Inuvik, N.W.T. engineering site information

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CANADA

INUVIK, N.W.T.
ENGINEERING SITE INFORMATION

BY

J. A. PIHLAINEN

(WITH A SUPPLEMENT BY D. W. BOYD)

TECHNICAL PAPER NO. 135

OF THE

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PREFACE

Members of the Division were privileged to serve on the site survey team which carried out extensive investigations in 1954 in the Mackenzie River delta area in the search for a new site for the settlement of Aklavik, N. W. T. Much information on site conditions and terrain features at East Three (as it was then referred to) was collected prior to and following the selection of the present townsite of Inuvik in August 1954.

The results of these investigations, which are of interest to engineers, are summarized in this paper and include observations on soil and permafrost conditions, depth of thaw, ground temperatures and general terrain features. It is hoped that it will be of use in future planning for any proposed expansion at the site.

One of the responsibilities undertaken by the Division as a contribution to northern development has been the collection and publication of engineering site information on northern settlements as the opportunities arise. This report serves to help fill another gap in the limited amount of information available on northern site conditions.

The author, now in private practice, was for ten years a research officer with the Division, engaged on studies of northern terrain and associated engineering problems.

Ottawa
August 1962

Robert F. Legget,
Director.

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INUVIK, N.W.T.

ENGINEERING SITE INFORMATION

by

J. A. Pihlainen

LOCATION

Inuvik is located at latitude 68°21' N, longitude 133°44' W, approximately 1,200 miles north of Edmonton and 120 miles north of the Arctic Circle. It is located on an upland adjacent to the eastern edge of the Mackenzie Delta approximately 75 miles south of the Beaufort Sea and 35 miles east of the delta town of Aklavik (Fig. 1).

HISTORY

The oldest settlement in the region is Fort McPherson, established by the Hudson's Bay Company during the middle of the nineteenth century on the Peel River 25 miles upstream of its junction with the Mackenzie River. It was the main post for the Arctic coast until 1912 when fur trade competition by the Northern Traders Company forced the establishment of a post in the delta. This was the beginning of Aklavik, where the Anglican Church established a mission in 1919 and the Roman Catholic Church one in 1926. The fur trade and missions, with schools and hospitals, soon established Aklavik as the main centre for the western Arctic.

Increased government activity in the Mackenzie Delta and the difficulties of large scale construction in its principal settlement, Aklavik, prompted a government decision in December 1953 to investigate the possibility of relocating government facilities at Aklavik in a better location. A survey party, with members from various government departments having interests in the region, was assembled to carry out these investigations. Detailed field investigations were carried out from April to August 1954 at four potential sites. In August, on the basis of this information and after a field review of the potential sites, that known as East Three was selected by the government as the new Aklavik townsite (1).

During the summer of 1955 detailed site investigations were carried out at "East Three" for the Department of Public Works by Foundation of Canada Engineering Corporation Limited. In addition, construction began on access roads to the principal borrow pits, and on warehouses and construction quarters. During 1956 this type of work was continued, as well as the construction of the airstrip about 7 miles south of the townsite. During 1957 the installation of piling was initiated on a large scale for the foundations of permanent structures and construction of hostels was begun. Extensive pile operations were continued during 1958, and construction of the powerhouse, utilidors and hospital was begun. By proclamation in July (1958) the area known since 1954 as "East Three" was named "INUVIK," Eskimo for "the place of man." (See Fig. 2 for Plan of Principal Buildings, 1959.)

GEOLOGY

The modern Mackenzie Delta, 100 miles long and 50 miles wide, is an estuarine type, having partially filled in the trough between the Richardson Mountains on the west and the Cariboo Hills on the east (see Fig. 1). Although the trough may be structurally controlled, it is a river eroded and a glacier-modified valley (2). The Richardson Mountains, which confine the delta on the west, are composed of shales, sandstones and conglomerates of Cretaceous age and rise to heights of 2 and 3 thousand feet above the delta. Between the edge of the mountains and the delta is a belt of coalescing alluvial fans in which material resembling glacial drift has been observed.

The Cariboo Hills form the most striking feature on the east side of the delta and are reported to resemble Tertiary lignite-bearing formations described from other parts of northern Canada and Alaska (3). North of the Cariboo Hills one or more old Mackenzie River deltas, along with a veneer of post-glacial sediments, are suggested (2). In addition, some of the deposits may be fluviatile, lacrustrine, or marine. In general, the formless and undulating character of the ground south of the Cariboo Hills suggests glacial drift through which Palaeozoic dolomite, limestone and slaty shale are exposed near Inuvik and farther south.

The origin of the soils at Inuvik has not been established and requires further field study. It has been suggested that the terrace on which a large portion of the town is located is a kame terrace, but another theory suggests that the granular deposits were laid down in a preglacial lake by Boot Creek.

CLIMATE

by

D. W. Boyd*

Weather records at Inuvik cover only a few years, but observations, mostly temperature and precipitation, have been recorded for over 30 years at Aklavik, 35 air miles to the west. Any present statement of the climate at Inuvik must be based on the assumption that it is not greatly different from that at Aklavik.

Temperature

The mean annual temperature at Aklavik and Inuvik is the same, 16°F (Table I). Although observations at Inuvik are limited, some seasonal temperature variations between Aklavik and Inuvik are suggested. Daily maximum temperatures at the two locations are about the same in winter but are about 4 deg higher at Inuvik during the summer. Daily minimum temperatures on the other hand average about 2 deg lower at Inuvik throughout the year. Thus the average daily range of temperature is greater at Inuvik by about 2 deg in winter and by about 6 deg in summer.

The lowest temperature recorded at Aklavik (in 32 years of observations) was -62 deg. The average of the lowest temperatures in each year is -51 deg. A comparison of monthly minima indicates that about the same record low temperatures could be expected at Inuvik. The record high temperature at Aklavik was 93 deg and the average of the highest temperatures in each year is 83 deg. The comparison of monthly maxima suggests that record high temperatures at Inuvik can be expected to be 2 or 3 deg higher than at Aklavik.

Precipitation

Table II shows the normal rainfall, snowfall and total precipitation at Aklavik (10 in. of snow equivalent to 1 in. of rain). Corresponding values for Inuvik are based on a comparison of monthly totals for only two years. The results suggest that rainfall at Inuvik is slightly less than at Aklavik, but that Inuvik snowfall is greater. It

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* D. W. Boyd is a member of the staff of the Meteorological Branch of the Department of Transport seconded to work full time as Climatologist with the Division of Building Research.

should be emphasized that the uncertainty in the values for Inuvik may be almost as great as the difference between the two stations.

Wind

Ten years of wind records are available from Aklavik, but the Inuvik records are too short to make any comparisons. A brief statement of Aklavik winds however, is useful for some appreciation of probable wind conditions at Inuvik.

At Aklavik, the strongest winds occur in June with an average of only 8 miles per hour; in November and December the average is less than 5 miles per hour. For almost half the time the wind is from the north or northwest, and for about one-third of the time from the south or southeast.

Only the average wind speed and direction for each hour are recorded at Aklavik and the greatest of these hourly winds in the 10-year record is 51 miles per hour. An analysis of extreme winds indicates that an hourly wind speed of 64 miles per hour should be expected once in 30 years and that gust speeds should be expected to reach or exceed 88 miles per hour.

TABLE I

MEAN DAILY TEMPERATURES, AKLAVIK AND INUVIK, N. W. T.

Month	AKLAVIK Mean Daily Temperature			INUVIK Mean Daily Temperature		
	Min	Max	Average	Min	Max	Average
January	-26	-10	-18	-28	-10	-19
February	-24	- 9	-17	-26	- 9	-18
March	-18	0	- 9	-20	1	-10
April	- 2	19	9	- 4	21	9
May	23	40	31	21	43	32
June	40	58	49	38	62	50
July	47	66	56	45	70	58
August	42	58	50	40	62	51
September	32	44	38	30	47	39
October	15	25	20	13	27	20
November	- 9	3	- 3	-11	4	- 4
December	-23	-10	-17	-25	-10	-18
Yearly Average	8	24	16	6	26	16

TABLE II

PRECIPITATION AT AKLAVIK AND INUVIK, N. W. T.

Month	AKLAVIK Precipitation (in.)			INUVIK Precipitation (in.)		
	Rain	Snow	Total	Rain	Snow	Total
January	0	6.6	0.66	0	7.6	0.76
February	0	5.9	0.59	0	6.8	0.68
March	*	4.4	0.44	*	5.0	0.50
April	*	6.0	0.60	*	6.9	0.69
May	0.25	3.0	0.55	0.16	3.4	0.50
June	0.63	2.1	0.84	0.42	2.4	0.66
July	1.39	*	1.39	0.92	*	0.92
August	1.32	1.2	1.44	0.87	1.4	1.01
September	0.60	3.4	0.94	0.40	3.9	0.79
October	0.07	9.0	0.97	0.05	10.3	1.08
November	0	8.7	0.87	0	10.0	1.00
December	0	4.8	0.48	0	5.5	0.55
Yearly Total	4.26	55.1	9.77	2.82	63.2	9.14

* denotes trace - less than 1/100 in. of rain or less than 1/10 in. of snow

RELIEF

In the Inuvik region, the upland adjacent to the delta rises gently for 1 to 1 1/2 miles and is bounded on the east by a high interior upland rising over 150 feet. Inuvik is located on the lower level adjacent to the delta. Its eastern boundary is delineated by the steep slope to the higher land, which roughly parallels the edge of the delta. The Inuvik region extends generally in a north-west to south-east direction in which the landforms are similarly oriented; the general west to east orientation of the lakes emphasizes this condition.

The relief of the region is one of flats at varying elevations, gentle undulations separated by shallow swales, rounded knolls, hummocky hills and ridges of varying heights. Drainage is to the west or north-west by streams rising in steep gullies in the high interior upland. Drainage is controlled by the relief, especially in the southern part where the streams flow in parallel courses between the ridges. As a rule, the ridges, knolls and undulations are well drained, but some of the lower flats are not.

VEGETATION

Spruce and birch are the dominant tree types, with secondary stands of willow and alder. The ground is generally hummocky, with a vegetative ground cover of ground birch, reindeer and sphagnum moss, grass tussocks, Labrador Tea and berry plants. Birch predominates on the south-facing slopes of the landforms and on the well drained areas; spruce on the north-facing slopes; stunted spruce, willow and alder are found on more poorly drained areas. Few trees grow on low flat areas except along stream courses where there are dense thickets of willow and alder.

On the townsite flat and its associated knolls and ridges to the west (between the flat and the East Channel) the trees are mixed spruce and birch in open stands interspersed with scattered willow and alder. The spruce reach a maximum diameter of 9 in. at breast height; the birch, with average trunk diameters of 6 in., reach a maximum height of approximately 35 ft. There are several charred stumps indicative of former burns. During the summers of 1954 and 1955 much of the town area was cleared of brush and smaller trees as well as larger trees that conflicted with road or building sites. Brush and tree clearing in the hospital area was carried out during 1956 and 1957.

Willow thicket up to 12 feet high grows on the lower slope from Boot Lake to the townsite flat. Further up, mixed spruce and birch merge with the tree vegetation on the townsite flat. Dense willow thicket approximately 10 feet high grows in a depression extending south-east from the south half of Twin Lake and extends north along the east shore of the lake where there is a small stand of spruce 60 feet high.

The natural vegetation in the Inuvik area, before any construction, has been summarized from aerial photographs taken in September 1955 in the form of a map (Fig. 3). This map shows the distribution of trees, shrubs and moss on the basis of height.

SOILS

A typical sequence of subsurface materials at the Inuvik townsite is shown in Fig. 4. A living cover of vegetation, mostly moss, is found everywhere, over brown to black peat, which can be as deep as 13 feet. Pure ice formations up to 1 foot thick are occasionally found in the peat. Underlying the peat there is usually a brown gravel with sand or silt which varies in thickness from 1 to 14 feet. This material is, in turn, underlain by a grey gravel with sand, silt or clay up to a thickness of 9 feet. On a grain size distribution basis the brown and grey gravels are similar. Granular deposits are underlain by various combinations of grey fine grained soils, mostly silt sized. Ice lens concentrations are high and often the material can be described as ice with silt inclusions as well as layers of clear ice.

The areal distribution of soils in the Inuvik townsite area is shown in Fig. 5. In general, brown or grey gravel with sand or silt is usually found throughout the site under peat up to a depth of 13 feet. Accordingly, the depth of peat above the coarse grained soils constitutes a major subdivision of the soil distribution mapping. Isolated areas of fine grained soils form the remaining subdivisions.

