Permafrost at Uranium City, Saskatchewan with notes on the development of the new townsite: a progress report

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CANADA

DIVISION OF BUILDING RESEARCH

PERMAFROST AT URANIUM CITY, SASKATCHEWAN

with notes on the development
of the new townsite

A PROGRESS REPORT

by

R. F. Legget

Report No. 60

of the

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PREFACE

From the start of its work, in 1947, the Division of Building Research of the National Research Council has regarded the study of permafrost as one of its principal responsibilities, in keeping with its concentration upon building and allied problems of special interest to and peculiar to Canada. As a centre for field work in this subject in the far North, the Division opened a Northern Research Station at Norman Wells, N.W.T., in 1952, in co-operation with Imperial Oil Limited.

An important part of this essentially long-term study is an investigation and the delineation of the southern limit of permafrost in Canada. The Division therefore welcomed an inquiry which it received in 1952 from the Government of Saskatchewan with reference to soil temperature conditions, and the possibility of permafrost at the new townsite of Uranium City, then being planned in the north of that province.

This paper is a Progress Report of studies made at and visits paid to Uranium City consequent upon that original inquiry. The writer has made this investigation his personal responsibility because of his interest in it, and because of its importance. Due to other demands upon his time, he has been very slow in getting this Report completed. It was originally drafted following the 1952 visit, held up pending the 1953 visit, and again held up (mainly because of work on the National Building Code) to such an extent that it was re-drafted to include observations of 1954. Further delay in the reproduction of the Report is also the writer's own responsibility. K.N. Burn, of the Soil Mechanics Section, has rendered useful assistance with his analysis of the soil temperature records, etc.

The Report is now issued as a progress statement only. It is hoped that it will prove of some use to those responsible for developing Uranium City and other projects in the same area, that it may stimulate local interest in the problem discussed, and possibly lead to the obtaining of additional information of value.

If any who read this Report can assist either with relevant information or by guiding inquiries to sources of

such information, the writer will be most grateful. Communications should be addressed to him in care of the Division of Building Research, National Research Council, Ottawa.

Results so far obtained show that much useful information can be obtained from the study of permafrost in the Uranium City area, information which not only will have a very practical value but will be a contribution to the scientific knowledge which alone is going to solve the riddle of the origin of permafrost and its trend, if any, at the present time. This blending of the scientific and the practical is the constant aim of the Division in all the work which it is now privileged to be carrying out in all parts of the country.

R. F. Legget,
Director.

Ottawa, Ont.

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PART ONE

URANIUM CITY: LOCATION AND CLIMATE

Uranium City is a new townsite which is being developed in the bush of northern Saskatchewan by the Provincial Government, through its Department of Mineral Resources (the Department of Natural Resources and Industrial Development until 31 March 1953). The town is being developed to serve the needs of an area which achieved sudden fame in 1950 when an important find of uranium ore was made by the Eldorado Mining and Smelting Company. Development of this mine and the associated mill led to great activity in the district and much prospecting. The discovery of the Gunnar uranium mine in 1952, in the same area, gave added impetus to development and to prospecting. Although the Gunnar property is not yet connected by road with Uranium City, its influence is felt in the new town which is now well established and which seems to have an assured future.

(2) LOCATION

The Beaverlodge area, in which Uranium City is located, lies about midway along the northern shore of Lake Athabasca. The Lake is a part of the Mackenzie River system, being fed by the Athabasca River (and many similar waterways) and drained by the Slave River. Latitude of the area is 59° 34' N. and longitude 108° 37' W. It is, therefore, just to the south of the boundary between Saskatchewan and the Northwest Territories. The area is about 440 miles northwest of Prince Albert, Sask., and 450 miles northeast of Edmonton, Alta., the two centres from which regular air services operate.

(3) HISTORICAL NOTE

Fort Chippewayan at the west end of Lake Athabasca is one of the oldest and most historic settlements of the Northwest. Fond du Lac and Stony Rapids are correspondingly small old settlements at the east end of the Lake, which is about 160 miles long. These were the only settlements of any sort until gold was discovered in the late thirties close to the Beaverlodge area, this leading to the development of Goldfields as a convenient centre on the Lake. Goldfields was a thriving little mining community from 1938-1942 but it is now derelict, due to the closing of all the gold mines, many of its buildings having been moved to Uranium City over winter ice. The first shaft for the Eldorado development was sunk in 1950 and the main shaft in 1952, the mill starting to operate in the same year. The site of Uranium City was selected and surveyed in 1951. The first building was started

there in the summer of 1952. Practically all the projects to be mentioned in this Report are therefore developments of the last two or three years.

