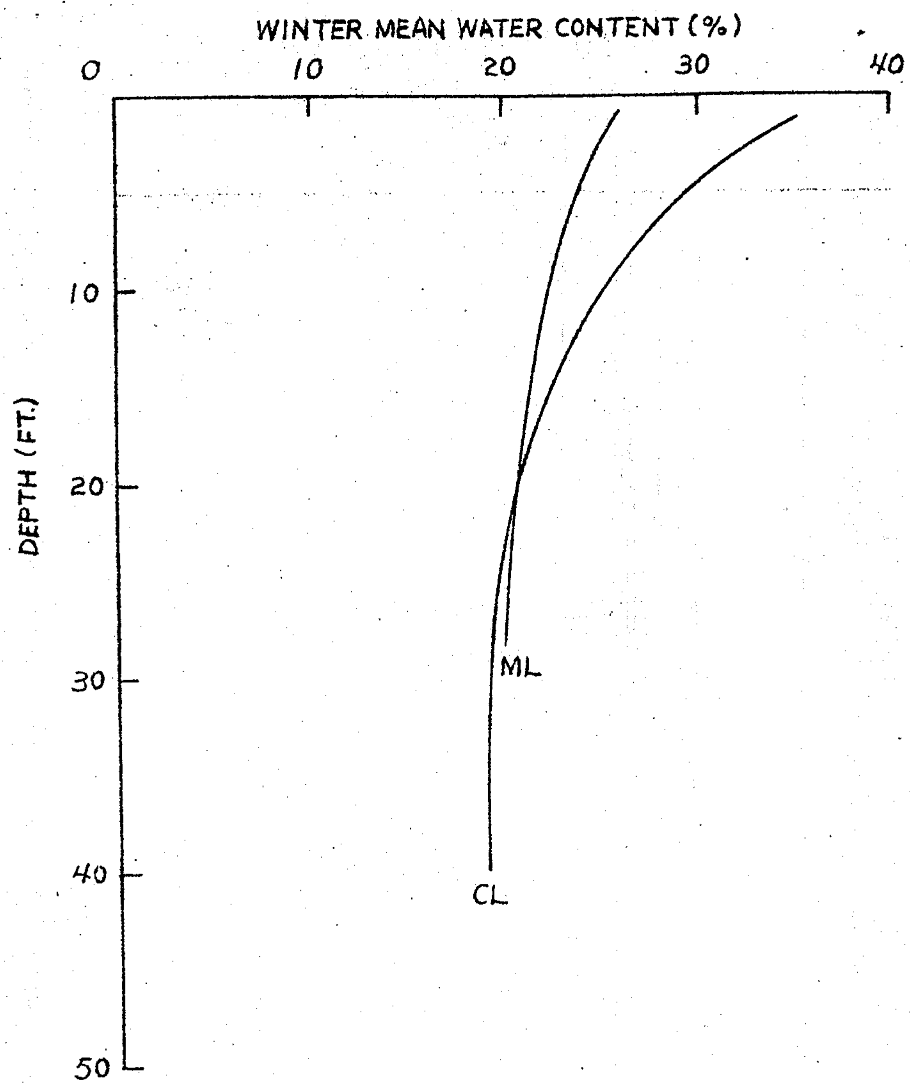
NTS MAP NO. 95J
CAMSELL BEND



NOVEMBER - MARCH

NTS 95 O

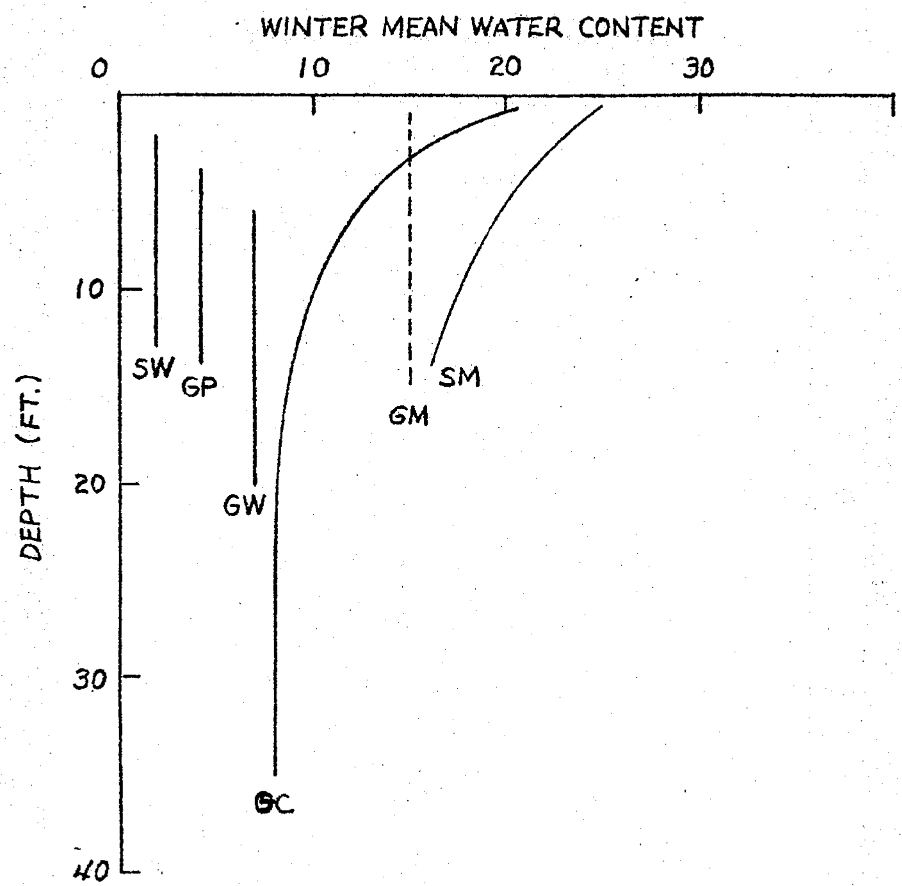
WRIGLEY



NOVEMBER – MARCH

NTS 95 O

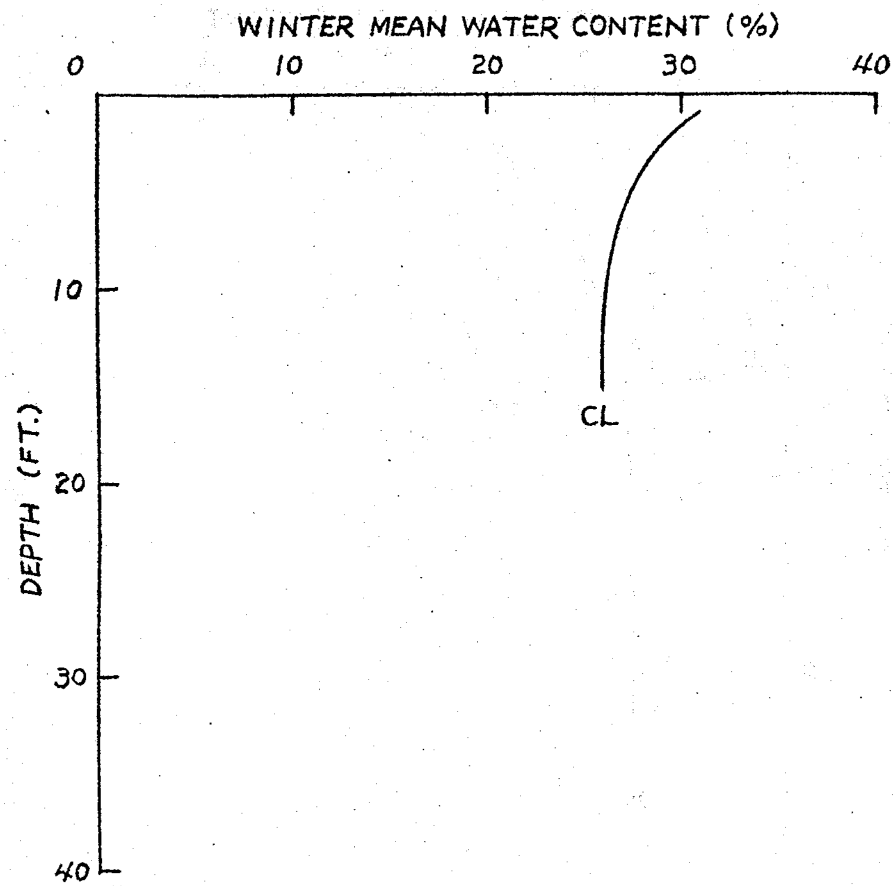
WRIGLEY



NOVEMBER – MARCH

NTS 95 N

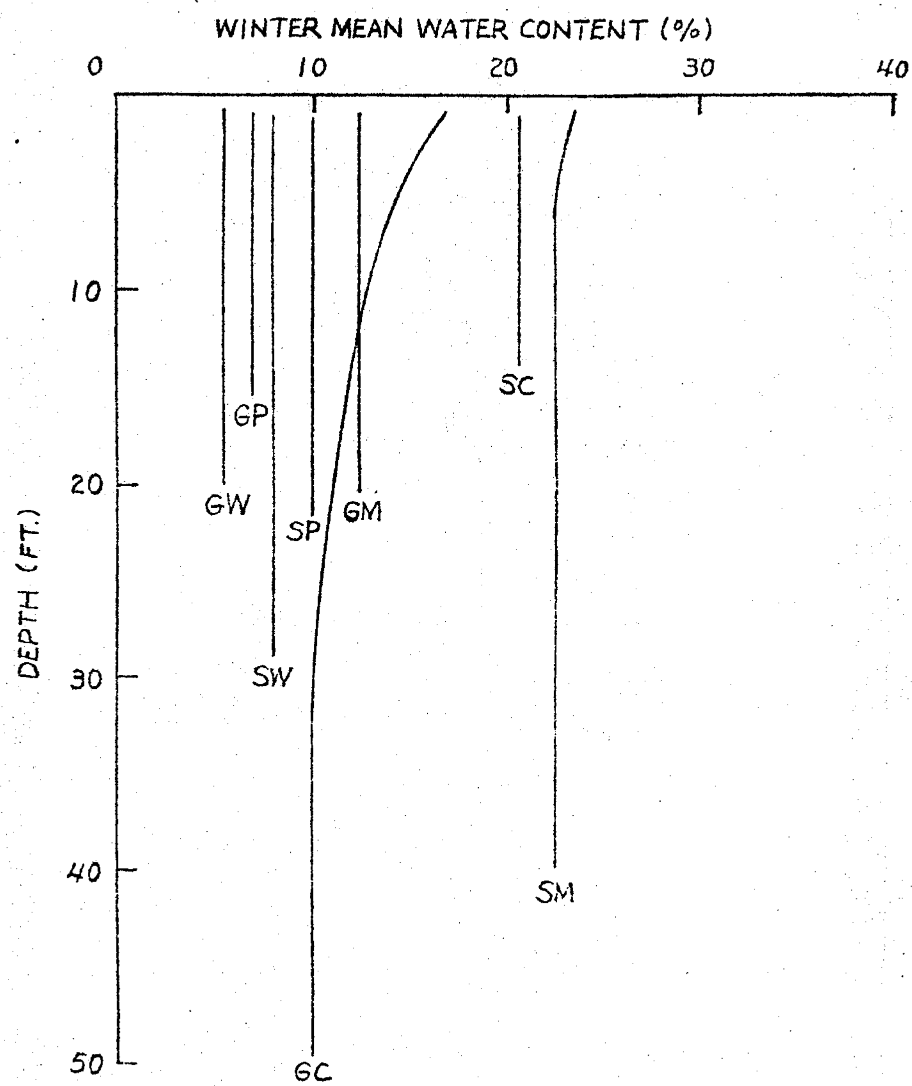
DAHADINNI RIVER