The predominant subsurface materials observed at Inuvik are as follows:

Peat or organic material
Brown gravel with sand or silt
Grey gravel with sand, silt or clay
Fine grained soils
Ice

These subsurface materials are more variable than the discussion to this point would indicate, and more detailed notes on their occurrence are reported in the following sections.

Peat; Organic Material

The organic material or peat found at the Inuvik townsite varies in colour from brown to black. Its structure is predominantly one of non-woody, fine fibres interspersed with varying amounts of small and large woody and non-woody particles. There is usually a distinct separation between the peat deposit and the mineral soil but in some cases the organic material grades into the mineral soil.

One of the most significant properties of this peat is its moisture content. Its predominantly fibrous structure holds large quantities of water like a sponge. This water retention ability is emphasized by the test results of moisture content determinations which, for convenience, are carried out on a weight basis, (moisture content percentage equals the weight of peat sample water divided by the dry weight of the peat sample multiplied by 100). Since the specific gravity of peat is approximately 1.5 (normally mineral soils have a specific gravity of approximately 2.7) moisture contents in hundreds and occasionally thousands of per cent are obtained.

The moisture content of 112 thawed and 32 frozen peat samples from the active layer at Inuvik were determined from June to September 1958. The average for the thawed samples was found to be 347 per cent. When these results were analysed statistically, the average values of moisture (or ice) content in the thawed and frozen peat were found to be equal for a 99 per cent significance level. Moisture content differences between frozen and thawed peat may be different in certain further subdivisions of these materials, but on an over-all basis the differences could not be detected by these observations. On a combined basis, the average moisture content of peat (frozen or thawed) was found to be 369 per cent.

The large variances for both frozen and thawed peat suggest that for critical calculations moisture content should not be estimated on the basis of average field observations. In such cases, these values are best obtained by samples taken at the location for which the calculations are to be made.

The high moisture content of Inuvik frozen peat cements the peat fibres and particles into a solid, wood-like mass. This ice is not generally visible by eye, although some ice segregation in the form of thin, hairline ice lenses does occur. Relatively thick ice masses are also associated with peat; these may occur near the surface, in which case the ice may be light brown and appear cloudy because of vertically oriented air bubble streaks. More often, ice is found in the peat at depths greater than the active layer; it may be as thick as 2 feet and clear except for a cloudiness produced by air bubbles. At times, flakes, globules or lenses of peat may be found in the ice and the material could be described as ice with peat lenses. These large ice masses are generally parallel to the ground surface, although some irregularly oriented ice "dykes" have been observed. It has not been possible to determine the areal extent of any individual ice mass, but observations suggest that some of these areas would be measured in hundreds of square feet.

Brown Gravel with Sand, Silt or Clay

The most prominent soil at Inuvik is a brown gravel with sand, silt or clay. It is found throughout most of the townsite in a layer from 5 to 14 feet thick under a varying mantle of organic material. All of the roads and the gravel pads for most of the buildings in the town have utilized this material from borrow pits at Twin Lake or near Boot Creek.

The range of 17 grain size distributions for the townsite brown gravel is shown in Fig. 6. A grain size distribution for a typical good borrow pit material is also included. It should be noted that the gravel is generally well graded in all sizes from silt to cobbles (stones greater than 3 inches removed for grain size tests). The maximum boulder encountered in test pits was 22 inches, although sizes over 8 inches were not common.

The material contains a considerable amount of poor igneous rock fragments which are subject to rapid decomposition. A small surface sample was examined by the Building Materials Section of the Division of Building Research as possible concrete aggregate. The following comments were made:

1. Normal spray washing is adequate for this material.

2. According to ASTM and CSA grading requirements for fine aggregate in concrete, the sand portion of this material is unsatisfactorily graded after washing, being seriously deficient in the 30-50 and 50-100 fractions.

3. According to ASTM and CSA specifications, the losses in the magnesium sulphate soundness test are much too high, indicating an unsound material. It should be noted that this test by itself is not generally considered reliable. It does suggest the danger of using this material without exhaustive testing.

4. Microscopic examination by a trained petrographer classifies this material as an "indurated sediment" which has been transported a considerable distance by water. Such material can be very "tough" but its durability would depend on pore size and total porosity.

Field density determinations of 36 frozen brown gravel samples were carried out in 1955; these averaged 134 lb/cu ft. For 51 samples the average moisture or ice content was found to be 18 per cent. It is interesting to note that a statistical analysis of the field densities of brown, grey-brown or grey gravel showed that these densities were not different for a 95 per cent significance level (71 samples). Accordingly, the field density of Inuvik gravel can be taken as 136 lb/cu ft.

The ice in the gravel cements the particles into a well-bonded almost rock-like mass. The ice is usually visible on larger particles such as pebbles as a thin film or a coating up to 1/2 inch thick. Occasionally, thin hairline ice lenses horizontally oriented have been observed in the gravel fines. Only one occurrence of ice in the gravel (6 inches thick at a depth of 14.3 feet, TP 79) has been observed.

A brown silty gravel has been observed at the airstrip; grain size distributions of three samples are shown in Fig. 6. The material has a significantly higher silt and clay content than the townsite gravels, and in many cases may be described as a silt clay with stones and sand. With stones larger than 1/2 inch removed, the liquid limit ranges from 26 to 36 per cent and averages 21 per cent; the plasticity index ranges from 9 to 16 per cent and averages 11 per cent.

This matrix of silt with sand and stones is well bonded with ice not usually discernible by eye. At the top of the deposit the well bonded frozen soil matrix is interrupted by horizontal layers of ice up to 1 inch thick; these decrease in size and frequency with depth and almost disappear at the bottom of the deposit. Ice with silt inclusions has also been observed in the material (see "Ice"). The ice content throughout the material ranged from 19 to 92 per cent and averaged 34 per cent.

Grey Gravel

A grey gravel with sand or silt has been observed in areas mapped as brown gravels or deep peat deposits (Fig. 5). At these locations, the grey gravel lies underneath either brown sandy gravel or grey fine grained materials. The deposits usually occur near the end of test pit penetrations, and vary in thickness from 2 to 5 feet although one deposit is known to be at least 9 feet thick. Grey gravel is found at depths exceeding 7 feet and for that reason has not been utilized as extensively as the brown gravel even though it is a superior material petrographically.

The grain size distributions of three grey gravel samples from the townsite area are shown in Fig. 7. On a grain size basis, it is similar to the brown gravel. Field density determinations of 13 frozen grey gravel samples carried out in 1955 emphasize the similarity. These averaged 139 lb/cu ft.

Ice segregation in the grey gravel is usually similar to that in brown gravel, being indiscernible by eye but cementing the material into a hard mass. In some cases, however, the grey gravel blends into a predominantly fine grained material mixed with stones. Here the ice concentrations can be significantly higher. For 17 samples with normally only random thin horizontal ice lenses, the average ice content was observed to be 17 per cent.

A grey silt to clay gravel has also been observed at the airstrip where it is overlain by a brown silty gravel. The grain size distributions of three samples are shown in Fig. 7. As is found with the brown gravels, the grey airstrip gravels have higher concentrations of fine grained particles than the townsite gravels. The liquid limits of fines passing a No. 60 sieve ranged from 20 to 52 per cent and averaged 35 per cent. The plasticity index in these tests ranged from 7 to 22 per cent and averaged 15 per cent.

The grey matrix of silty gravel at the airstrip was well bonded by ice although it was not usually visible by eye. Random fine horizontal ice lenses up to 1/8 inch thick were also observed. Ice contents were generally low and for five samples ranged from 7 to 23 per cent and averaged 16 per cent.

Sub-rounded and angular pebbles of arseno-pyrite from 1/4 to 3 inches in diameter were found throughout the deposit in 1957. These would have passed unnoticed except for the unusual garlic or sulphur odour in the test pit as the randomly located pebbles were broken by the pneumatic hammer. Pebbles of arseno-pyrite have been subsequently observed in the grey gravel borrow pit material near Boot Creek.

Fine Grained Soils

Fine grained soils in the Inuvik townsite area are difficult to describe because of their wide variation and occurrence. In general, they may be separated into two broad subdivisions on the basis of occurrence and grain size distribution as follows:

(a) predominantly silt sized grey soils which usually occur below the brown or grey townsite gravels, and

(b) yellow to grey brown silt clays with sand or stones which are found near the ground surface.

Predominantly silt sized grey soils have been observed under brown or grey gravel throughout the townsite area. The thickness of these deposits at times exceeds 20 feet, although fortunately, they occur in only one or two areas immediately under the moss and peat mantle. At times, the deposits contain stones and sands but the significant feature is the large ice concentrations.

The ice in these fine grained soils is usually in the form of closely spaced horizontal layers or lenses varying in thickness from 1/16 to 3/4 inch. In many cases the amount of ice increases to such an extent that the material resembles ice with silt inclusions (see "Ice").

The grain size distribution of four typical samples of grey silt is shown in Fig. 8. Field density determinations of 13 samples showed an average density of 116 lb/cu ft (standard deviation 9 lb/cu ft), and the average ice content of 27 samples was 41 per cent (standard deviation 24 per cent).

The second broad subdivision of fine grained soil in the Inuvik region is a grey to yellowish brown silt clay with some sand or stones. It occurs close to the surface chiefly in the upper flat, above or north of the townsite. The grain size distribution of four samples is shown in Fig. 9. Ice segregation in the material is high and varies from horizontal or irregularly oriented ice layers up to 3/4 inch thick to large ice layers from 1 to 2 feet thick.

Silt clays with some sand and stone, similar to the Inuvik upper flat fine grained soils, have been observed south-east of Long Lake. The grain size distribution of 12 samples is shown in Fig. 10, as well as that of two samples from the drumlins north-west of Long Lake.

The low flat relief and the stunted to sparse vegetation north of the townsite, through which the "Navy Road" has been built, has some interesting ground phenomena. Frost mounds 4 to 5 feet in diameter and up to 2 feet high are frequent. In many locations they have ruptured into soil exposures known as clay boils. A grain size distribution of the material is shown in Fig. 11. The clay sized fraction is the highest observed at Inuvik. The liquid limit of the material is 52 per cent and the plasticity index 18 per cent.

Ice

Ice masses, or soil with so much ice that it may be considered ice, have been observed at varying depths throughout the townsite area (Fig. 12). This ice is chiefly associated with fine grained soils or peat, although one or two ice masses have been observed in brown or grey gravel.

Clear ice thicknesses range from 1 to 24 inches. They are most often found in peat and to a lesser extent in the grey fine grained soils. In the peat in the townsite area depths to ice range from 6 inches to 6 feet, with an average of 3 feet.

Ice with soil inclusions is most commonly found in fine grained soils. These deposits range in thickness from 6 inches to 12 feet, but on the average they are approximately 5 feet thick. They are found on the townsite flat at depths ranging from 12 to 15 feet; in the "industrial" area, and particularly in the wharf knoll area, ice with soil inclusions is found at shallower depths from 6.5 to 16 feet.

The upper townsite flat, on which no major construction is planned at present, has clear ice masses averaging 1 foot thick in a fine grained soil with stones at depths ranging only from 16 to 30 inches.

Extensive masses of ice and ice with soil inclusions have been observed in the borrow pits south of Boot Creek. One 3-foot thick mass of ice, underlain by brown gravel, was uncovered below 3 feet of moss and peat. At another location nearby (known as "Ice Hill"), a test pit 12 feet deep revealed 2 feet of brown gravel underlain by ice and ice with silt inclusions to the depth at which the test pit was abandoned.

No ice masses have been observed in the drumlin-like hills in the vicinity of Long Lake. One test pit in the low flats on the north-east end of the lake, however, did reveal two ice masses 6 inches thick at depths of 18 and 30 inches in a grey sandy gravel mixed with silt and clay.

In the airstrip area one test pit in an 8-foot deep peat deposit revealed only one large ice lens 2 inches thick at a depth of 21 inches. Ice with silt inclusions was, however, observed in all four test pits (Fig. 13). This form of ice segregation started in or just under the organic material and continued for 4 feet in two test pits and in 1 foot in one test pit. In the fourth test pit, with relatively little organic or peat cover, the ice with silt inclusions appeared 3 feet below the ground surface and continued for only 1 foot.

DEPTH OF THAW (ACTIVE LAYER)

The seasonal depth of thaw in permafrost areas, in what is commonly known as the "active layer," has long been recognized. Although its variability has also been known, there is still a tendency for engineers to regard it as a definite thickness for a locality.