(4) TRANSPORTATION

Access to the Beaverlodge area is of such unusual interest that it must be briefly noted even in this Report. There is no road or railway within several hundred miles and so all transportation is by air or by water. Heavy bulk freight comes by rail through Edmonton via the Northern Alberta Railways to Waterways on the Clearwater River near its junction with the Athabasca. Thence it travels by barges, pushed by Diesel tugs, down the Athabasca and across the Lake to a wharf in Black Bay at Bushell. A road (to be described in detail later) connects the wharf with Uranium City and Beaverlodge, as the Eldorado Mine development area is called. All other transport services are by air, many thousands of tons of freight and practically all personnel in the entire area having been moved in by plane. Float-equipped planes were first used but in 1952 the Mining Company cleared an airstrip near the Mine for the use of its own two private planes. The field is now used also by Canadian Pacific Airlines for regular services to Fort Smith and Edmonton, and by Saskatchewan Government Airways for regular services to Prince Albert.

(5) GEOLOGY

The local geology can best be described as typical of the Precambrian of Canada, typical being used in a physiographic sense since the uranium ores have made the area anything but typical in its rock types. Reports on the bed-rock geology are available (1, 2). The topography consists of much glaciated bed-rock, giving a rolling terrain, most of the depressions between rocky hills having glacial soils and muskeg in them with the accompanying numerous lakes and interconnecting streams. The country is well wooded, jack pine being widespread, with white birch in some areas. As can be seen from Fig. 1, some of the local lakes are very large, the hills around combining to form with them a singularly beautiful part of "The Shield".

(6) CLIMATE

Unfortunately, but quite naturally, there is not yet a regular Weather Station in the Beaverlodge area. Fortunately, however, regular weather observations had been taken at Fond du Lac from 1905-1937. As this is only 50 miles away in an easterly direction, the Fond du Lac records can be used for Uranium

City with a reasonable degree of certainty. Figure 2 is a graphical presentation of average weather data for the period noted. It will be seen from this that the local climate is relatively dry, with a short summer season, and a long cold winter. Average annual air temperature for the period noted is 23.6 °F.

PART TWO

LOCAL PERMAFROST

(7) A GENERAL NOTE

Early in the planning stage of Uranium City, the Division was approached (by Mr. A. Bereskin, Controller of Surveys, D.N.R., Saskatchewan) as to the availability of any information about soil temperature conditions which might be expected at the townsite. A negative reply had then to be given but this inquiry started a singularly happy liaison with Mr. Bereskin and others in his Department. Two automatic 3-pen recording thermometers were sent by the Division to the townsite in November 1951. They were installed by the staff of D.N.R., and have been in operation since that time. The results obtained are discussed later in this report.

Since it seemed probable that permafrost conditions might be encountered in the Beaverlodge area (and for a number of other reasons) Messrs. Pihlainen and Handegord of the DBR staff accompanied the writer on a visit to Uranium City in July 1952. Mr. Handegord paid a further visit, accompanied by Mr. R.J.E. Brown, in July 1953. The writer paid a further visit in July 1954. The first visit confirmed early suspicions about permafrost so that all three visits have provided much interesting information. A report was drafted on the 1952 visit but its completion was held up pending further study of soil temperature records. It has been redrafted to form this Report which incorporates information obtained during the visits of 1953 and 1954.

(8) LOCAL SOIL CONDITIONS

Although it now seems reasonably certain that for a depth of at least 10 feet, ground temperatures in the Beaverlodge area are generally below freezing (apart from the usual annual variation in the upper few feet), the degree of freezing is so slight that, in the language of local hard-rock drillers who are experienced in the North, "there is no permafrost in

the rock". By this they mean that they do not usually experience any trouble in the Beaverlodge area due to freezing of wash-water or freezing-in of drill rods, even if left in holes over night. The following discussion of permafrost therefore relates to conditions in soil only.