NOVEMBER-DECEMBER

NTS 95 N

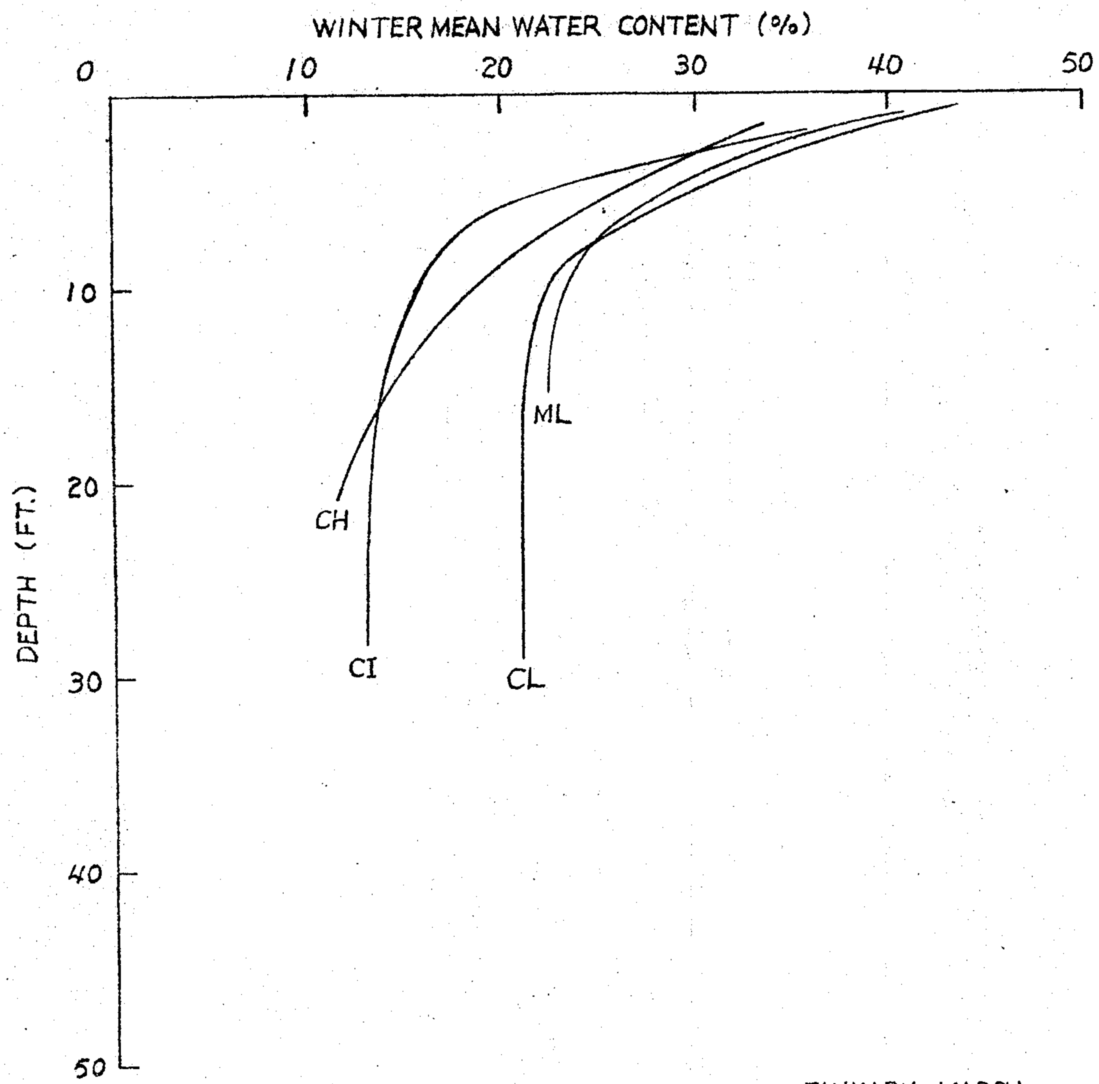
DAHADINNI RIVER



JANUARY - MARCH

NTS 96C

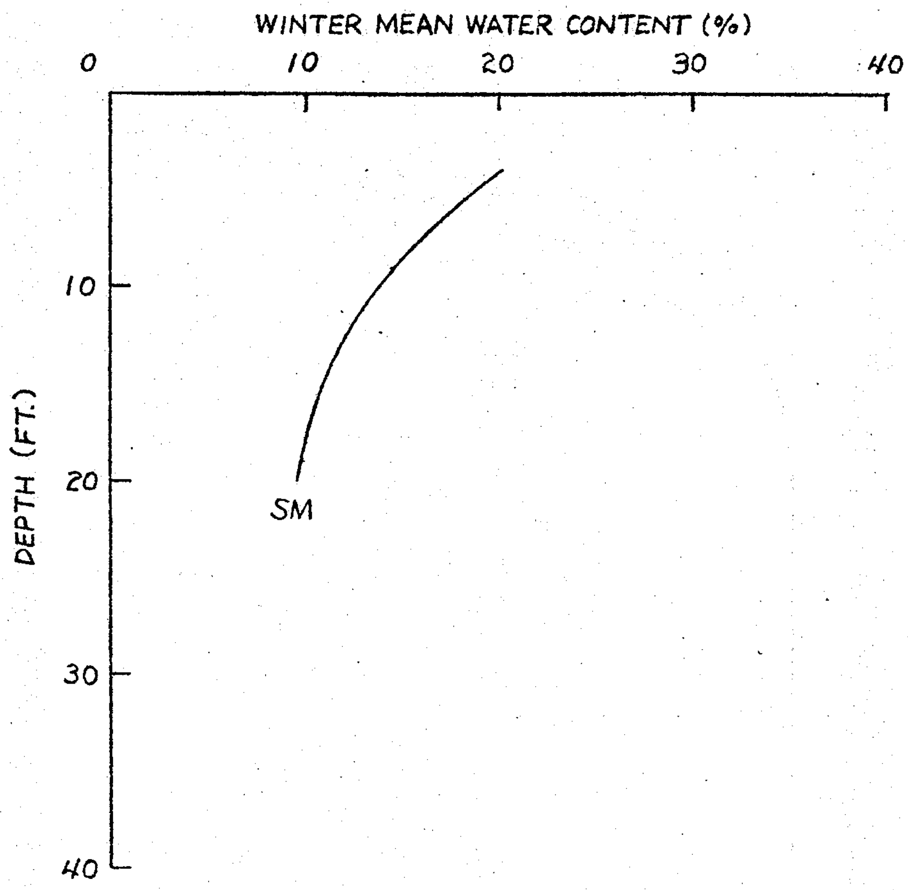
FORT NORMAN



JANUARY - MARCH

NTS 96C

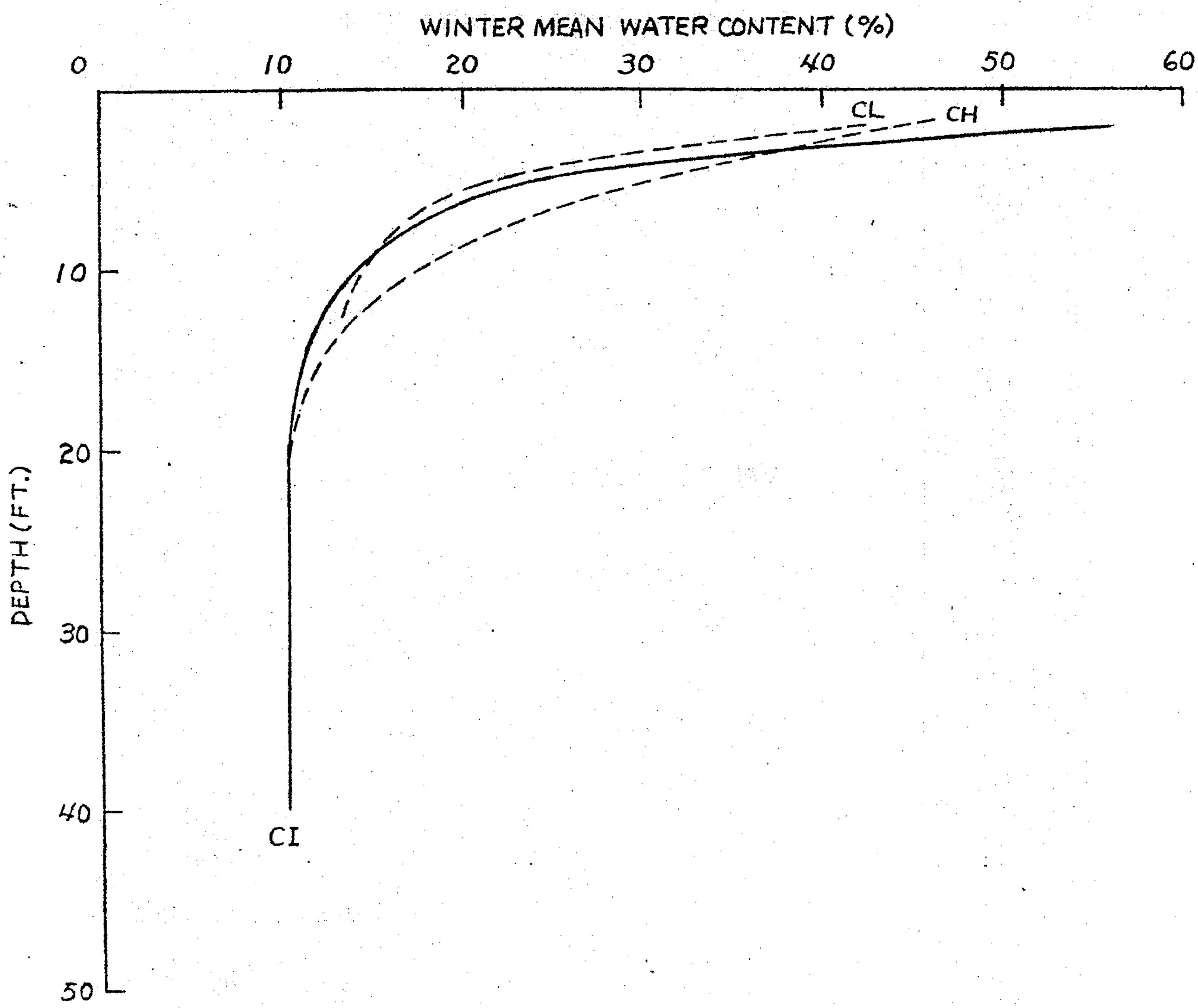
FORT NORMAN



NOVEMBER – MARCH

NTS 96 F

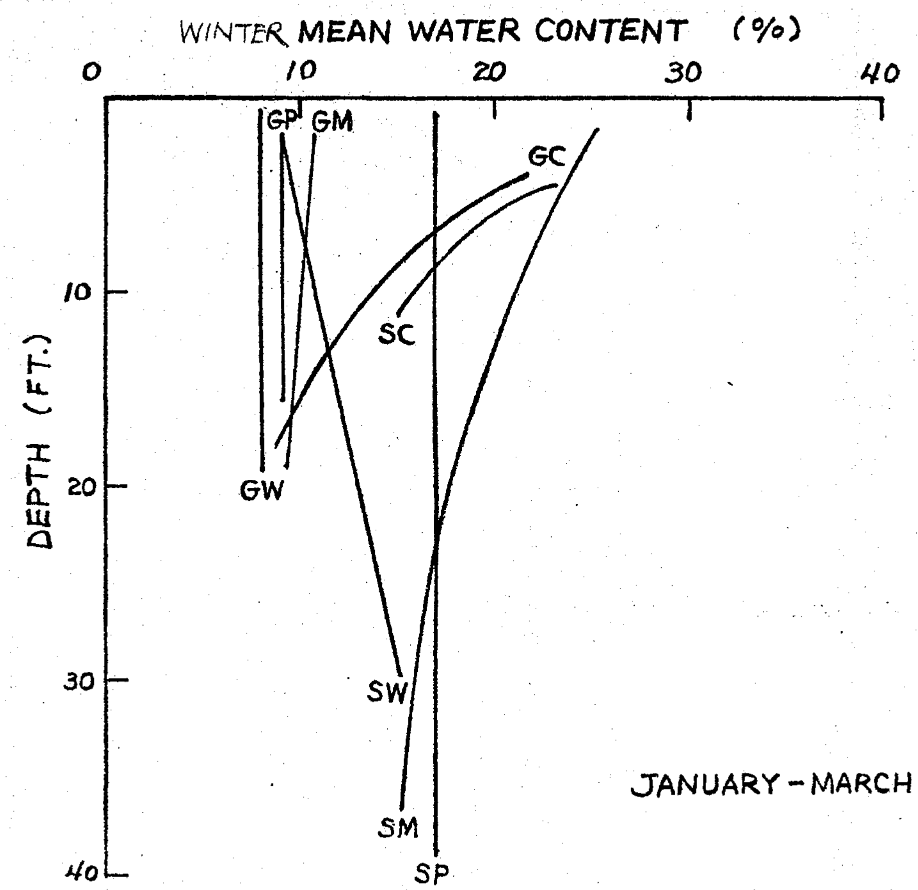