In fact it is some reflection of the energy available in a locality to thaw frozen ground. Prediction of the energy change between the terrain surface and the atmosphere cannot be readily reduced to a simple basis, however, even though the result is a simple concept such as the depth of thaw. The dominant weather elements that affect this energy change are sunshine, air temperature and wind. In addition, relief, orientation and the presence of nearby objects, as well as the absorptivity and emissivity characteristics of the surface involved, enter into the problem. Additional complication is provided by the effects of precipitation, condensation, evaporation, plant transpiration and the thermal characteristics of the soil. Even if all of these individual factors could be measured, there remains the problem of recombining these variables in the calculations.

Engineering planning and design in the north require some knowledge of the seasonal depth of thaw for a locality. In particular, the range of depths of thaw under original terrain conditions and some indication of the increase in the depth of thaw from the disturbance caused by construction are required. The following observations attempt a first approximation of these questions for Inuvik. The 1954 Inuvik depth of thaw observations reflect original terrain conditions. Those for

1957 serve as an indication of the immediate changes in depth of thaw that can be anticipated during initial disturbance of an area.

1954 Inuvik Depth of Thaw (Active Layer)

During July and August, 1954, before occupation and before any construction in the Inuvik region, 25 test pits were excavated for preliminary soils and permafrost investigation. The depth of thaw was recorded when each test pit was started and is shown in Fig. 14. Instead of plotting the date on which the depth of thaw was observed, the "thawing index" for the date has been used (the thawing index is a cumulative total of the number of degrees above 32°F of the average air temperature for each day up to the date of observation). The thawing index is used as a first approximation of the energy expended in thawing frozen soil. The many limitations of accepting a measure of air temperature to reflect energy changes are appreciated but are considered justifiable in this preliminary qualitative engineering appraisal. Its use allows a more convenient comparison of similar records for different years and locations. Also included in Fig. 14 is a brief notation of the thawed material.

Depth of thaw observations made late during the 1954 thawing season are of interest since they offer some indication of the active layer at Inuvik before occupation. As would be expected, the thickness of the moss and peat mantle has a significant effect on the depth of thaw. Observations on the 22nd of August (thawing index 1938 degree days) record a range of thaw from 12 inches in peat to 51 inches in gravel with a 4-inch cover of moss and peat.

1957 Inuvik Depth of Thaw (Active Layer)

During the summer of 1957, nine areas in the immediate vicinity of the Inuvik townsite were chosen for depth of thaw observations to give representative seasonal thaw information on undisturbed terrain with varying cover of trees, shrubs and moss; on disturbed areas where trees and shrubs had been removed; and on stripped areas where all the living organic cover had been removed. Thaw measurements were made by probing and with test pits. Three to six thaw depths were made at each location and the average value recorded. The observations were carried out monthly or twice monthly as the season progressed.

Figure 15 records the extreme limits of the depth of thaw (plotted versus degree days of thaw) for stripped, disturbed and undisturbed terrain at Inuvik during 1957. As expected, significant differences in the depths of thaw for stripped and undistrubed areas are very evident, and some indication of the variability within these two terrain groups is also obtained.

In neither undisturbed nor disturbed areas (where the moss has been left intact) could the observations detect differences in depth of thaw that would be significant from a construction point of view. Thus the dominant factor is the moss cover; the presence or absence of trees and shrubs does not appear to affect depth of thaw appreciably.

In areas stripped of vegetation the dominant factor appears to be the underlying soil type. Fine grained soils show less thaw than coarse grained soils. At Inuvik the fine grained soils usually contain more ice than the coarse grained soils so that a distinction based solely on grain size is not generally in order.

Thus the maximum observed depths of thaw experienced at Inuvik just three years after occupation are approximately 2 feet in either undistrubed or disturbed areas where the moss cover is left intact; approximately 5 feet in areas stripped of moss and underlain by fine grained soils; and 8 feet in areas stripped of moss and underlain by coarse grained soils. The volume changes or the terrain elevation changes associated with these thaws have not been recorded but do form a part of future studies. The implications of such terrain settlements should be considered in any engineering planning and design.

SOIL TEMPERATURES

Soil temperature observations at the townsite reflecting original conditions have not been obtained. Some indication of these temperatures is possible, however, from records of two thermocouple installations made there in August 1955 as well as from one at the airstrip in March 1957. There have been many difficulties with field installations and the probability of observer error in some instances is considerable. It is evident that the results can be questioned for both of these reasons. The observations, however, are included with the thought that some qualitative appraisal of original soil temperatures is possible.

Thermocouple Installation ATX-15

On August 17 1955, four days after a thermocouple was installed at a depth of 47 feet, a temperature of 29.3°F was recorded. By the 22nd of September, when observations for the year ended, the temperature had decreased to 27.4°F.

Observations for the year 1956 were resumed in June and continued intermittently on approximately a weekly basis until September 22. For this interval the observed temperatures ranged from 24.5 to 26.5°F. The average soil temperature for eleven observations in this interval was 25.7°F (standard deviation 0.5°F). Much of the deviation can be attributed to observer error.

Observations for 1957 began on 25 June and ended on 6 October. The average of eight twice-monthly observations was 26.1°F (with no significant standard deviation). Observations for 1958 began on 16 June and ended on 14 September, with observations again on a twice-monthly basis. The average soil temperature for seven such observations was 25.9°F (with a standard deviation of 0.3°F).

In summary, a temperature of 25.9°F at a depth of 47 feet has been observed at Inuvik. This temperature has not changed appreciably in the years 1956 to 1958.

Thermocouple Installation ATX-12

The installation is located in Block 28, south of Distributor Street and south-east of the firehall. Originally, no construction was contemplated in the area but the construction of the nearby utilidor has now disturbed it. The installation has thermocouples 1, 2, 3, 4, 5, 7.5, 10, 12.5, 15, 17.5 and 20 feet below the ground surface attached to a pile. The location was steamed and the pile driven to depth on August 13, 1955. Soil temperature observations for the 2-, 5-, 10-, 15- and 20-foot depths for 1956 are shown in Fig. 16. Observations continued at the installation and the records for 1957 are shown in Fig. 17. The observations for 1958 are not included in this portion of the report, since a considerable amount of construction activity has taken place in the area.

Unfortunately, it was not possible in 1956 and 1957 to make continuous observations throughout the years and comments on the results are accordingly difficult. In general, seasonal temperature changes are detected as deep as 20 feet. The observations for 1956 are rather erratic; this may be due to the fact that the installation had still not returned to the original ground temperatures after the steaming, although more probably it is the result of observer error. The 1957 observations appear to be more consistent and are in general agreement with the 1956 observations.

Thermocouple Installation, Airstrip Box No. 1 (Green)

The airstrip thermocouple installation Box No. 1 (Green) is located approximately 1,000 feet north of the airstrip and approximately 200 feet east of the airstrip road in relatively undisturbed terrain that is considered representative of the area. The installation consists of three thermocouples each at 0, 0.5-, 1-, 2-, 3-, 4-, 5-, 10- and 15-foot depths. The installation was made in a test pit during 12 to 15 March, 1957. Soil temperature observations at depths of 2, 5, 10 and 15 feet are shown in Fig. 18.

In general, two characteristics of soil temperatures are well illustrated. The range (or amplitude) of ground temperatures as they are affected by seasonal air temperatures decreases with depth. For example, at a depth of 2 feet the range of soil temperatures is from approximately 13 to 39°F, while at a depth of 15 feet the range is only from 22 to 29°F. There is also a time lag during which minimum and maximum soil temperatures are recorded and which increases with depth. At 2 feet, the minimum soil temperature occurs in March and the maximum in August. At 15 feet the minimum soil temperature occurs in June and the maximum in January, or approximately six months after the air temperature extremes.

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(2) Mackay, J. Ross. Mackenzie Delta - A Progress Report. The Canadian Geographer, No. 7, The Canadian Association of Geographers, Ottawa, 1956.

(3) Kellaway, G. A. Notes on the Geology of the Mackenzie Delta - Abstract. The Canadian Geographer, No. 7, The Canadian Association of Geographers, Ottawa, 1956.