The local soils are easily described. Much of the superficial soil is sand and gravel, rock fragments being in general only slightly rounded from their original angular character, resulting from glacial action. Occasional deposits of clean well-rounded gravel are found, suggestive of extensive water sorting and transportation of original glacial deposits. Underlying many of the sand and gravel deposits, and very frequently the muskeg which is so common a feature of the valley terrain, hard-packed deposits of glacial silt are found. When wet, this appears to the untrained eye to be clay, and it is often so described locally. The records of typical mechanical analyses are given in Fig. 3. Table 1 gives the results of simple identification tests upon the same samples.

TABLE 1

Test Results for Uranium City Soils

Sample No.	Location	Liquid Limit	Plastic Limit	Plasticity Index
37-10	Stony Rapids Airport	40.8	34.8	6.0
37-11	B'lodge Road: Mile 2	17.6	15.2	2.4
37-12	"	24.4	19.7	4.7

In combination, these results show that the material in question, although variable to some degree, is a silt, its glacial origin suggesting that it may properly be described as "glacial rock flour".

(9) THE TOWNSITE

Since the area in which the Department is naturally most interested, and for which soil temperature information is most necessary, is the Uranium City townsite, it is natural that attention should have been concentrated upon this area. Soil conditions are peculiar: they must therefore be briefly described. The area selected was a naturally beautiful one,

adjacent to the Fredette River and not far from Martin Lake. Before clearing started, the entire central part of the town-lot area was covered with aspen and poplar with only a little spruce. These are well known as indicators of a gravelly soil and excavations proved the soil to be generally a clear sand and gravel mixture, with only a very thin vegetal cover, grading into almost pure sand in the lower portion of the site. The area is quite steeply graded, from about Fredette Road and Fission Avenue down to a low spot near the famous Guss Hawker's store (Lot 2 in Block 1, Fig. 4). A marked ridge separates this low area from the Fredette River so that it has no natural drainage outlet. It was not, therefore, surprising to find in 1952, before much clearing had been done, that it was covered with a thick layer of muskeg in which the groundwater level stood high.

(10) FIELD OBSERVATIONS

(a) In the Townsite

It was naturally in the townsite area that the first observations were made (1952). In the North, muskeg usually suggests permafrost and so a pit was excavated in the muskeg just described. Groundwater at about 18 inches limited excavation but a steel bar was forced down to a depth of just over 5 feet without any frozen ground (or anything but very loose, wet muskeg) being encountered.

It was stated locally that frost had been encountered in excavating for a garage in this area and so another pit was excavated across the Uranium Road in an area where trees were still standing ('B' in Fig. 4 B). Ground-level was about 3 feet higher than hole 'A'. Sand was encountered as soon as vegetation was removed and persisted to a depth of 7 feet. The sand was damp but not wet, down to a depth of 4 feet 6 inches. Here a frozen condition was encountered but since it did not look like permafrost, digging was continued. As anticipated, the frost layer stopped at a depth of about 6 feet, and damp sand continued to the bottom of excavation at 7 feet. Probing with a rod failed to reveal any further evidence of ice.

Later in this same visit, a deeper hole was excavated (by Indian labour) in order to remove one of the DBR recorders. Clear dry sand was encountered to a depth of 12 feet at location 'C' (Fig. 4).

On each of the three visits, a number of excavations for building foundations were examined. By means of a test hole in the bottom of one of these ('D' in Fig. 4) a depth of almost 10 feet below ground-level was reached, fine sand persisting to this depth beneath a surface deposit of 4 feet 6 inches of gravel. Other excavations were similar, in one case only a

layer of compact silty sand being reached beneath the loose sand and gravel. In no case other than the first pit noted was any trace of frost or frost action observed at any time. Since, however, the ground was quite dry, this did not necessarily mean that its temperature was not below freezing.

(b) Along the Road

Those who know the area assured the writer, during the 1952 visit, that these observations at the townsite were misleading. There was much evidence along the road to confirm this suggestion. Accordingly, a point was chosen at random (at about mile 3 on the Uranium Road), where surface vegetation was typical, trees around being tamarack, black spruce and birch, the slope facing the North. Excavation showed 6 inches of muskeg cover, then 3 feet of very wet silt (in the condition of "bull's liver") at which depth, 3 feet 6 inches, ice was encountered which further work showed to be true permafrost. Close study of the roadsides suggested that this was the typical local condition, for wooded areas on north slopes, rather than what was seen at the townsite.