MAHONY LAKE



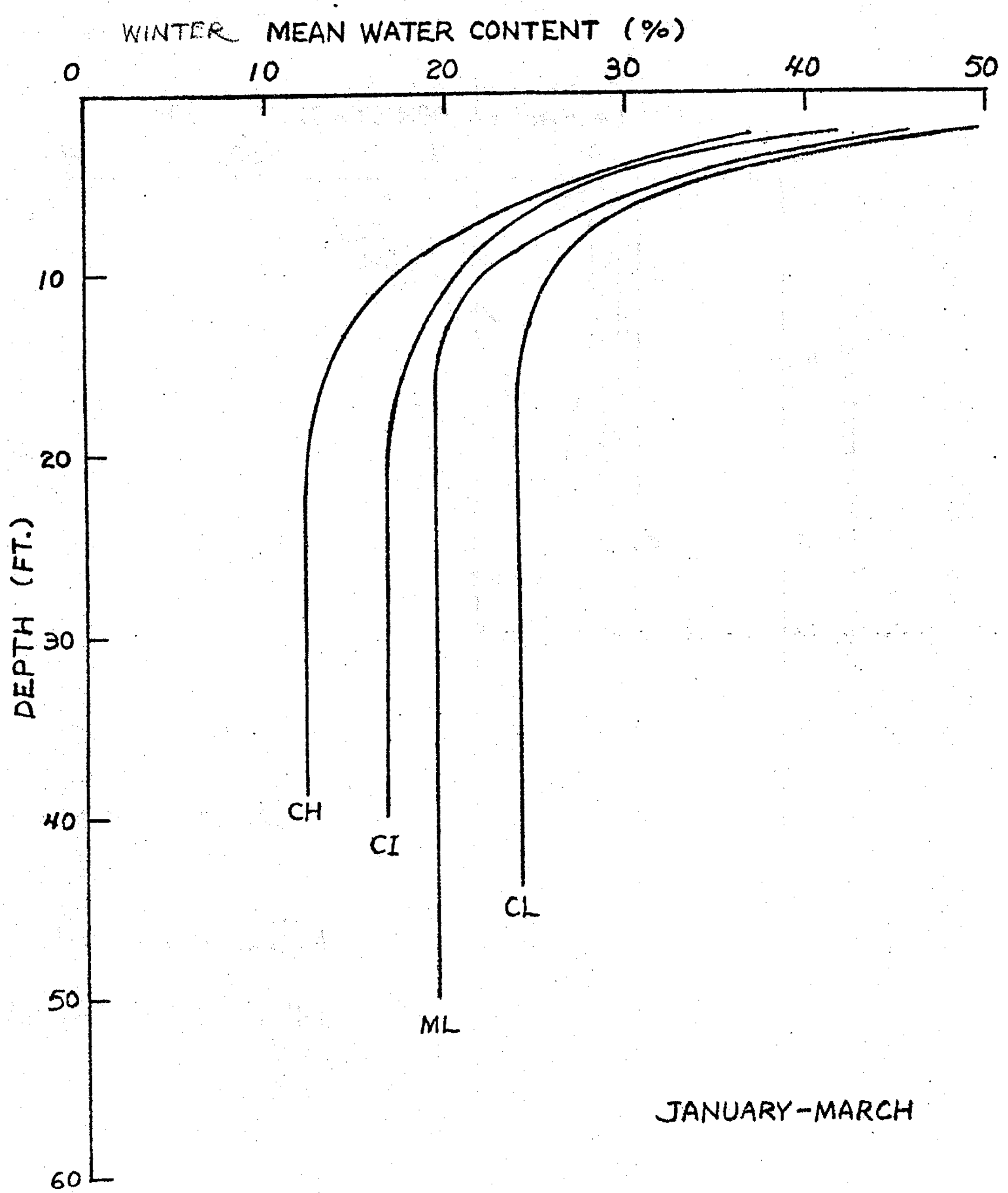
NOVEMBER–MARCH

NTS 96 F

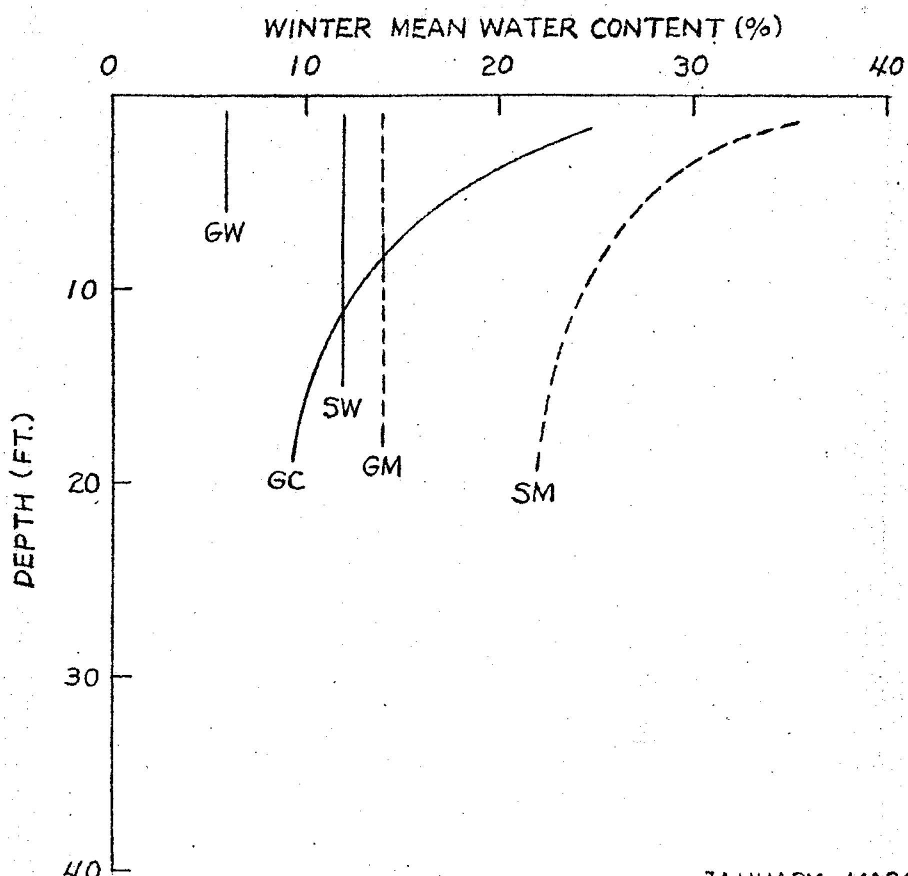
MAHONY LAKE



NTS MAP NO. 96 E
NORMAN WELLS



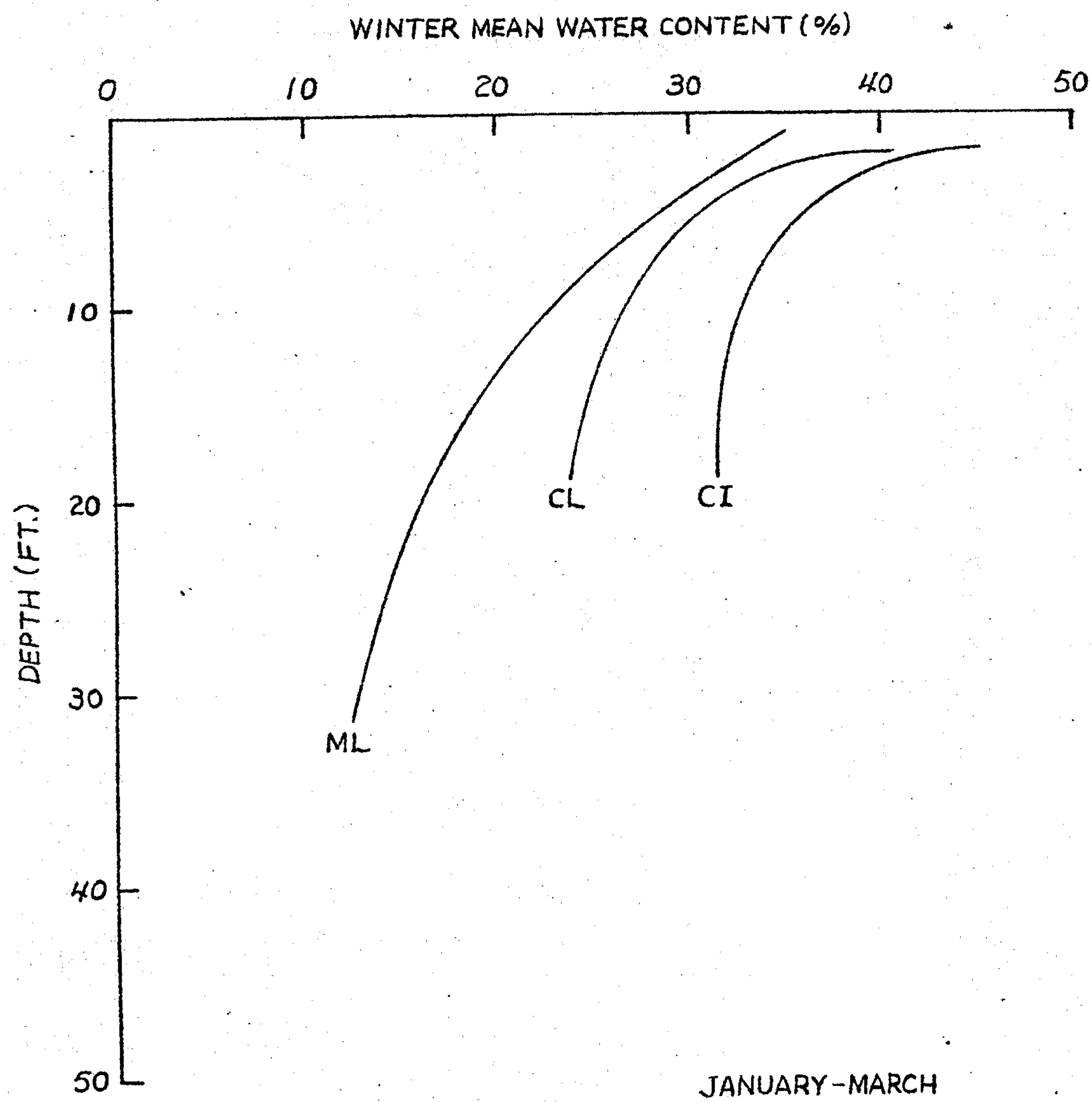
NTS MAP NO. 96 E
NORMAN WELLS



JANUARY-MARCH

NTS 106 H

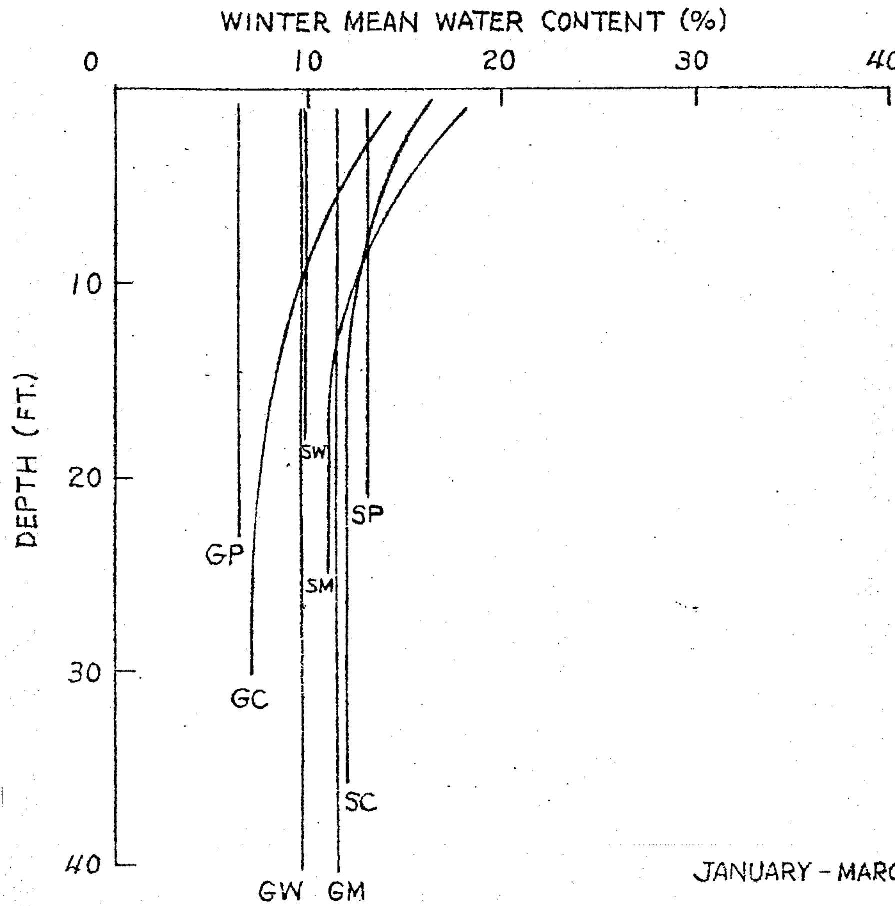