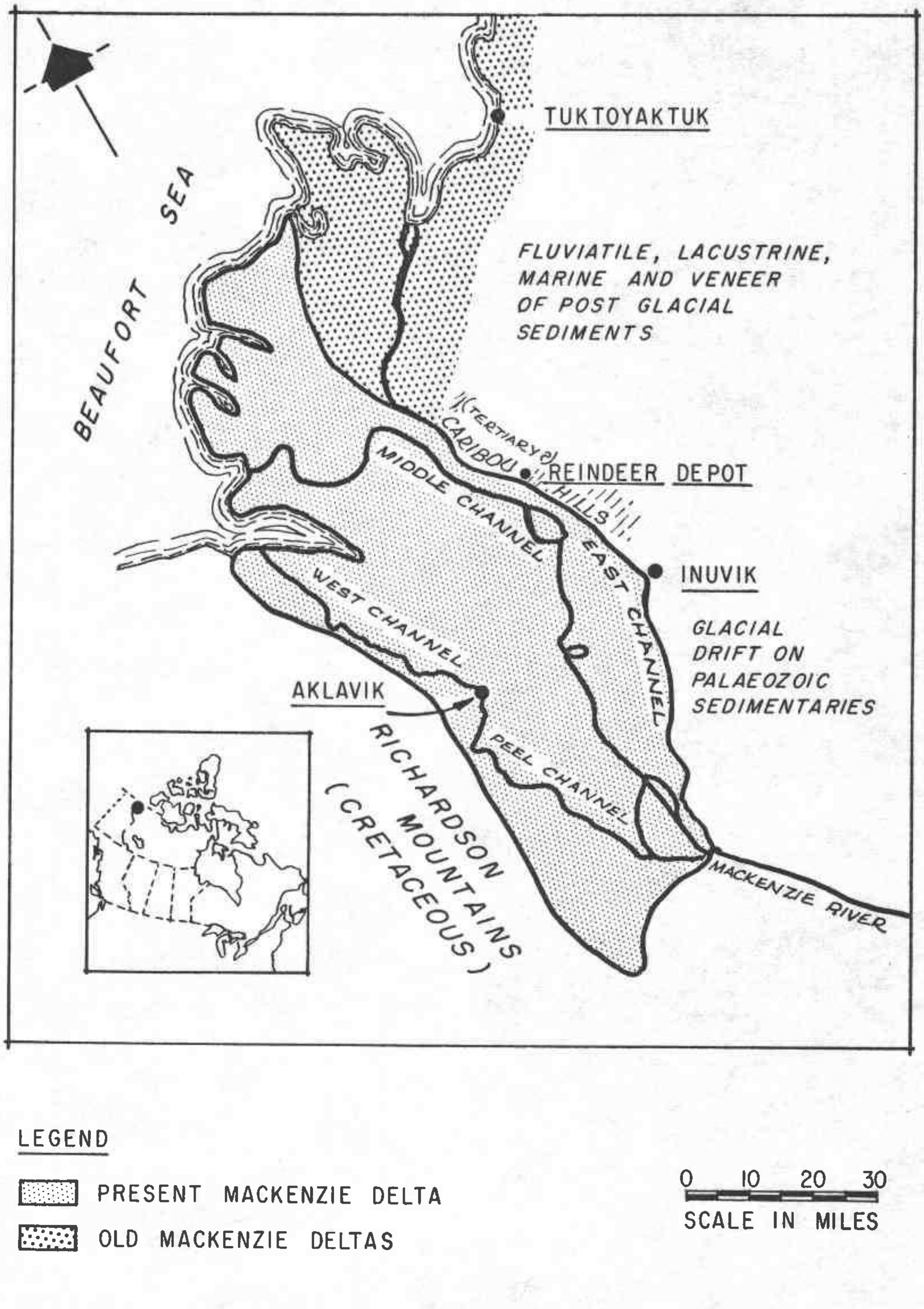


FIGURE I THE INUVIK REGION

BR. 2643 - 1

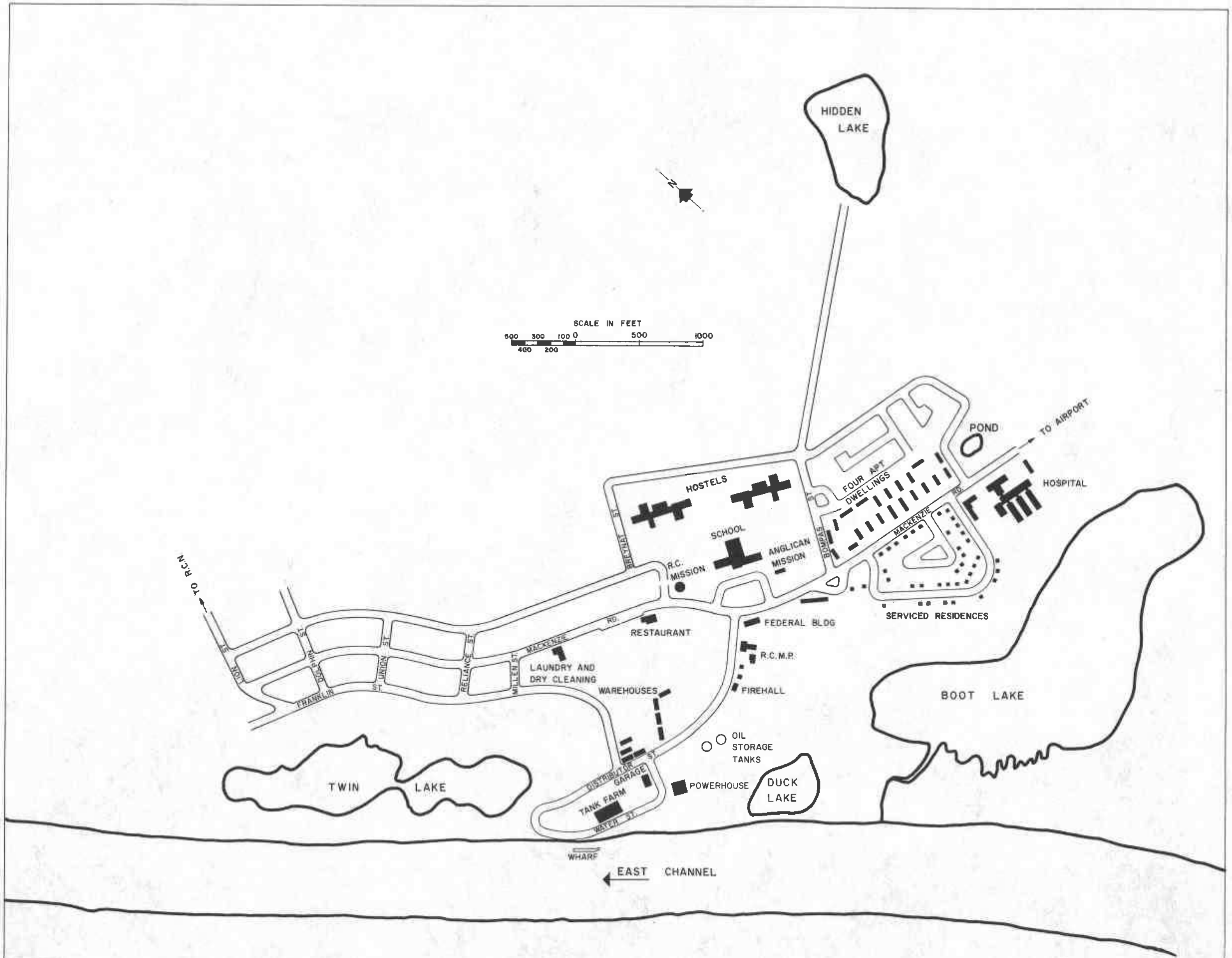
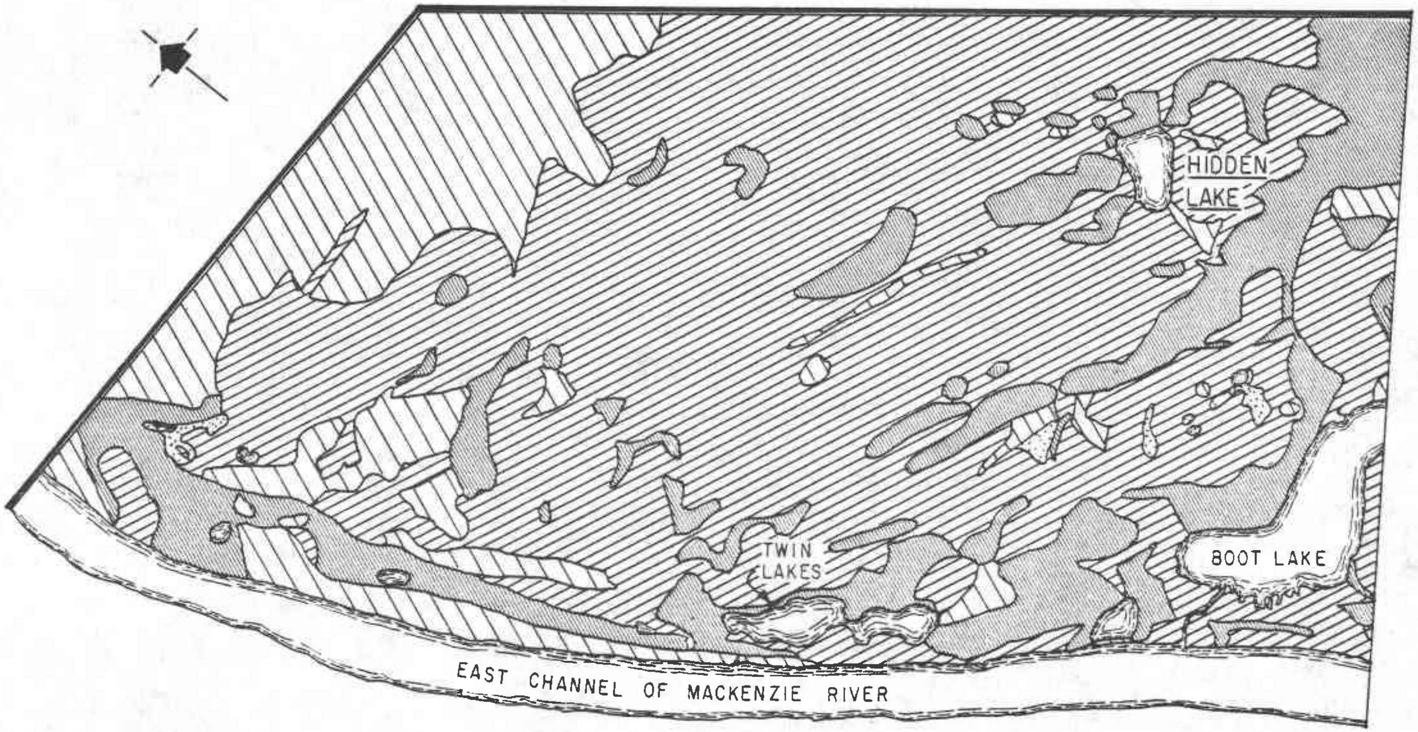


FIGURE 2 PLAN OF PRINCIPAL BUILDINGS, INUVIK, 1959



NATURAL VEGETATION

- TREES OVER 15' HIGH (ALSO SMALLER TREES, SHRUBS & GROUND COVER OF MOSS)
- TREES BETWEEN 5' & 15' HIGH (ALSO SHRUBS & GROUND COVER OF MOSS)
- SHRUBS BETWEEN 2' & 5' HIGH (GROUND COVER OF MOSS)
- PLANTS LESS THAN 2' HIGH & GROUND COVER OF MOSS