(c) At "Ice Hill"

Instead of excavating on a south slope, and at the suggestion of Mr. George Langford (at that time in charge of road construction), ground conditions at a particularly troublesome spot on the Uranium Road were investigated. The location is at mile 5. The trouble was quite unusual since the elevation is relatively high, the road rising to the bad spot from both directions, and since there are a number of exposures of bed-rock all around suggesting shallow cover. Failure of the original roadbed, however, had occurred. Excavation in the adjoining muskeg revealed a dry, compact and well-matted texture to the muskeg which was in definite layers. At a depth of 2 feet 6 inches, a sudden change took place to permafrost consisting of relatively "fresh" muskeg, still in layered formation, quite solidly frozen.

This was quite the most surprising example of permafrost which the writer and Mr. Pihlainen had seen. A second pit was dug to check the observation with exactly similar results. Mr. Langford confirmed the observation from his own experience when first building the road at this location in the summer of 1951, his recollection being that the depth in August varied from 2 feet to 2 feet 6 inches. In view of the special interest of this location, it was decided to move one of the DBR temperature recorders from the townsite to this "Ice Hill", as it began to be known; details of this installation are given later.

This interesting spot was visited again by Mr. Handegord in July 1953, and he found a similar condition, permafrost being reached at a depth of 14 inches. It was again visited by the writer in July 1954. One of the old holes was found just as it had been excavated. Excavation was continued and permafrost found at a total depth of 3 feet 6 inches or about 18 inches below the bottom of the old pit. A new pit was dug a few feet away and permafrost was encountered, as previously, at a depth of about 15 inches.

(11) EXPERIENCES DURING CONSTRUCTION OPERATIONS

Although many more observations of permafrost and associated phenomena were made during each of the three DBR visits, they can most usefully be described in association with notes on construction operations, especially since it was possible to talk, during these visits, with those who had had much experience in working in the Beaverlodge area, experience which they gladly shared and which naturally conditioned the observations made during the relatively brief stops of the writer and his colleagues at Uranium City.

(a) In Diamond Drilling

An obvious starting point for inquiries about such practical experience is the extensive diamond drilling which has been carried out in the Beaverlodge area. Unfortunately, inquiries in this direction have not proved very fruitful. Quite naturally, diamond drilling -- in this area at least -- is carried out with one objective only in view, the obtaining of good rock cores which may be tested for their ore content. "Overburden" is of no interest either to the driller or his employer, unless it causes trouble. As already noted, diamond drilling at Beaverlodge is not regarded as difficult, in relation to frost problems and so the depth to which soil is frozen is not generally noted. The only specific figures which could be obtained during all three visits suggested a depth of permafrost of between 25 and 30 feet, but these depths were not well authenticated.

(b) Well at Bushell

A well which was sunk at the tiny port of Bushell in 1952 was described to the writer. It was sunk to a depth of 26 feet, the first 22 feet in sand and gravel and the last 4 feet in what the well-digger described as "gumbo". The presence of bed-rock close to the bottom level reached was suspected. Apart from the first 6 feet which proved to be very tough and compact, the digging proved very easy and no frost was encountered.

(c) At the Eldorado Mine

In general, construction experience at the Mine appears to have been devoid of permafrost troubles, with the exception of one notable operation. Foundations for buildings, etc., have naturally been placed on solid rock whenever possible. Although some difficulties have been experienced with a few of the fine residences which the Mine has built, these appear to have been due to what may be called "ordinary winter frost action" rather than to permafrost.

The one exception noted above was the construction of the Main Shaft of the Eldorado Mine. It was located near the centre of a basin-like depression in the surrounding glaciated rock hills. When construction started, late in 1951, it was found that the basin was filled, to the ground-level between rock outcrops, principally with muskeg. This was in frozen condition, and construction operations had the effect of freeing a good deal of water from it, making shaft sinking a slow and difficult operation. Bed-rock was reached at a depth of about 30 feet and the overburden was apparently frozen throughout this distance. Quite naturally, the objective of those at work on this project was to get the shaft-sinking going smoothly in the bed-rock as quickly as possible. Frozen overburden was therefore only a nuisance (to put it mildly) to be penetrated with all possible speed. In consequence, no very accurate records seem to have been kept of this minor part of the operation; none, at least, have so far been located.

(d) At the Uranium City townsite, Bushell, etc.