SANS SAULT RAPIDS



JANUARY-MARCH

NTS 106H

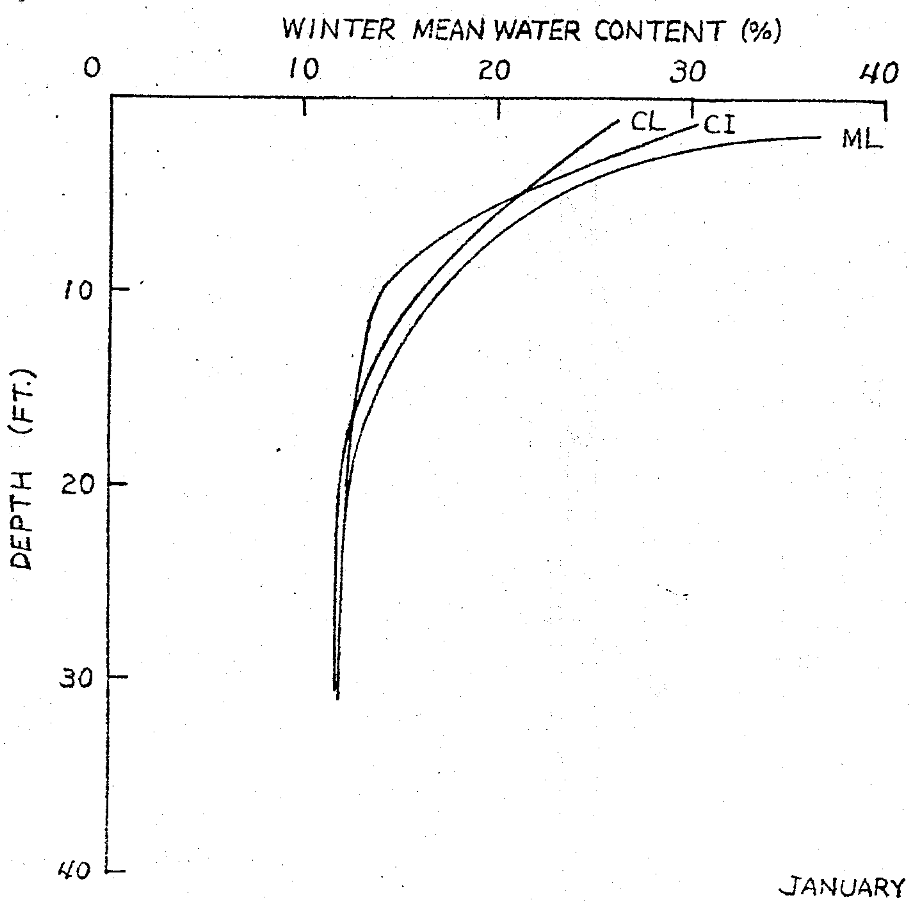
SANS SAULT RAPIDS



JANUARY - MARCH

NTS 106 I

FORT GOOD HOPE



JANUARY - MARCH

NTS 106 I

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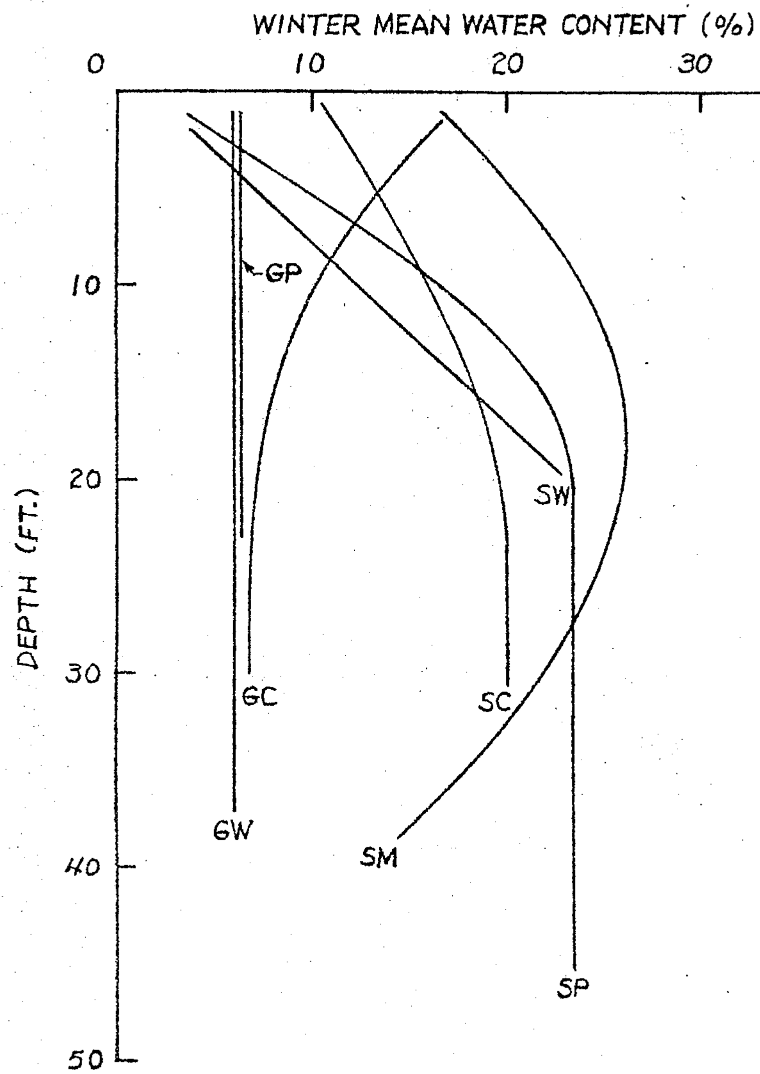
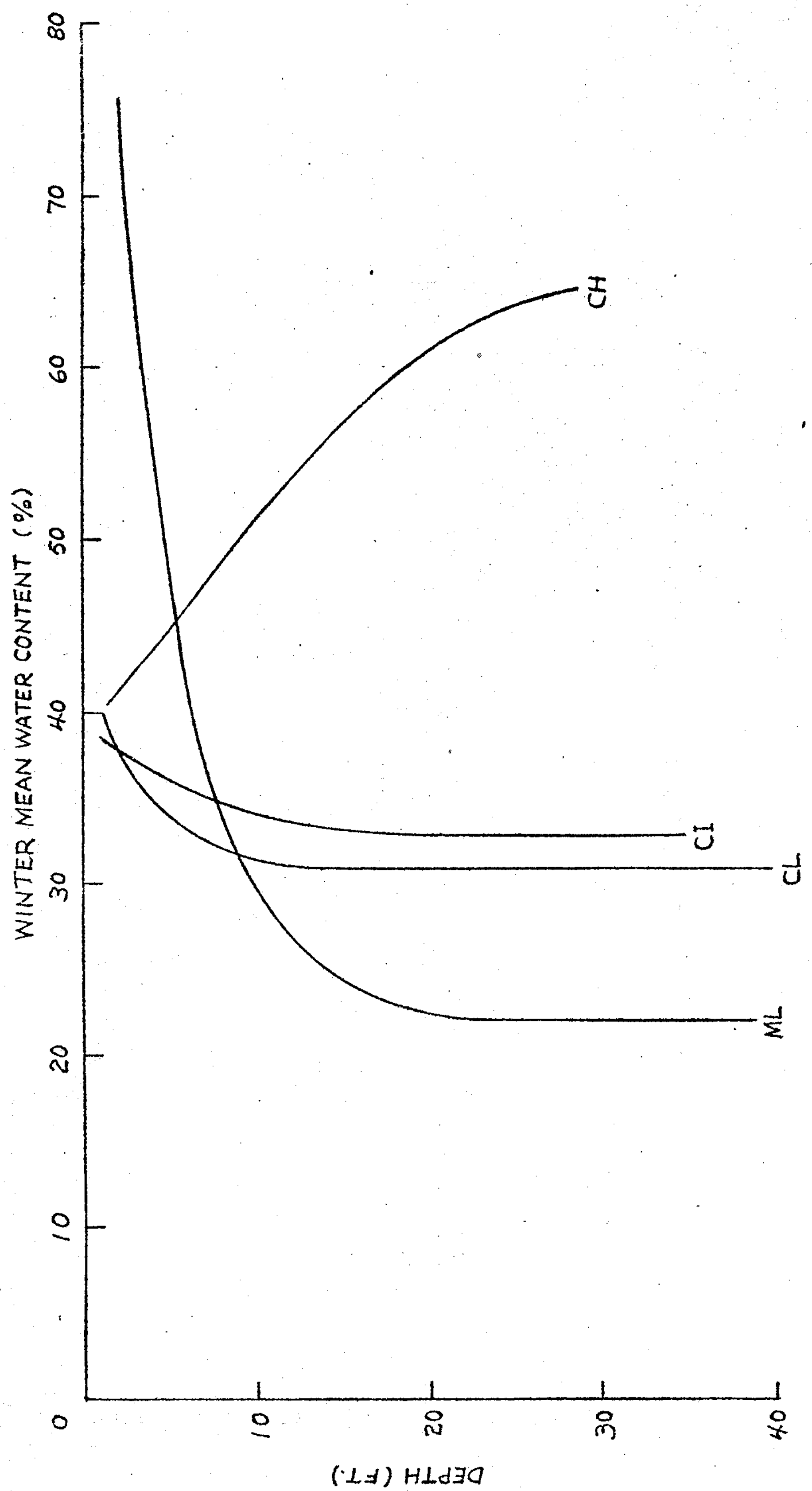