FIGURE 3 NATURAL VEGETATION BEFORE CONSTRUCTION

BR. 2043-15

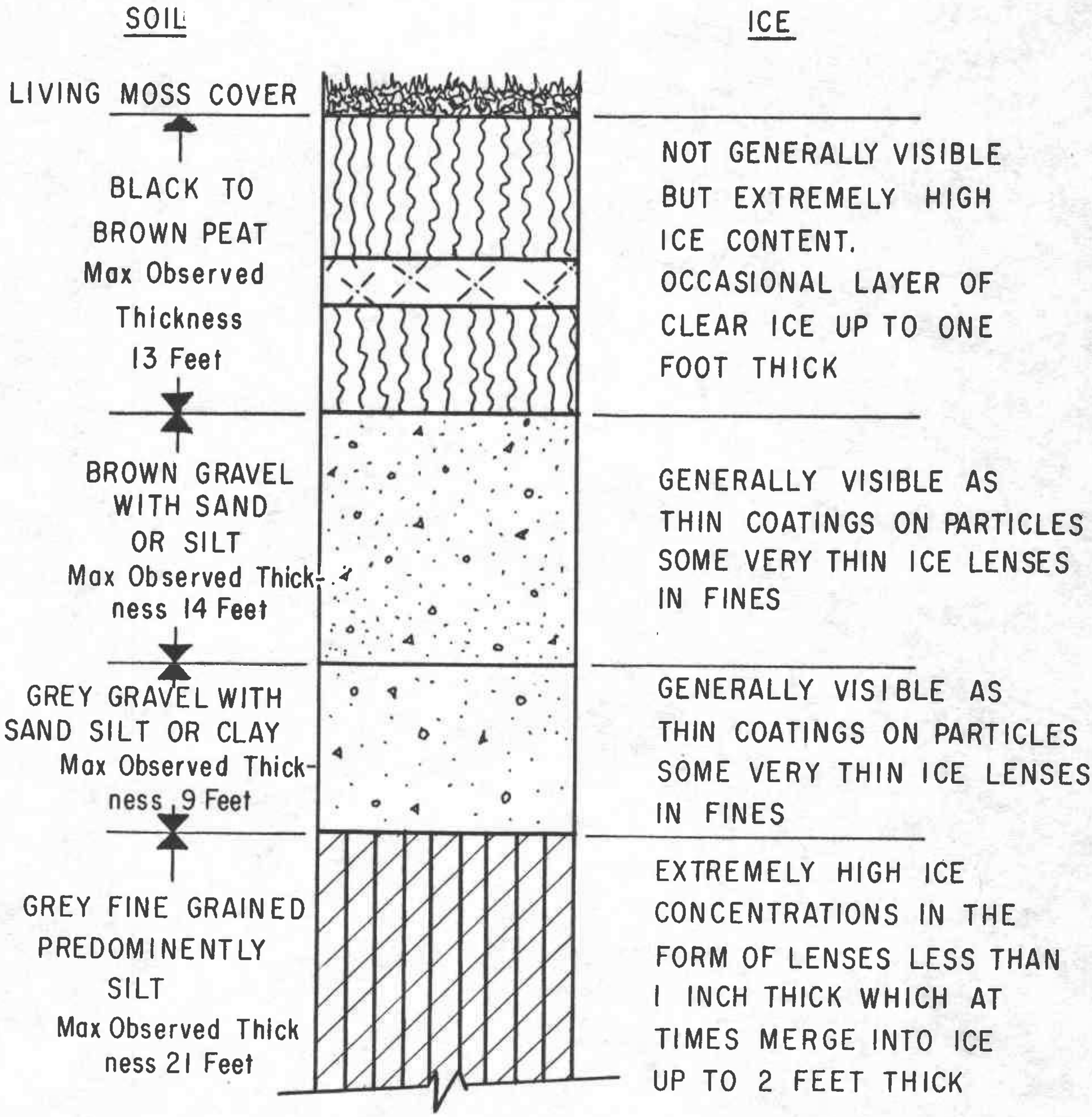


FIGURE 4

TYPICAL SEQUENCE OF SUBSURFACE MATERIALS AT INUVIK

BR 2643-2

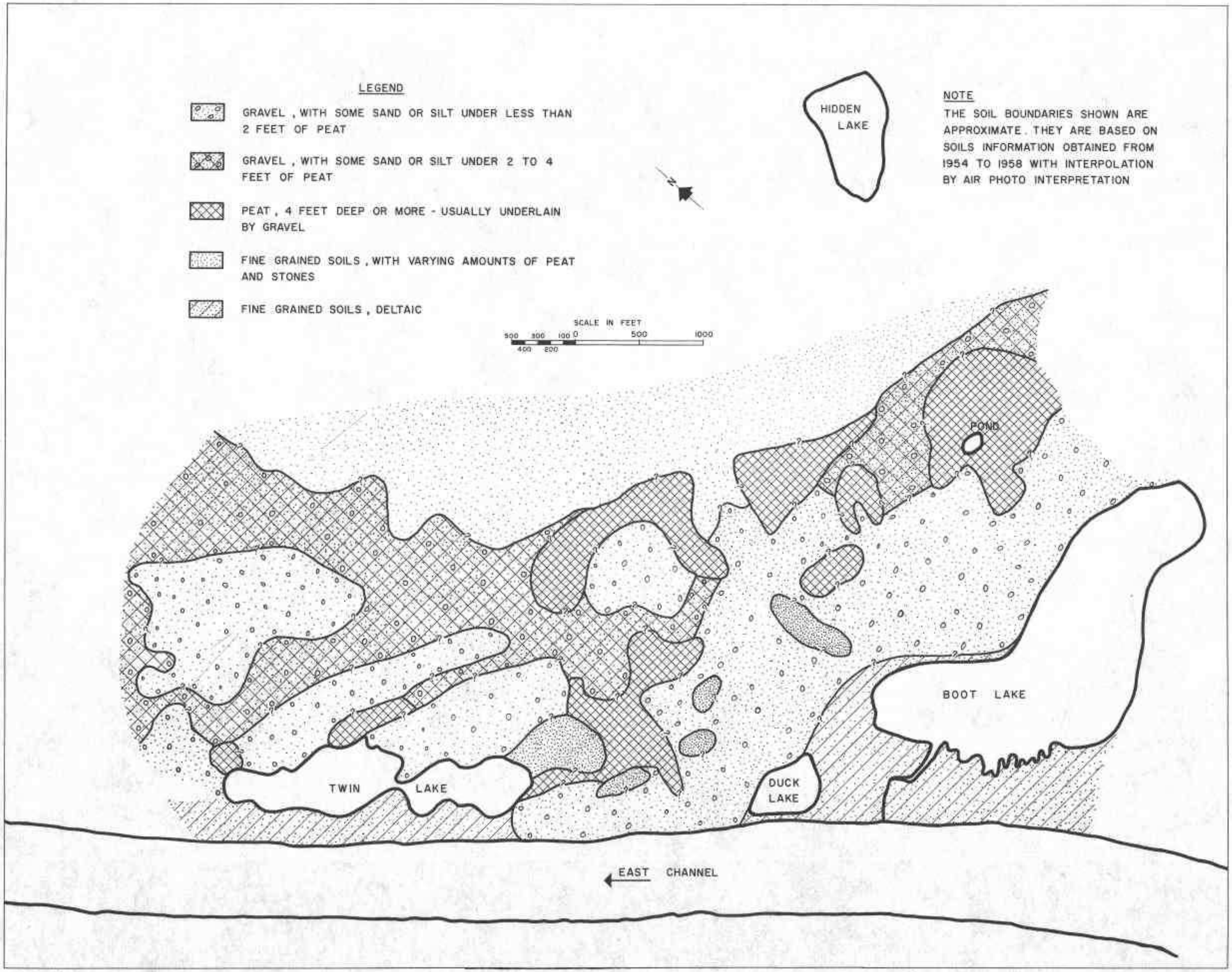


FIGURE 5 INUVIK, SOILS DISTRIBUTION

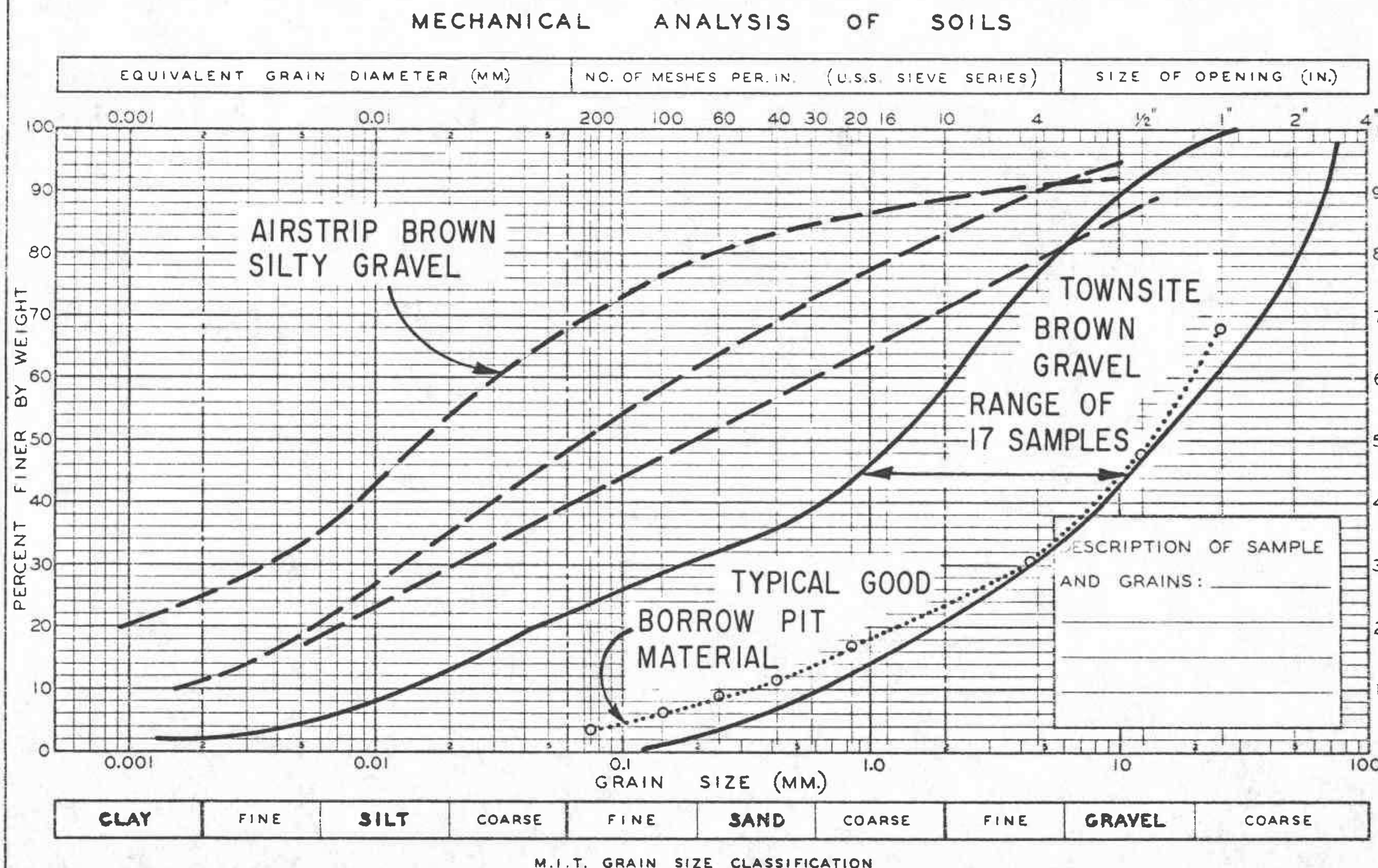


FIGURE 6
GRAIN SIZE DISTRIBUTION - INUVIK BROWN GRAVEL

BR. 2643 - 3

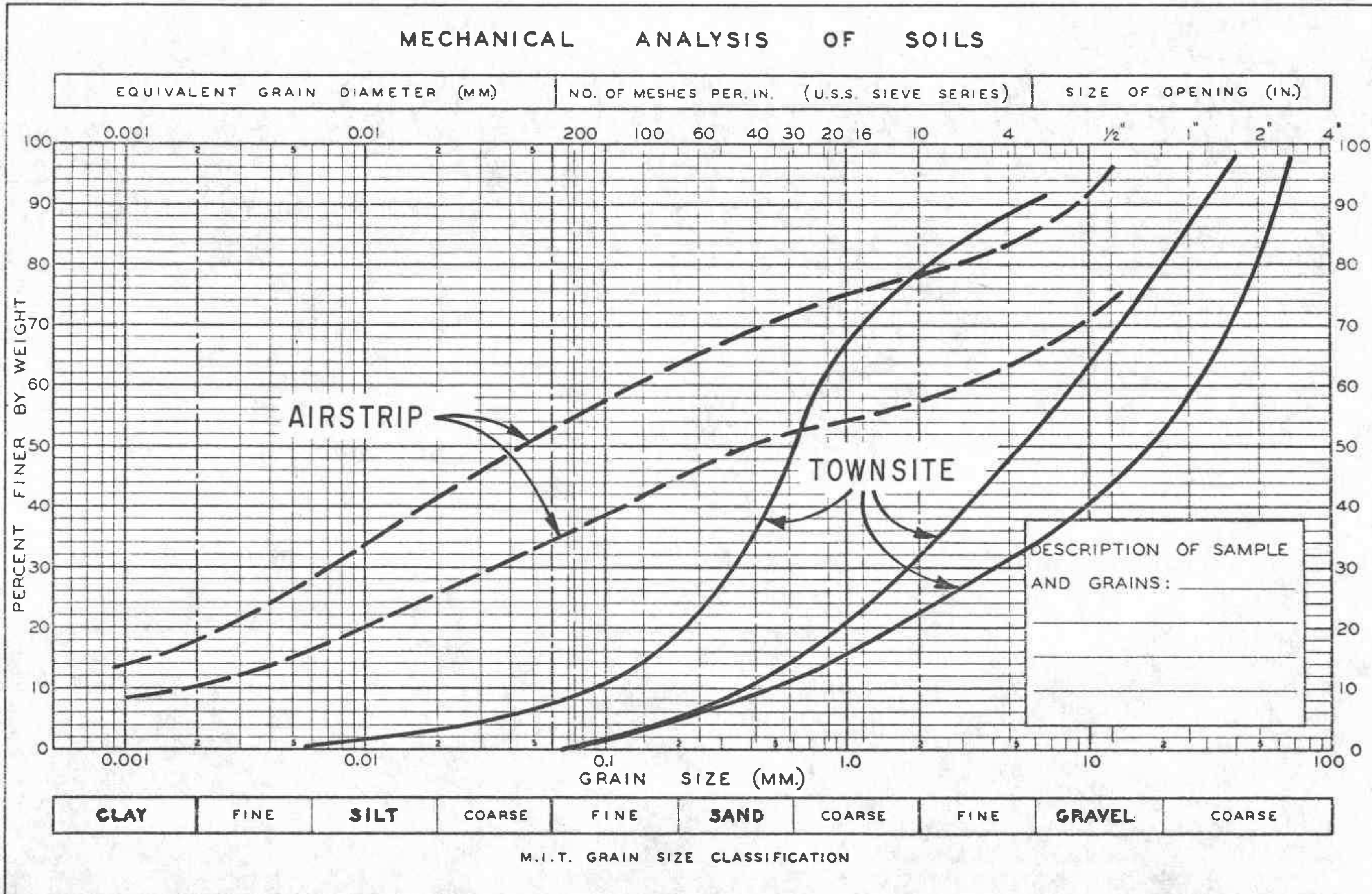


FIGURE 7
GRAIN SIZE DISTRIBUTION - INUVIK GREY GRAVEL

BR. 2643-4

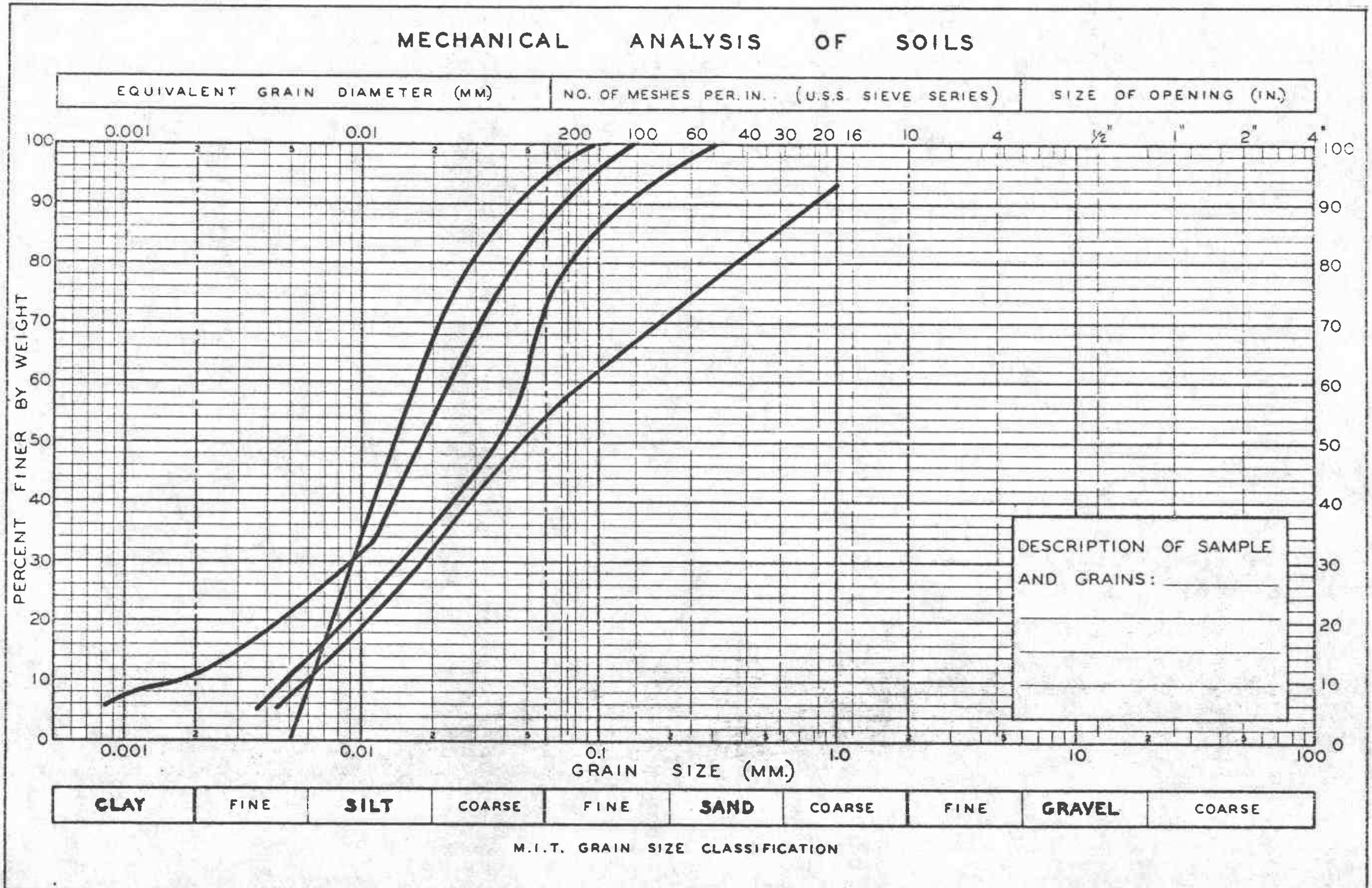


FIGURE 8
GRAIN SIZE DISTRIBUTION - INUVIK GREY SILT

BR. 2643-5

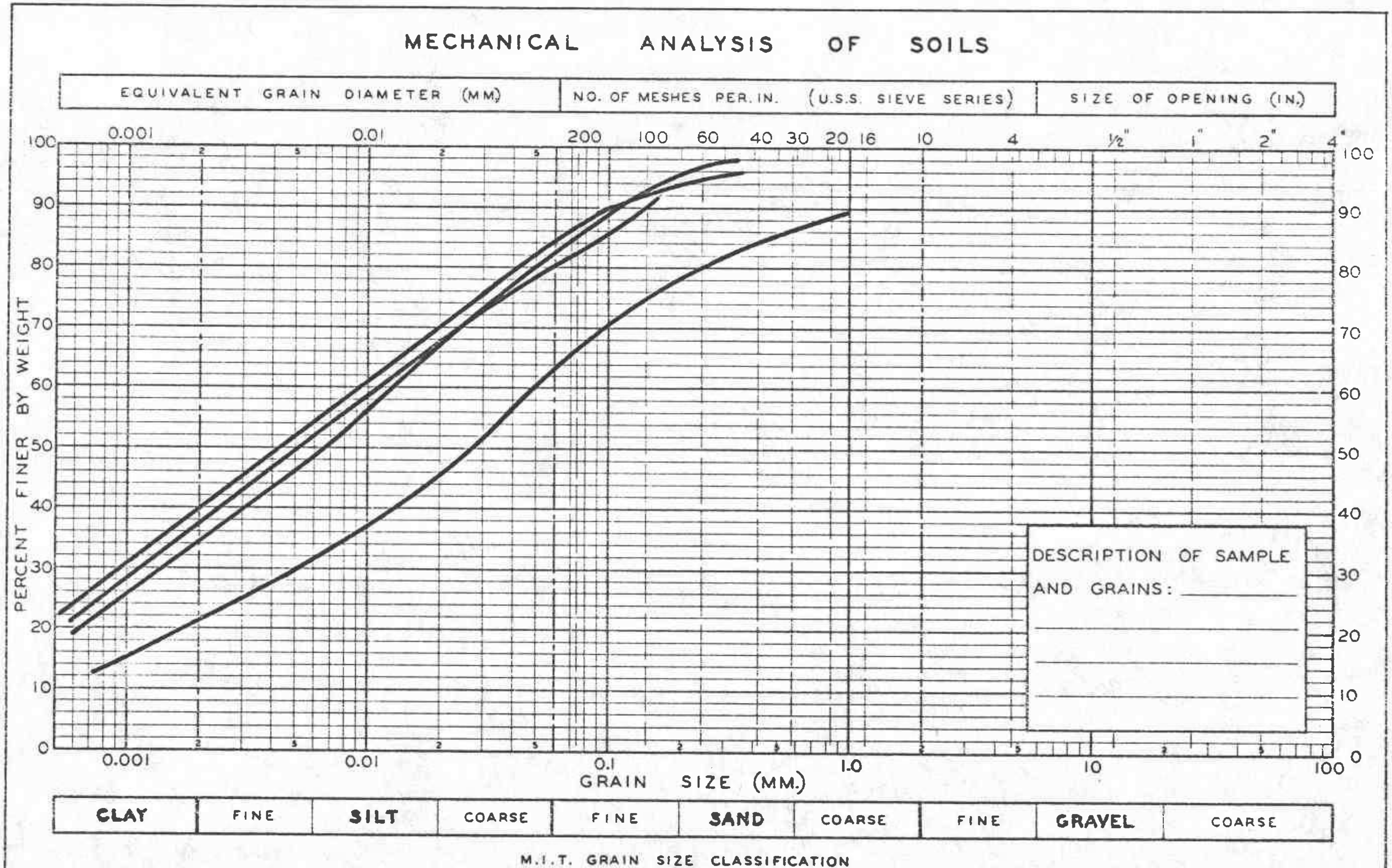


FIGURE 9

GRAIN SIZE DISTRIBUTION - INUVIK SILT CLAYS WITH SOME SAND & STONES

BR. 2643-6

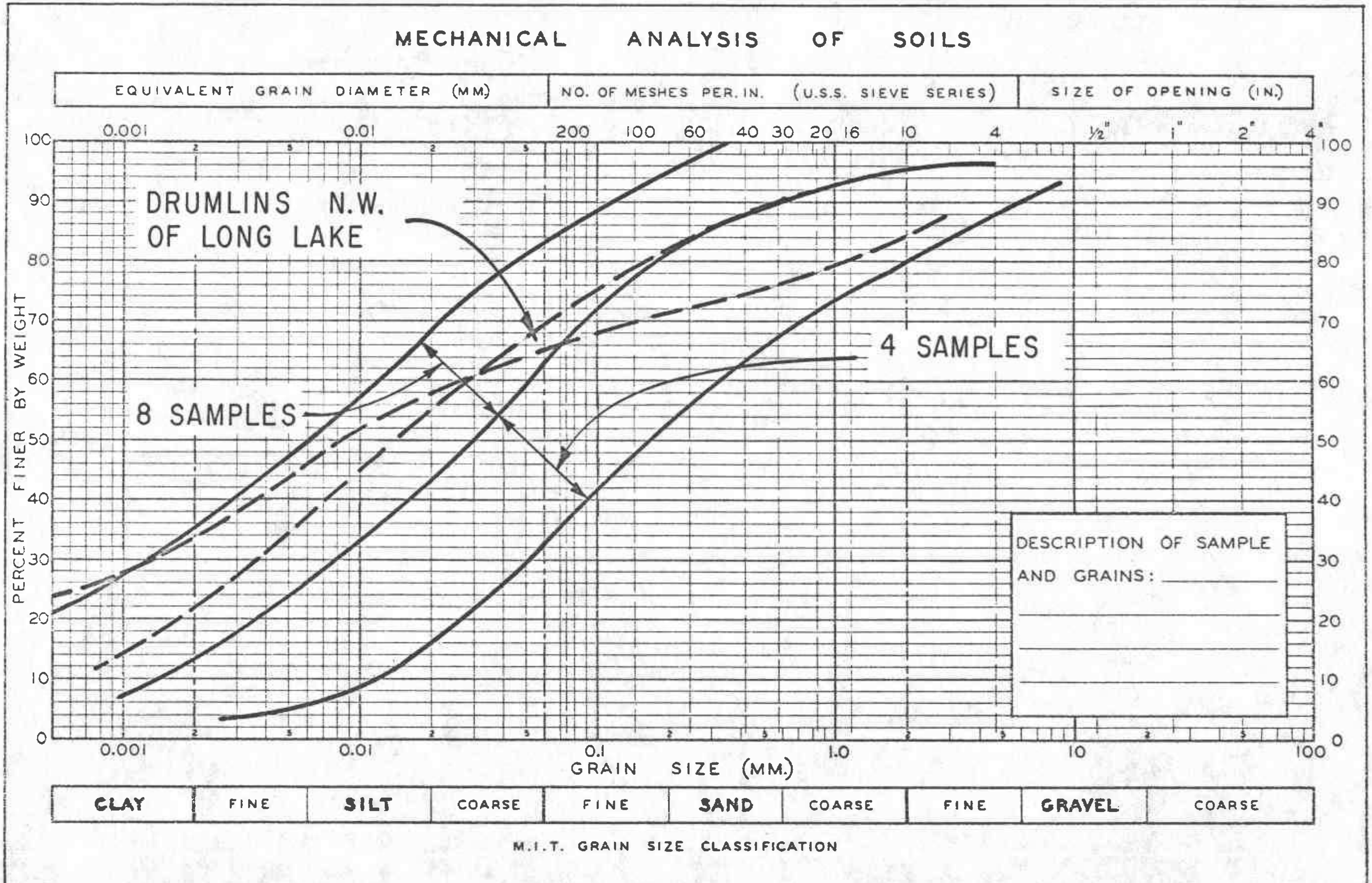


FIGURE 10 GRAIN SIZE DISTRIBUTION - SILT CLAY WITH SAND OR STONES S.E. OF LONG LAKE

BR. 2643-7