JANUARY – MARCH

NTS 106 O

TRAVAILLANT LAKE



JANUARY-MARCH
NTS 106 O
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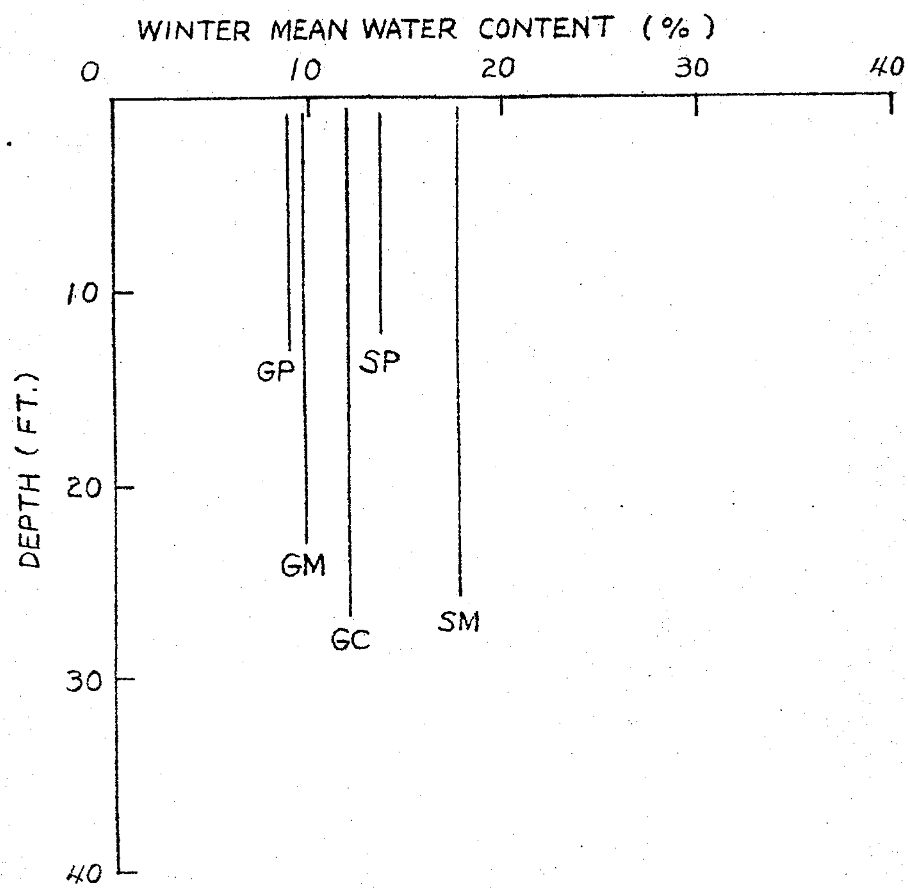
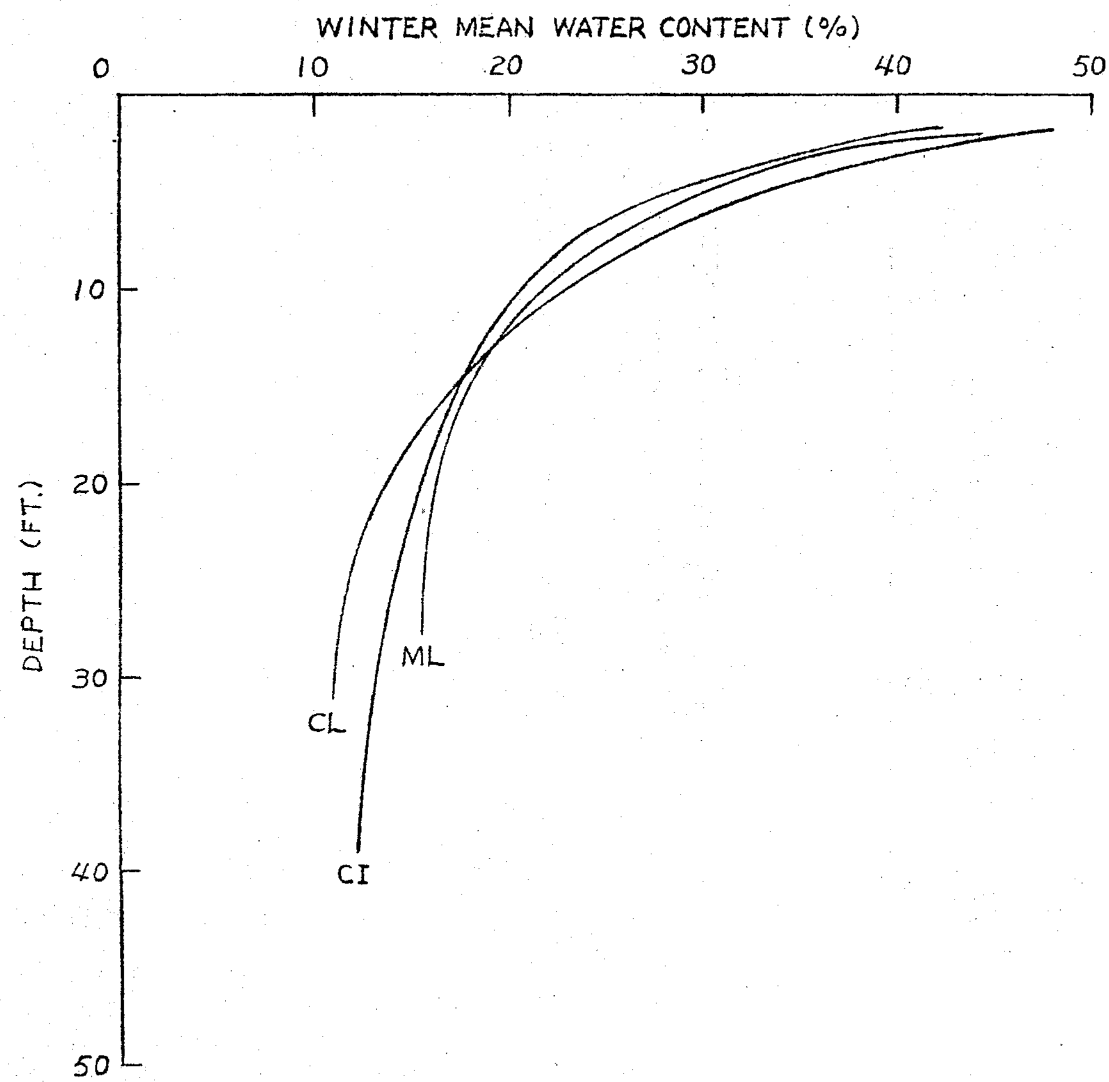