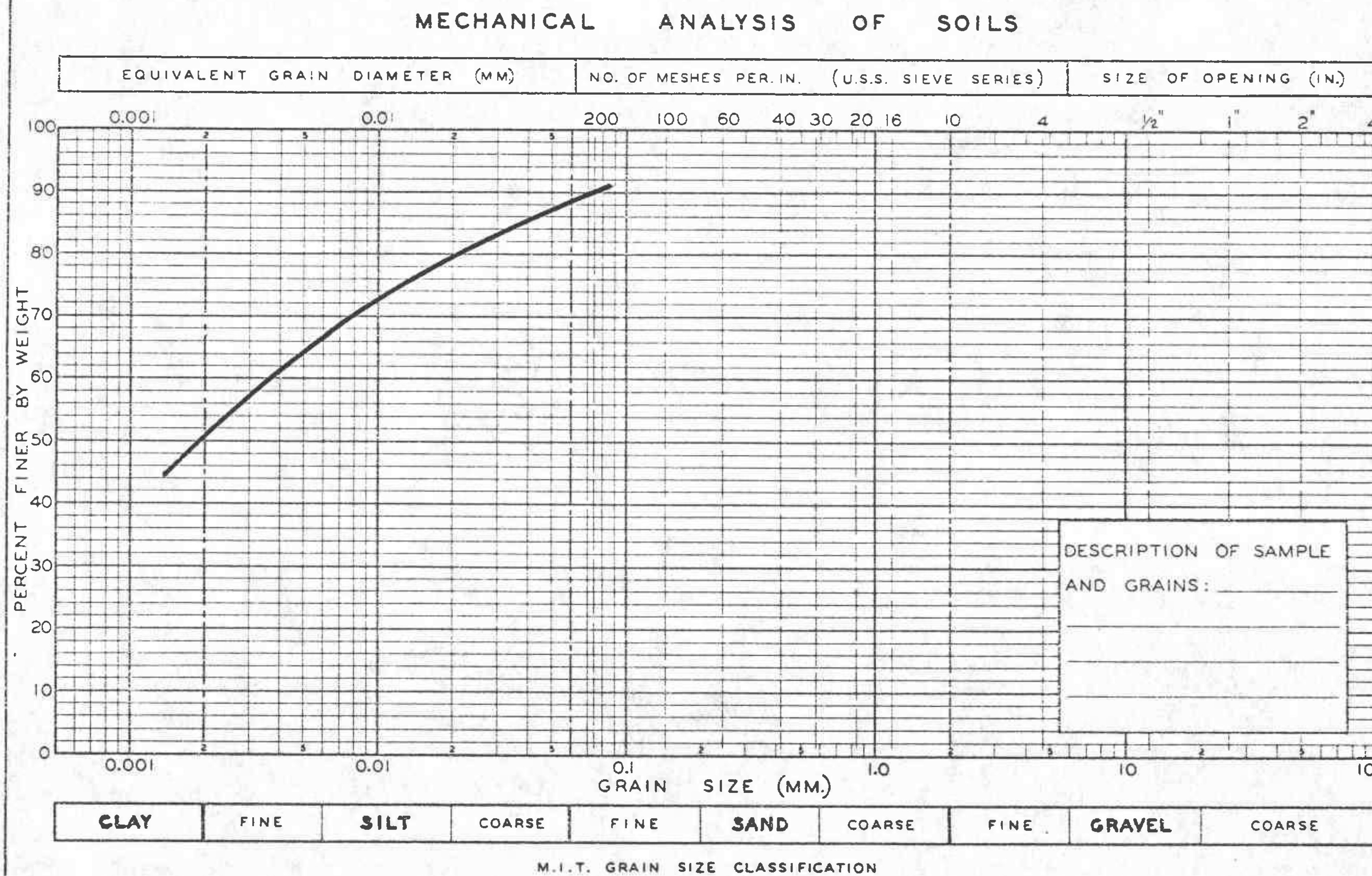


FIGURE II
GRAIN SIZE DISTRIBUTION - "CLAY BOIL" NAVY ROAD, INUVIK

BR. 2643 - 8

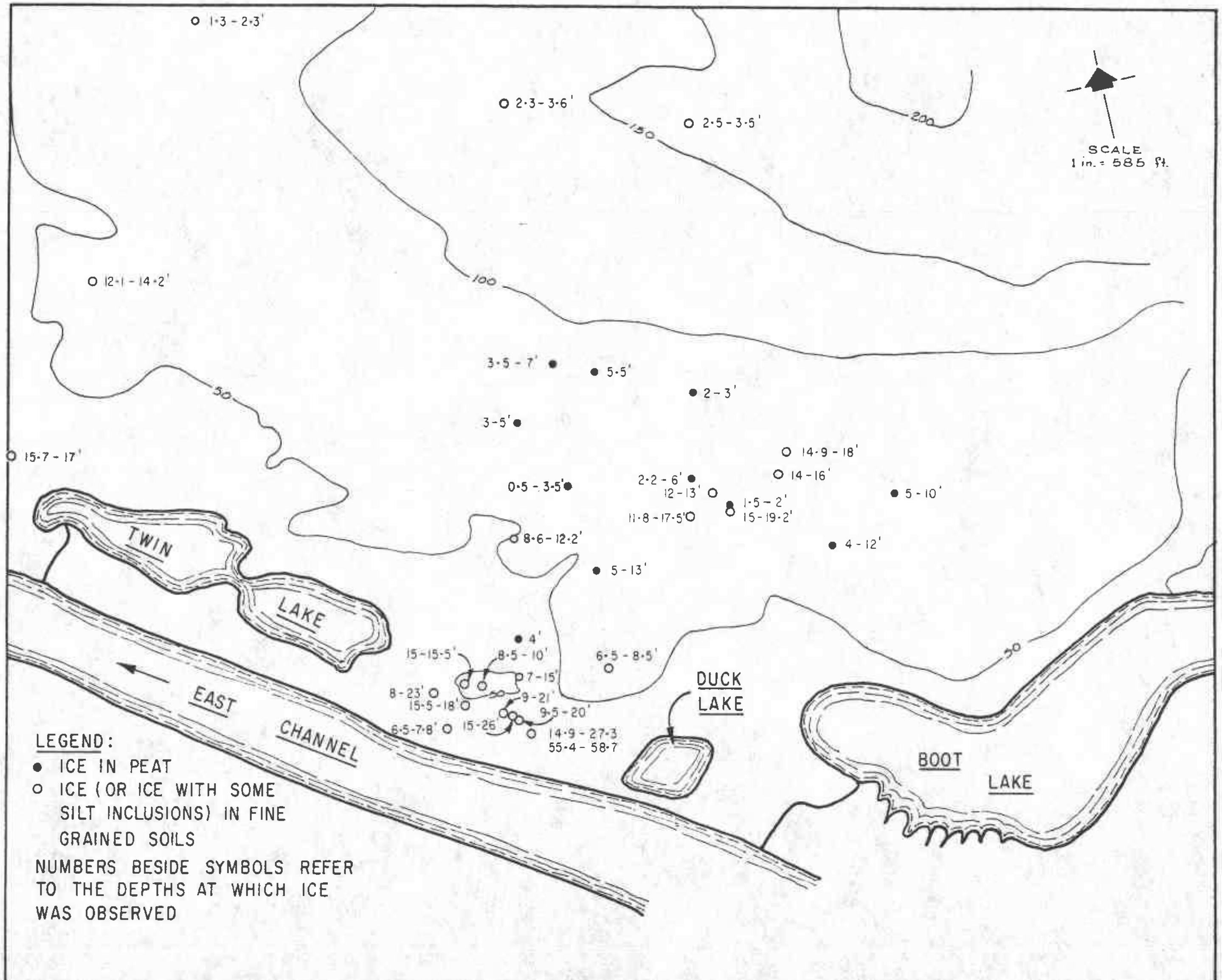


FIGURE 12 GROUND ICE OCCURRENCES AT INUVIK

BR 2643-9

Figure 13

Ice with silt inclusions encountered at 4-foot depth below a 12-inch organic cover at the Inuvik airstrip area.

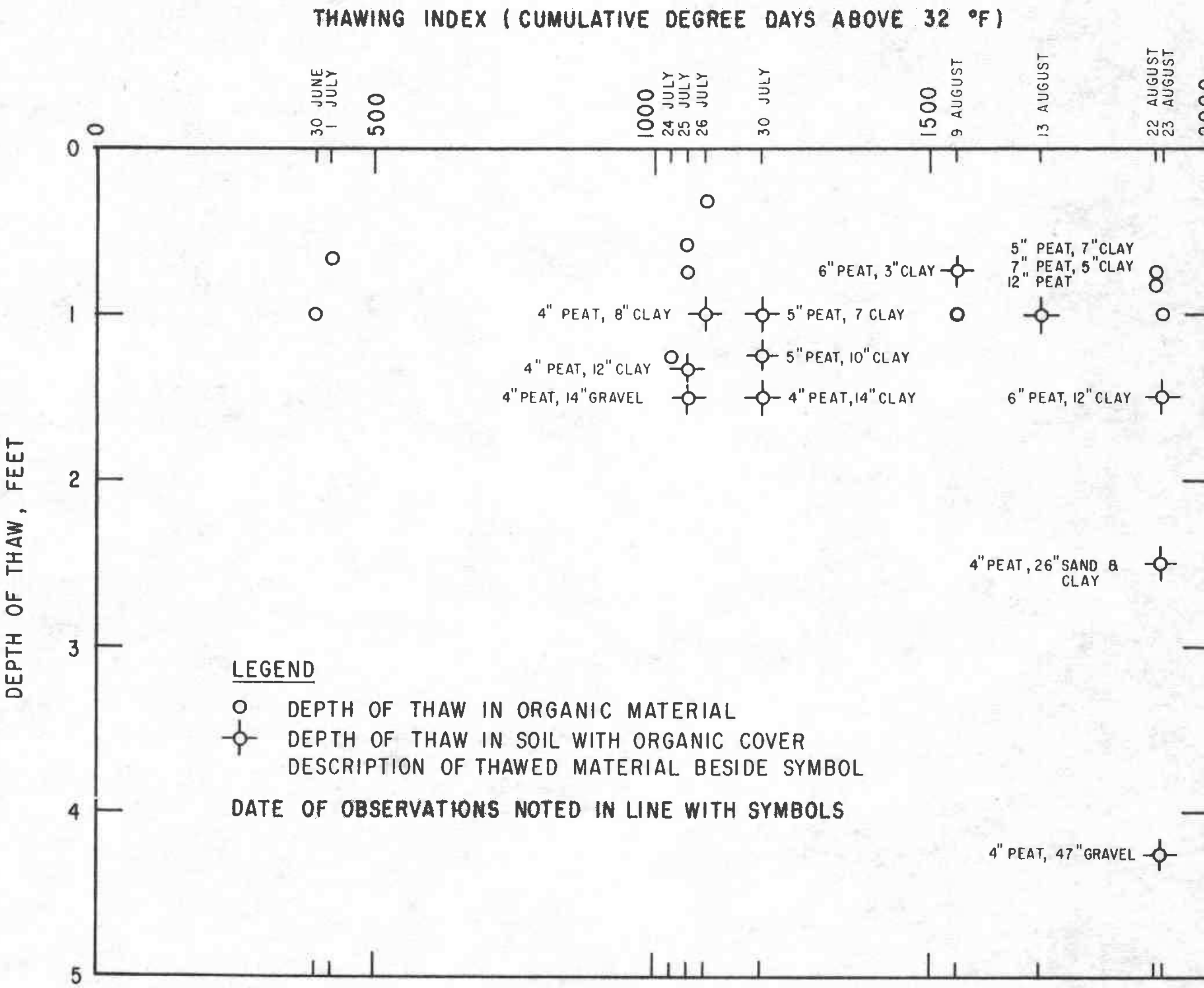


FIGURE 14
DEPTH OF THAW AT INUVIK PRIOR TO OCCUPATION (1954)

BR 2643-10

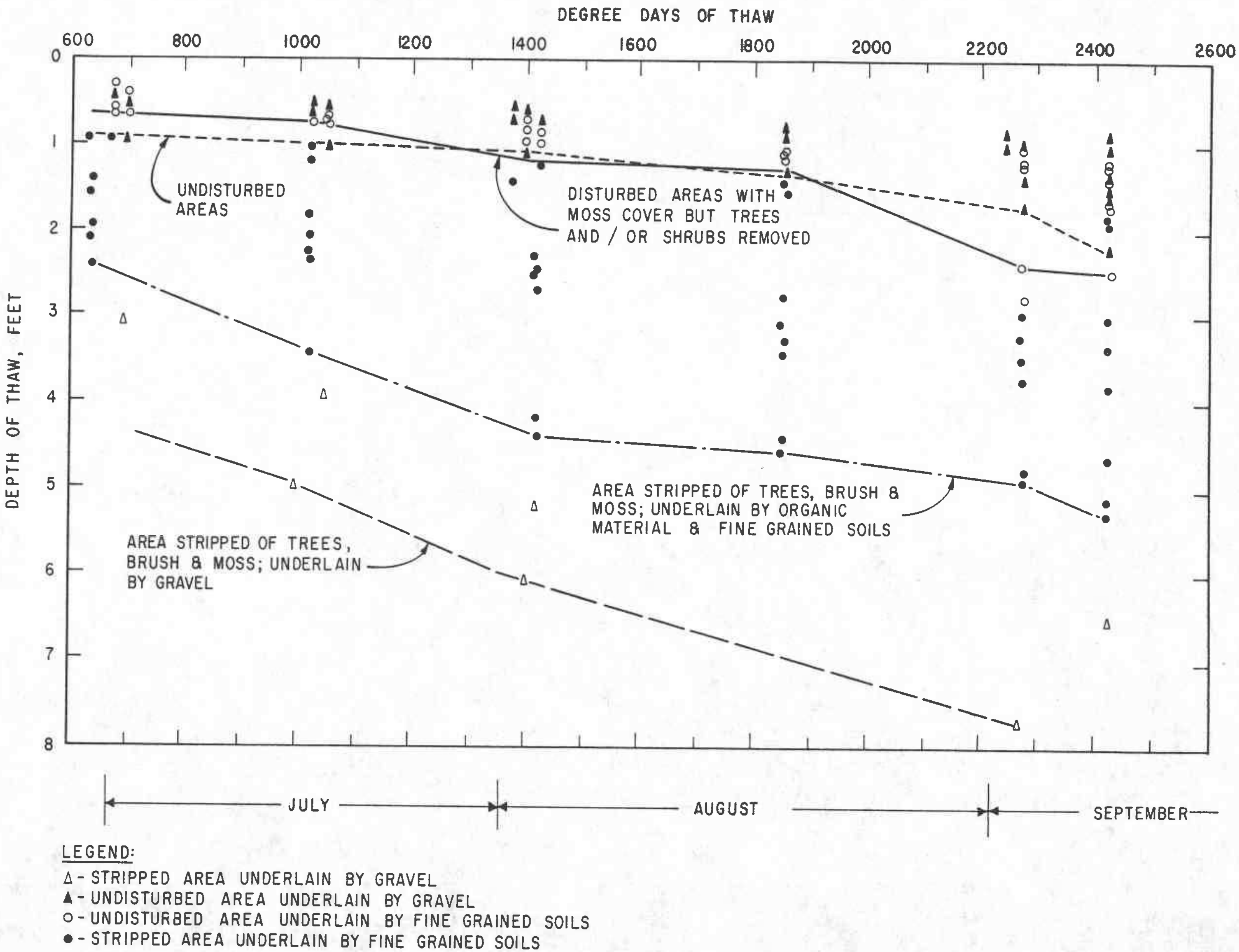


FIGURE 15
EXTREME LIMITS OF THE DEPTH OF THAW AT INUVIK, 1957

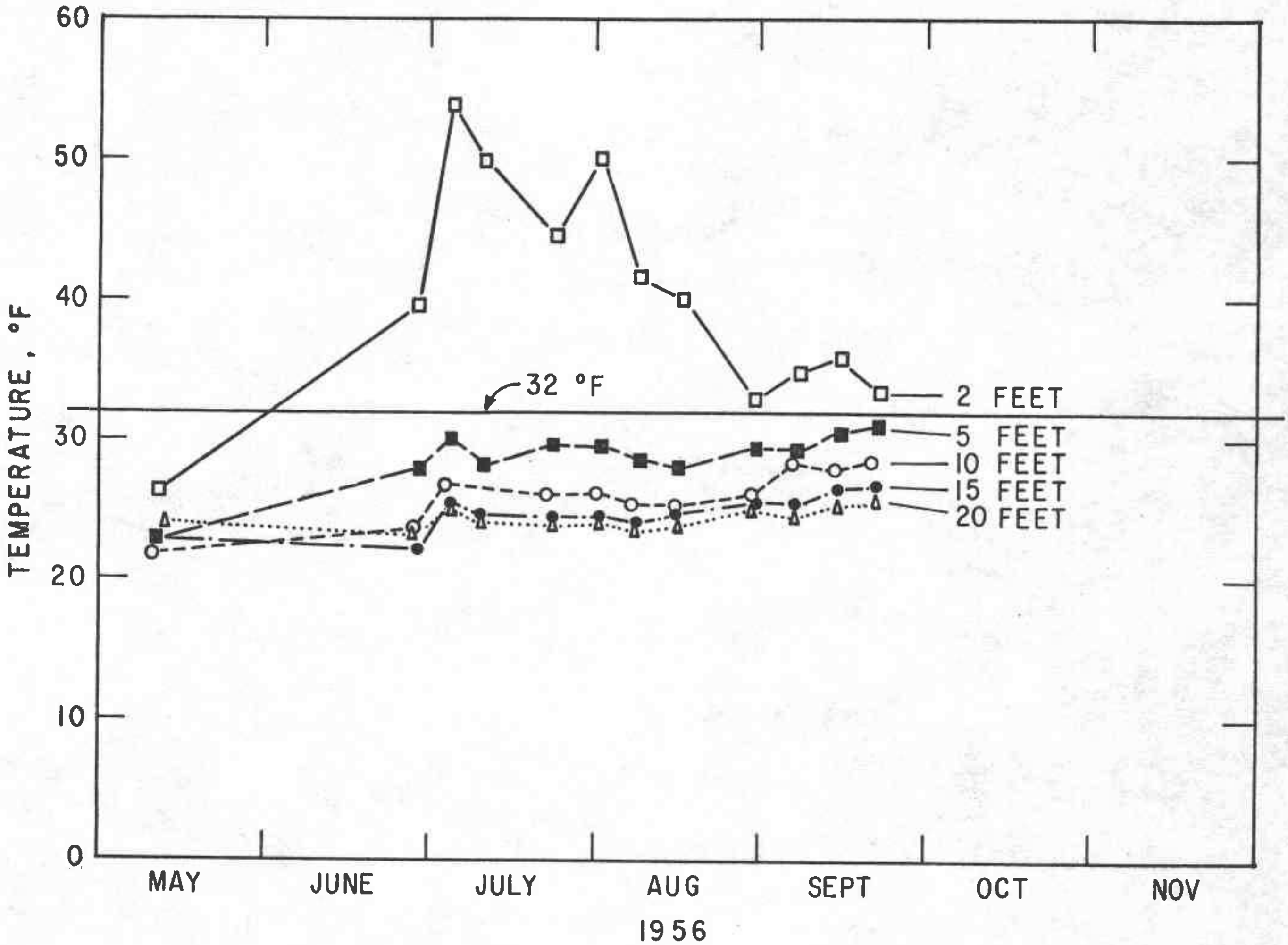


FIGURE 16

INUVIK SOIL TEMPERATURES 1956 - UNDISTURBED AREA
(Thermocouple Installation, ATX - 12)

BR 2643-12

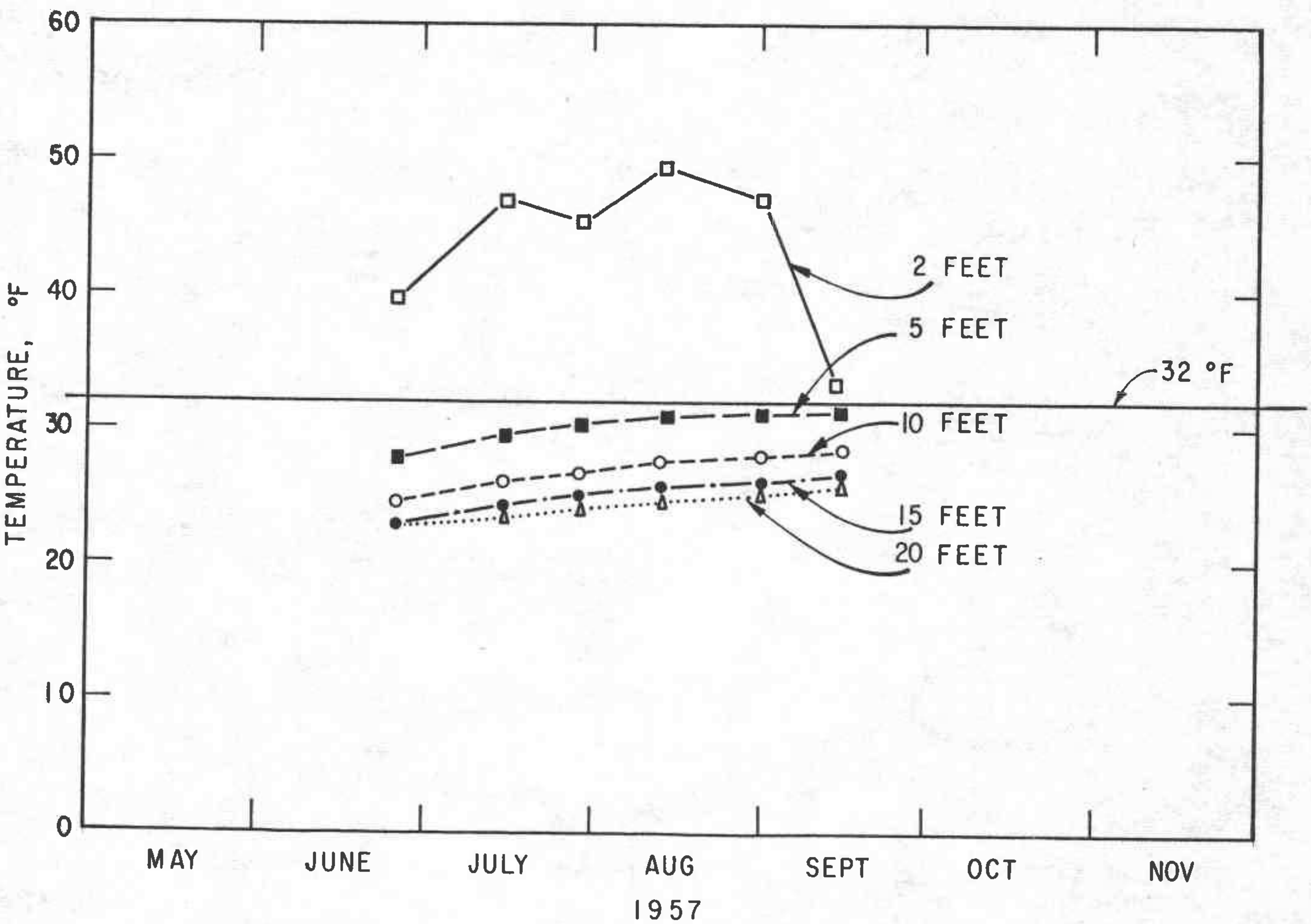


FIGURE 17

INUVIK SOIL TEMPERATURES 1957 - UNDISTURBED AREA

(Thermocouple Installations ATX - 12

BR 2643-13

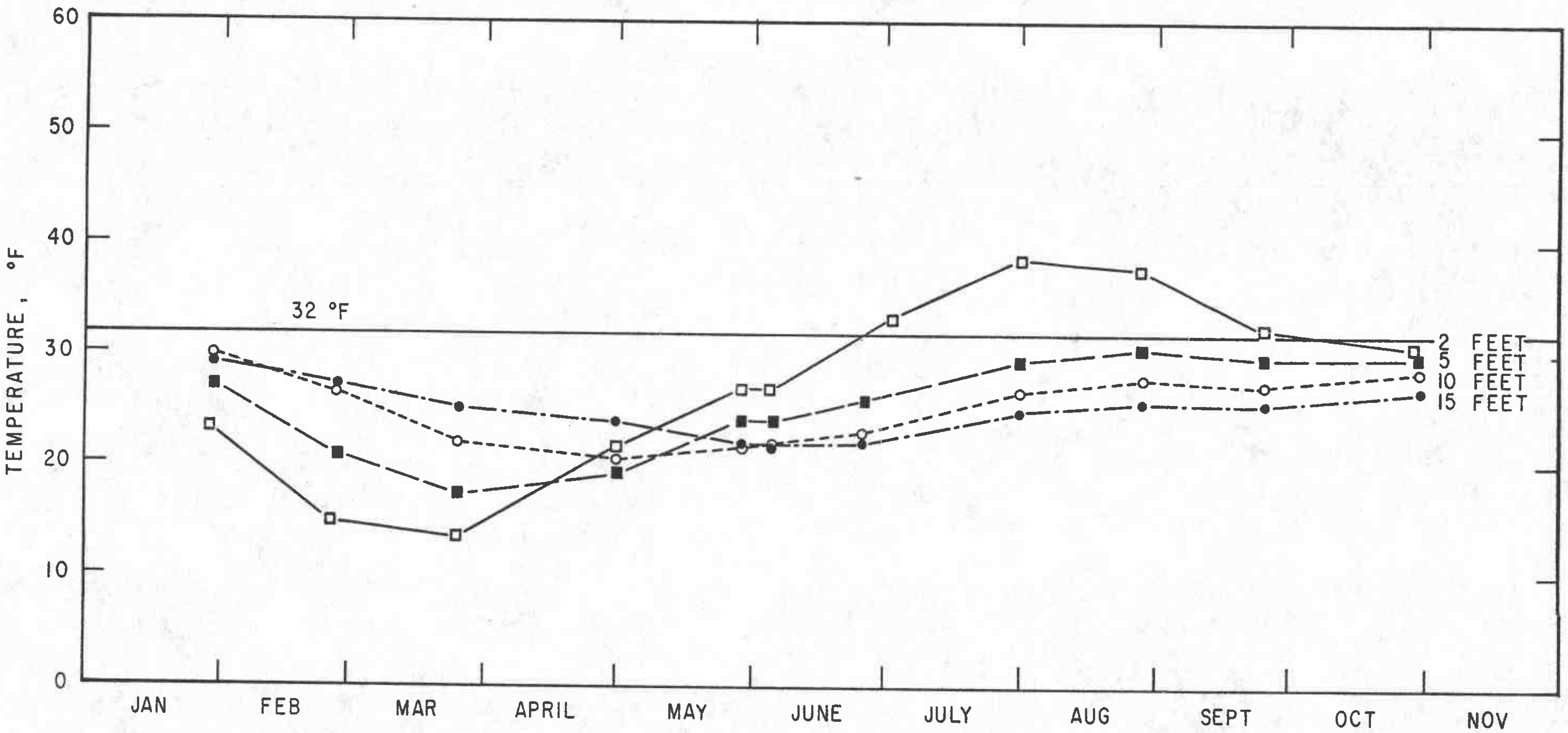


FIGURE 18
INUVIK SOIL TEMPERATURES 1958 - UNDISTURBED AREA
(Airstrip Site Installation No. 1)

BR. 2643-14