NOVEMBER – DECEMBER

NTS 106 N

ARCTIC RED RIVER



NOVEMBER – DECEMBER

NTS 106 N

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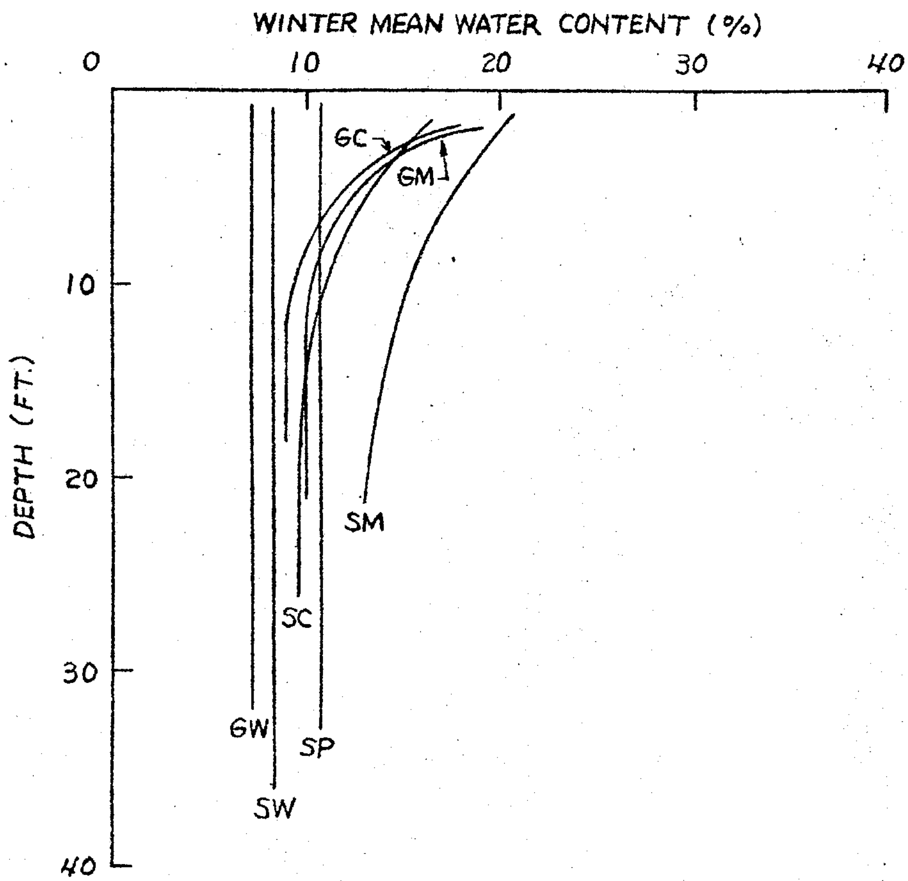
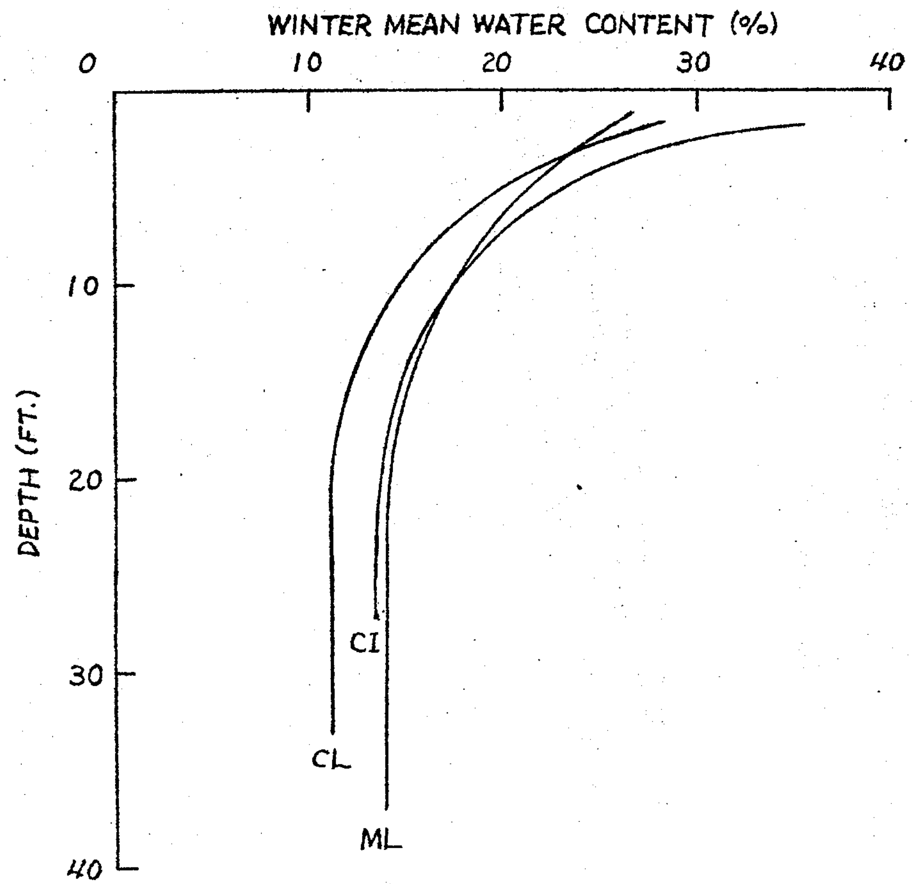


NOVEMBER–MARCH

NTS 106 M

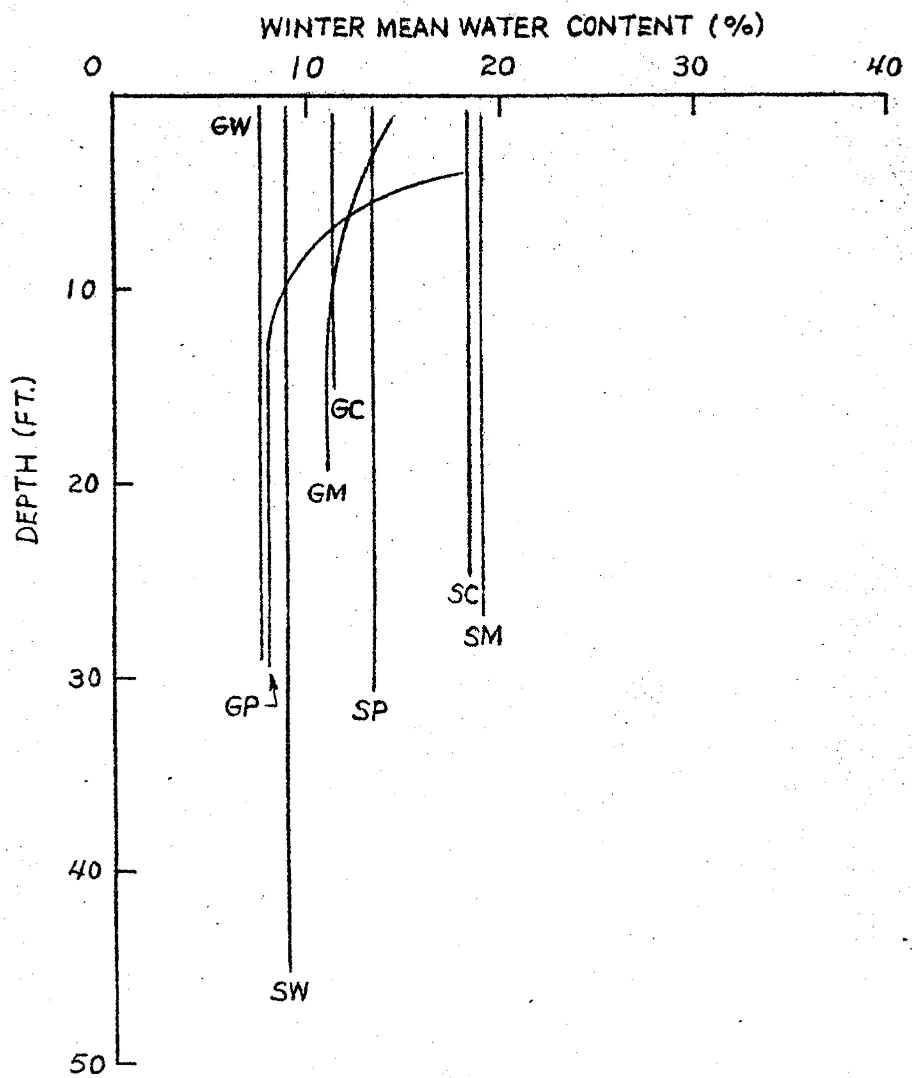
FORT McPHERSON



NOVEMBER–MARCH

NTS 106 M

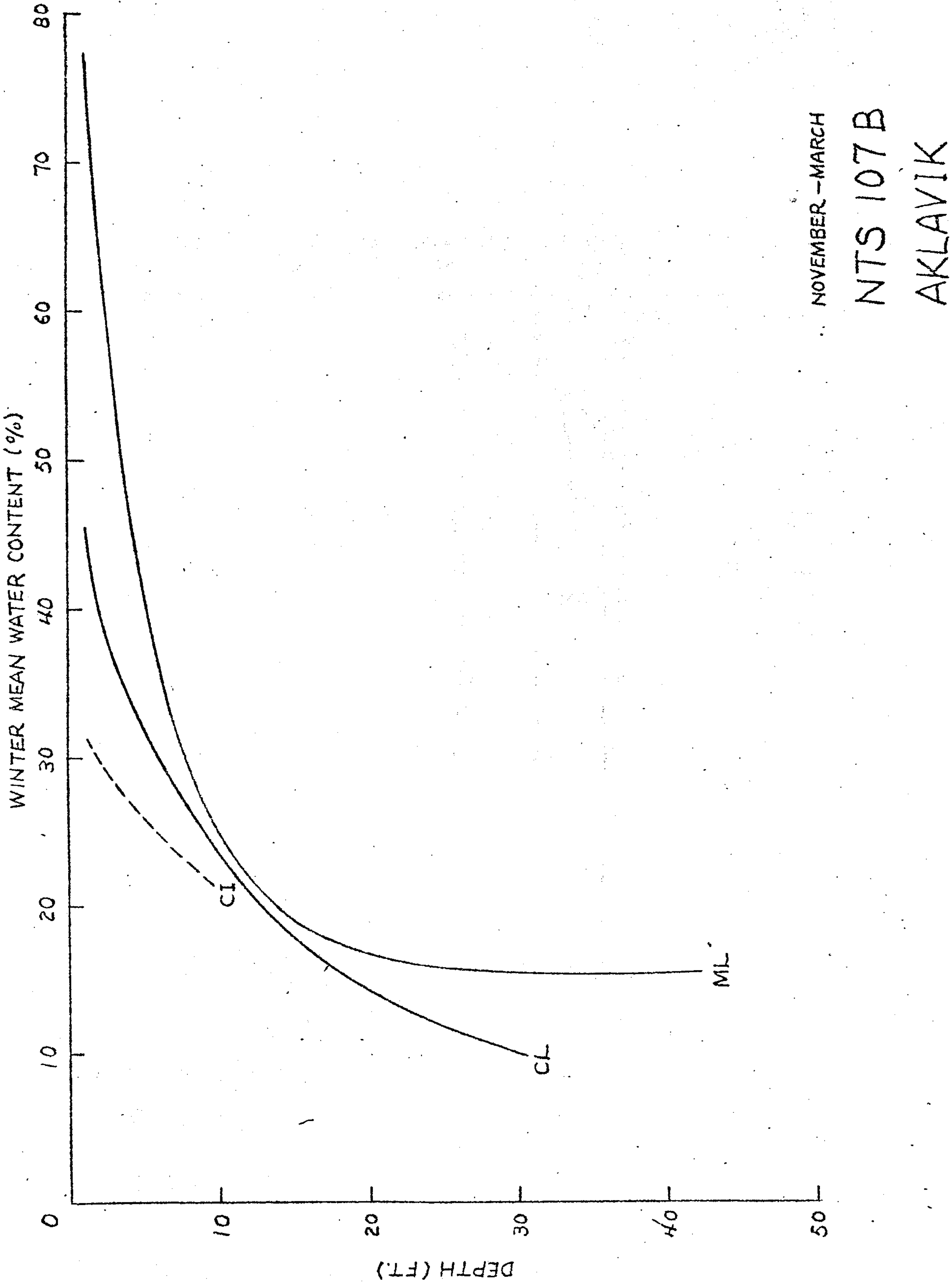
FORT McPHERSON

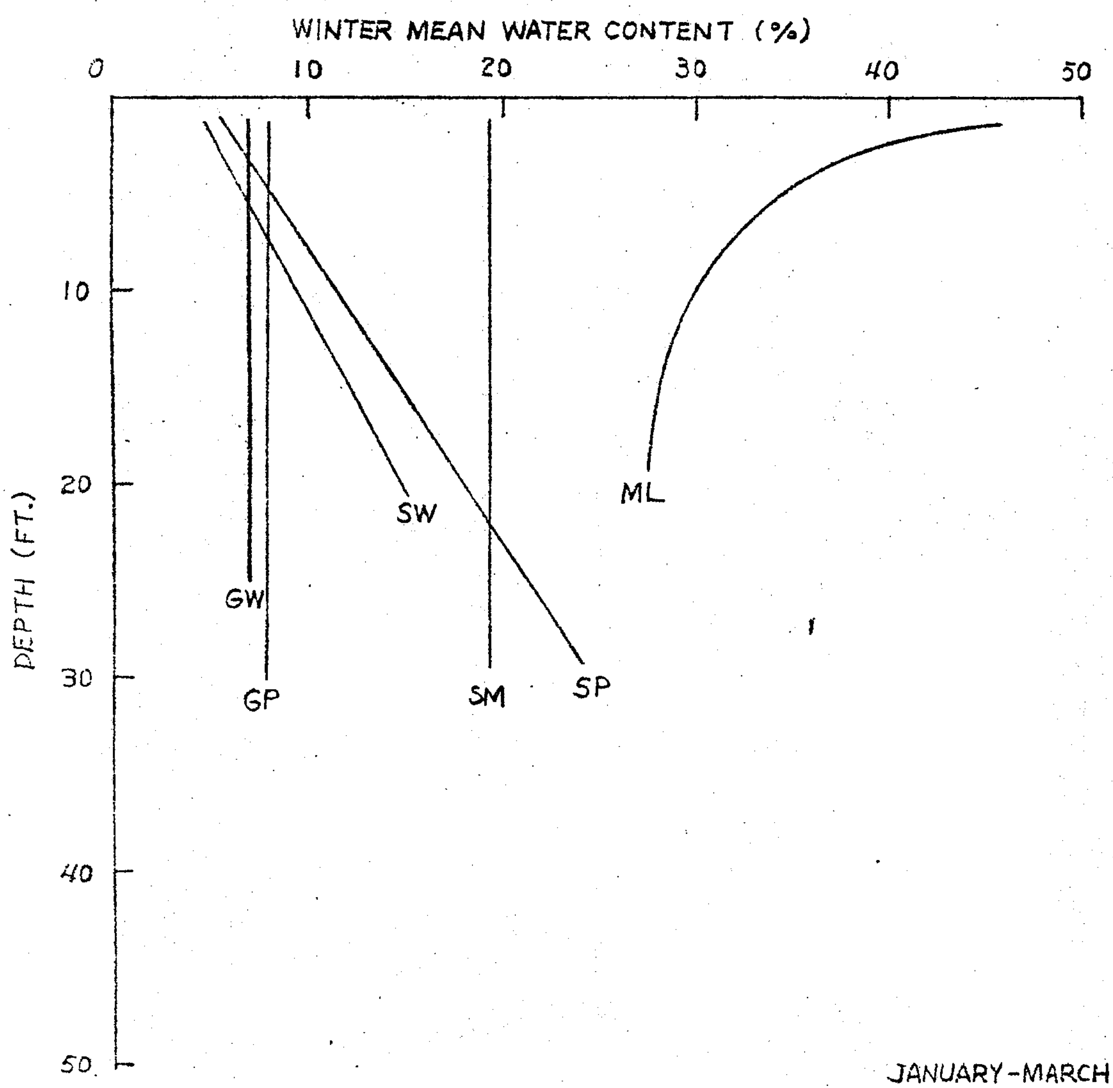


NOVEMBER–MARCH

NTS 107 B

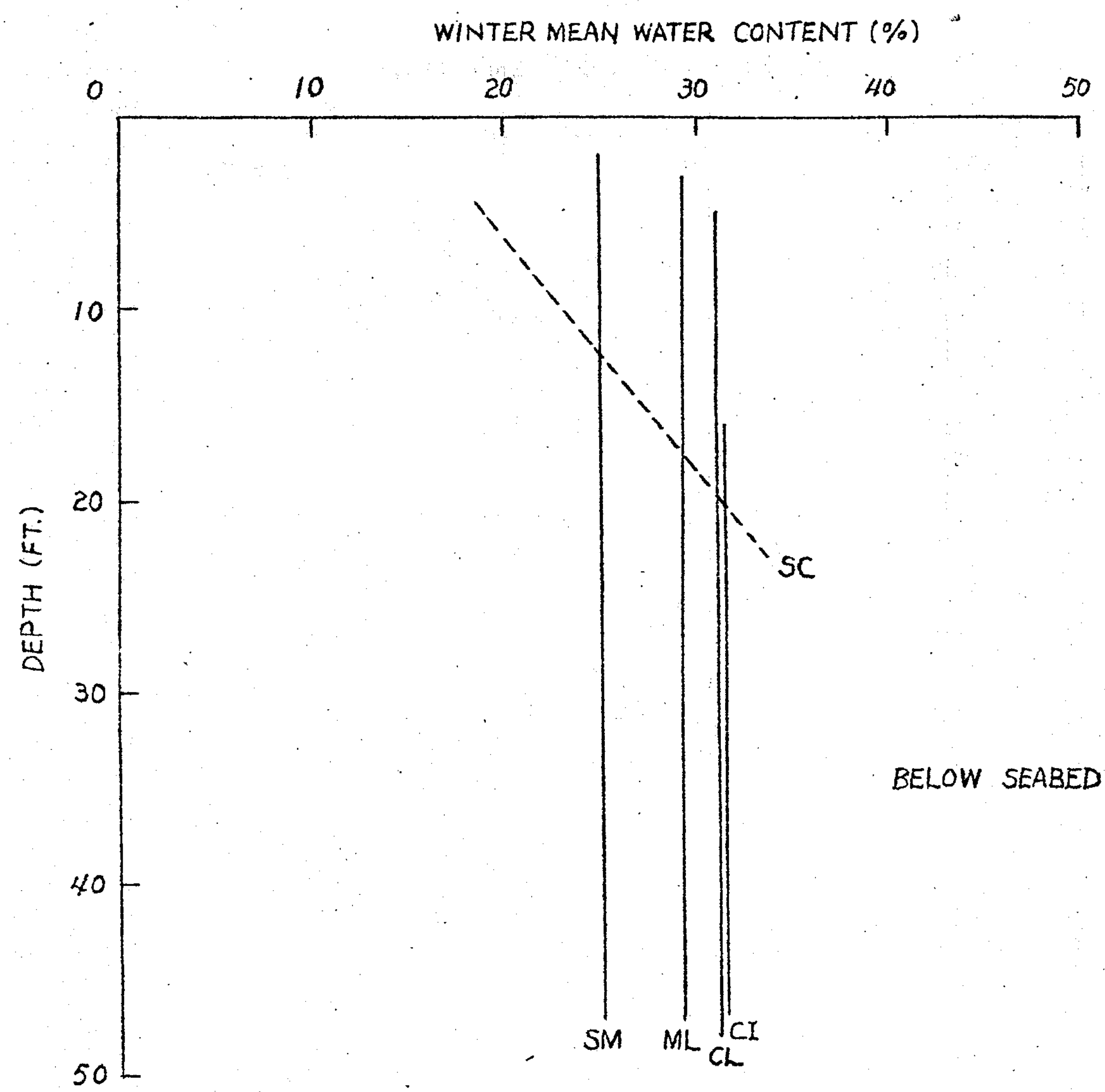
AKLAVIK


WINTER MEAN WATER CONTENT (%)
DEPTH (FT.)
0
10
20
30
40
50
60
70
80
CI
CL
ML
NOVEMBER - MARCH
NTS 107 B
AKLAVIK



JANUARY-MARCH

NTS 107C
MACKENZIE DELTA



JANUARY-MARCH

NTS 107C

MACKENZIE DELTA

APPENDIX VI

WINTER MEAN ICE CONTENTS

NTS 96C		WINTER ICE CONTENT (%)								
DEPTH		SOIL GROUP								
		SP			SM			SC		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1				25.0					
	2	20.0			6.9	4-20	4.2			
	3				40.0					
	4	10.0			13.6	5-40	11.7			
	5				38.5	37-40				
	6	20.5	1-40		11.6	1-70	15.2			
	7				29.5	20-39				
	8				13.1	1-70	16.6			
	9	1.0								
	10	10.0			12.2	1-70	16.4			
	11									
	12				10.1	1-70	15.5	10.0		
	13							5.0		
	14				10.0	1-70	16.2	10.0	5-15	
	15									
	16				8.0	6-10				
	17									
	18									
	19									
	20									
	21									
	22				6.0					
	23									
	24				6.0					
	25									
	26				6.0					
	27									
	28				13.5	7-20				
	29									
	30				7.0					
	31									
	32				7.0					
	33									
	34				6.0	5-7				
	35									
	36				7.0					
	37				5.0					
	38				7.0					
	39									
	40									
	41									
	42									
	43				5.0					
Mean of the Soil Group		13.7			11.8			8.8		

NTS 96C		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		ML			CL			CI			CH		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1	5.0			5.0	5-5	0.0	29.2	10-40	12.8			
	2	22.6	1-75	20.4	10.0			25.3	5-80	15.2	17.1	5-60	20.2
	3	45.0	20-70					36.3	25-65	13.0			
	4	20.8	5-75	18.6	5.5	5-10	1.6	23.5	5-60	15.1	23.0	5-40	13.5
	5				5.0			21.7	5-65	25.2	15.0		
	6	18.0	10-30	7.6	37.5	5-70		15.4	1-45	11.3	29.2	10-60	22.2
	7							10.4	2-20	8.8			
	8	15.0	5-30		45.0	5-70		11.6	1-30	9.4	22.5	20-25	
	9				5.0	5-5	0.0	25.0	20-20				
	10	13.3	5-20		45.3	1-70		10.6	1-20	8.3	19.0	10-30	7.4
	11							10.0					
	12	22.5	15-30		60.0	50-70		15.5	1-50	12.1	18.8	10-25	
	13							12.5	10-20				
	14	10.0	5-15		22.6	1-70	26.7	11.6	1-49	15.5	22.5	15-35	
	15							22.5	20-25		15.0		
	16	20.0			5.0			12.8	1-20		20.0	10-35	10.5
	17										10.0		
	18							25.0			5.0		
	19				5.0								
	20										5.0		
	21												
	22				30.0								
	23												
	24							50.0					
	25												
	26												
	27												
	28												
	29												
	30							5.0					
	31												
	32												
	33												
	34	20.0											
	35												
	36												
	37												
	38										20.0		
	39												
	40												
	41												
	42										5.0		
	43												
	44												
	45							30.0					
	46												
	47							20.0					
Mean of the Soil Group		20.5			19.8			18.7			19.9		

NTS 96C		WINTER ICE CONTENT (%)								
DEPTH		SOIL GROUP								
		OL			OH			PT		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1	52.7	30-99	22.5	35.8	10-80	23.8	28.9	5-60	17.8
	2	47.6	5-90	23.6	31.8	5-70	22.3	44.2	20-80	19.0
	3	60.0			70.0			60.0	60-60	
	4	52.5	30-75	19.4	50.0	40-60		70.0	60-80	
	5									
	6	70.0						90.0		
	7									
	8							8.0		
Mean of the Soil Group		48.6			33.4			34.7		

NTS 96E		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		GW			GP			GM			GC		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1												
	2	12.5	5-20		12.5	10-15		20.0	10-40	12.7	35.0	10-70	
	3							10.0					
	4	10.0			12.5	10-15		30.0	20-40		32.2	1-60	23.5
	5	10.0	10-10					3.0	3-3				
	6				15.0			13.8	5-30		17.0	5-30	9.7
	7	10.0											
	8	10.0						10.0			14.2	5-30	9.2
	9												
	10	3.0						7.5	5-10		9.3	2-20	
	11										2.0		
	12							10.0			5.7	2-10	
	13												
	14							10.0	5-15		5.0		
	15												
	16							15.0			20.0		
	17												
	18												
	19												
	20												
	21												
	22												
	23												
	24												
	25												
	26												
	27												
	28							5.0					
Mean of the Soil Group		9.8			13.0			13.9			18.4		
		OL			OH			PT					
	1	42.6	13-50	27.1	30.0	10-50		21.8	10-30				
	2	32.0	3-90	22.8	48.4	10-90	21.4	44.0	7-92	23.8			
	3	16.3	13-21					15.0					
	4				53.8	25-80							
	5	30.8	7-85	18.2	48.0			45.4	2-84	31.8			
	7												
	8												
	9	21.5	7-35										
	10												
Mean of the Soil Group		30.8			48.5			41.6					

NTS 96E		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		SW			SP			SM			SC		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1												
	2	20.0			7.2	2-25	10.0	19.5	3-50	19.0			
	3												
	4							10.0			25.0	20-30	
	5				2.8	2-3		8.5	2-32	8.4			
	6				15.0	10-20		33.3	10-70		15.0		
	7												
	8	10.0			20.0			10.0	10-10				
	9	7.5	5-10		3.0	3-3		2.0					
	10	20.0			5.3	2-20	7.2	7.8	3-20	7.5	15.0		
	11												
	12	20.0						5.0					
	13												
	14	20.0						7.5	5-10				
	15							1.7	1-3				
	16							20.0					
	17												
	18				2.5	2-3		2.0					
	19												
	20							1.0					
	21												
	22												
	23												
	24												
	25							2.0	1-3				
	26												
	27												
	28												
	29												
	30							1.0					
	31												
	32							5.0					
	33												
	34							5.0					
	35												
	36												
	37												
	38												
	39												
	40												
	41												
	42												
	43												
	44												
	45												
	46							10.0					
Mean of the Soil Group		15.0			6.2			11.8			20.0		

NTS 96E		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		ML			CL			CI			CH		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1				15.0			15.0			10.0		
	2	22.5	3-83	17.7	33.4	2-90	22.6	26.1	1-75	18.6	18.4	5-40	13.6
	3							51.3	30-70				
	4	23.0	3-70	20.1	37.2	5-80	20.6	21.8	2-75	16.4	39.6	2-80	27.2
	5	12.5	1-48	10.8	23.2	1-92	23.1	20.4	3-81	18.4	17.0	3-30	
	6	20.0	10-35	9.4	27.9	5-60	17.4	19.8	1-75	16.7	19.1	2-50	19.7
	7	17.0			17.5	10-20		26.3	10-49		30.0		
	8	17.0	10-30	8.4	15.7	5-50	15.9	12.7	1-75	11.2	12.4	2-50	14.8
	9	4.0			3.2	2-5	1.1	10.0			20.0	7.43	
	10	5.9	1-25	6.0	13.7	1-71	13.9	14.1	1-73	16.8	17.3	5-77	19.4
	11							10.0	10-10				
	12	21.7	15-30		10.0	10-10		8.3	1-30	7.7	10.3	2-35	10.6
	13				12.3	10-17		10.0	10-10				
	14				7.0	5-10		9.2	1-25	8.3	6.6	2-15	4.4
	15				12.9	2-65	16.8	18.7	2-63	17.8	35.0		
	16	7.5	5-10					16.9	1-40	12.9	11.0	5-24	
	17	15.0			37.0			15.5	5-26				
	18	2.8	2-3		6.9	1-35	8.9	7.1	2-17	4.5	3.0	1-5	
	19							25.0					
	20	3.0	3-3		7.6	2-35	10.0	15.5	1-55	20.3	12.3	1-40	13.0
	21												
	22	15.0									5.0		
	23	10.0											
	24	15.0											
	26	3.0			2.7	2-3	0.5	5.7	1-13		3.0		
	26												
	27	15.0											
	28	3.0			13.3	2-35		1.7	1-2		10.0		
	29												
	30	3.0	3-3		4.3	3-7		5.7	1-13				
	31												
	32				35.0								
	33												
	34										10.0		
	35	3.0						3.0			1.0		
	36	5.0											
	37							2.0					
	38	5.0			20.5	5-35							
	39												
	40				3.0			3.0			10.0		
	41												
	42												
	43												
	44												
	45	3.0											
Mean of the Soil Group		15.5			22.4			17.9			15.5		

NTS 106H	WINTER ICE CONTENT (%)											
DEPTH	SOIL GROUP											
	ML			CL			CI			CH		
(m) (ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
1												
2	35.4	10-77	21.5	34.9	2-79	19.5	35.2	12-60	13.6	27.5	22-33	
3												
4												
5	37.2	10-90	23.3	23.5	6-90	21.7	27.2	2-55	15.7	12.0		
6												
7												
8												
9	28.0						21.0					
10	20.0	4-40	12.2	22.0	2-79	22.5	28.3	2-90	28.3			
11												
12												
13												
14												
15	20.0	4-30										
16							75.0					
17												
18	12.0			19.7	2-50		38.6	2-77	30.1			
19												
Mean of the Soil Group	29.7			27.3			32.5			22.3		
DEPTH	OL			OH			PT					
1												
2	39.0	30-50		57.0	38-87	21.0	7.5	5-10				
3	28.0						53.7	17-90	22.3			
4												
5	24.0	9-35		43.5	10-85		46.7	10-80				
6												
7												
8												
9				29.0								
10	80.0											
Mean of the Soil Group	37.1			50.7			48.5					

NTS 106I		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		ML			CL			CI			GM		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1	8.3	5-10		10.0								
	2	26.6	5-90	23.0	26.0	10-90	17.6	22.2	17-37	8.3	23.0		
	3	18.6	5-50	11.8	7.5	5-10							
	4	11.9	5-20	5.3	5.0								
	5	22.0	5-90	26.1	21.7	5-70	16.2	22.2	17-37	8.3	23.0		
	6	13.4	5-25	8.7							7.0		
	7	5.0	5-5										
	8	11.3	5-25		10.0								
	9	5.0									20.0		
	10	9.5	5-15	3.4	12.7	5-42	11.2						
	11	7.5	5-10								5.0		
	12	10.0	10-10										
	13	5.0	5-5										
	14	7.3	5-10										
	15	10.0	10-10		5.0						40.0		
	16												
	17	7.5	5-10								7.0		
	18	8.2	5-15	3.8	5.0						5.0		
	19				5.0								
	20	7.5	5-10										
	21												
	22												
	23												
	24	20.0											
	25												
	26												
	27												
	28												
	29												
	30										15.0		
Mean of the Soil Group		15.8			21.2			22.2			16.1		
DEPTH		OL			PT						SM		
	1	22.3	5-70	18.3	16.4	10-27	7.2				10.0		
	2	21.2	5-75	21.7	51.0	10-86	29.7				6.8	3-10	
	3	18.6	10-30	7.5	10.0	10-10					5.0		
	4	10.0			10.0						10.0	10-10	
	5	42.5	10-75		48.5	10-72					9.7	7-15	
	6	12.5	10-15								10.0		
	7												
	8												
	9												
	10										29.0	5-52	
Mean of the Soil Group		21.3			36.3						12.5		

NTS 106O		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		ML			CL			OL			PT		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1	28.3	20-40		20.0			21.7	5-40		12.5	10-20	
	2	21.7	20-25		10.0	5-15		19.2	10-40	10.7	10.0	5-20	6.1
	3	23.3	10-40	13.3	26.7	5-60		10.0			15.0	10-20	5.5
	4	25.0	10-50		40.0			40.0			20.0		
	5	22.5	5-50	15.4	6.7	5-10		12.5	10-15		36.7	20-70	
	6	27.0	10-50	17.2	17.5	15-20							
	7	5.0	5-5		55.0	40-70		5.0			30.0	20-40	
	8	13.3	10-15		13.0	5-25	7.6						
	9	5.0			35.0	10-70							
	10	5.0	5-5		70.0								
	11	35.0	30-40		25.0	5-70							
	12	5.0			80.0								
	13	5.0	5-5		31.7	15-40							
	14	35.0	30-40		15.0	5-25							
	15	10.0	5-20		25.0	10-40							
	16	5.0			20.0								
	17	10.0	5-15		23.3	5-40							
	18	7.5	5-10										
	19	5.0	5-5		22.5	5-40							
	20	41.3	10-99		15.0	5-25							
	21												
	22												
	23												
	24				5.0								
	25	80.0											
	26	5.0			20.0								
	27												
	28												
	29				10.0								
	30	99.0			75.0								
	31				20.0								
	32												
	33	99.0											
	34												
	35				30.0								
	36												
	37												
	38												
	39	12.5	5-20		20.0								
	40												
Mean of the Soil Group		22.3			25.5			18.1			19.0		

NTS 106N		WINTER ICE CONTENT (%)								
DEPTH		SOIL GROUP								
		ML			CL			CI		
(m)	(ft.)	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1									
	2	60.0			64.0	63-65		52.7	31-67	
	3				55.0			59.3	40-75	
	4				53.3	46-58		48.8	30-63	
	5	35.0						55.0	45-62	
	6	57.0			45.5	43-47		45.6	42-57	6.4
	7							42.8	35-55	
	8	45.0			65.0			45.3	37-61	
	9							43.0	42-44	
	10	43.0						39.0	36-45	
	11							37.5	32-43	
	12	41.0						37.3	32-45	
	13							42.0		
	14	40.0						39.0	32-53	
Mean of the Soil Group		45.9			55.4			45.5		

NTS 107B		WINTER ICE CONTENT (%)											
DEPTH		SOIL GROUP											
		CL			ML			OL			PT		
(m)	(ft)	Mean	Range	S	Mean	Range	S	Mean	Range	S	Mean	Range	S
	1				26.3	5-70	20.3	20.0			12.1	5-25	7.0
	2	10.0			26.5	10-50	9.5	28.3	5-70		15.0	10-20	
	3				21.8	10-40	9.6	25.0	20-30		25.0	10-40	
	4	26.7	10-40		21.7	5-40	12.2				80.0		
	5	15.0	10-20		19.1	5-30	7.0				10.0		
	6	5.0			17.0	5-35	9.8	10.0					
	7	25.0	10-40		9.7	3-20	7.3						
	8	5.0	5-5		15.8	5-30	12.4						
	9	12.5	5-20		7.5	5-15	4.2						
	10				25.0	5-50							
	11	5.0			11.7	5-20	6.1	25.0					
	12				8.3	5-20	6.1						
	13	30.0											
	14				16.6	3-50	19.9	40.0					
	15	35.0	30-40		3.0								
	16				15.8	3-50							
	17				7.7	3-15		20.0					
	18												
	19				5.0								
	20				6.5	3-10							
	21												
	22												
	23												
	24				6.5	3-10							
	25												
	26												
	27												
	28												
	29	17.5	10-25										
	30												
	31												
	32												
	33												
	34	25.0											
	35												
	36												
	37												
	38				5.0								
	39	20.0	15-25										
Mean of the Soil Group		18.0			17.7			25.0			19.0		