Construction experience at the townsite has been in line with what preliminary studies (p. 4) suggested, i.e., excavation in sand and gravel with no frost problems encountered. The only frost problem of which the writer has heard was a temporary freezing-up of one of the individual sewage installations, but this was of very short duration and clearly the result of cold winter weather.

Very little construction has been carried out at Bushell, apart from the wharf, a large storage shed and oil storage tanks. The first tank farm and the shed were founded on solid rock. During the 1954 visit, a new tank farm was inspected, the bolted steel tanks of which have been founded on sand and gravel mats placed on glacial silt, with the muskeg cover removed. No special problems seem to have developed, and the soil condition is similar to that at many locations on the road.

All other construction in the district, of which any details could be obtained, is either so light as to

create no foundation problems or else is founded on solid bed-rock.

There remains to be described the permafrost experiences on the road from Bushell to Beaverlodge which are of such importance that the next section of this Report will be devoted to them.

(12) EXPERIENCE ON THE URANIUM ROAD

So important was the early provision of transportation facilities to the Eldorado Mine that the first major activity of the Saskatchewan Department of Natural Resources and Industrial Development (now DNR) was the location and construction of an all-weather heavy-duty road from the wharf at Bushell to the Mine at Beaverlodge, passing the site of Uranium City on the way. The road is about 11 miles long. It was built in 1951 and had its first complete operating season in 1952. Tonnages landed at Bushell and so transported over the road, mainly to Beaverlodge and practically all in large trailer trucks, have been as follows:

1952	26,000 tons
1953	32,000 tons
1954	30,000 tons (estimated).

The fact that this gravel road has carried this tonnage of freight, as well as an appreciable volume of passenger car traffic (notably that of the twenty taxis which provide a vital link between the Mine and Uranium City) without any interruptions, despite the difficulties which have to be recounted, is tribute indeed to those who have been responsible for it.

The road was located by Mr. R. Hovdebo and Mr. G. Langford, in the first instance by means of a study of airphotos, the location thus chosen being then checked on the ground. Now that the area around can be seen conveniently, the location selected can be seen to be exceptionally favourable within the limits of the alternatives available. Good supplies of gravel were fortunately close at hand. For much of its length, the road could be located on solid rock or on shallow deposits over the rock. For possibly three of its eleven miles, however, there was no alternative to locating it over muskeg and so over permafrost.

There seems to be little point in recording the exact location of these sections since experience at most of them was similar. It should first be said that Mr. Langford, as Road Foreman, and his successor Mr. Herbert, both knew from practical experience the dangers and difficulties which could be created by the frozen glacial silt

whether used as fill or as a foundation bed. Alike in the construction of the original road, and in subsidiary roads more recently built, the silt -- assumed to be clay -- was used as fill in the absence of the road foreman by enthusiastic amateurs, if it may be so expressed, in an excess of zeal to get on with the work. In consequence, and just as would be expected with "frost susceptible material" of this character, frost boils and soft spots developed in the spring at places where the silt was so used; suggestions were made in 1952 for the removal of the offending material, so innocently placed in the fill.

More serious, however, were the troubles that developed from the indiscriminate removal of the muskeg cover over the silt, again contrary to instructions but again, one may be sure, only in an anxious endeavour to get the road through, and following the traditional and superficially obvious practice of removing from the road bed such apparently unsuitable material. Maintenance troubles have been a consequent legacy, now much decreased in magnitude from 1953, and especially from 1952, but still annoying.

With the muskeg cover removed, the silt gradually thawed out, in the heat of high summer. Its ice content was apparently more than enough to provide sufficient water to saturate the silt. (The one moisture content test conducted gave a moisture content exactly equal to the liquid limit but as one test only has been done, no great significance can be attached to this.) The resulting mixture of silt and water was at once very unstable and very slow-draining. Figure 5 is a typical view of this material adjacent to the road.

This photograph illustrates the sort of maintenance problem which resulted, but gives no idea of the continual worry that this material has proved to be in locations where the silt deposit was deep and the possibilities for drainage very poor. In one location, for example, the "road crew" (as the maintenance staff are called) say that they have placed as much as 17 feet of fill even though the apparent height of the embankment is only about 5 feet.

Once the damage of removing the muskeg cover has been done, then the only possible solution to maintenance problems is the steady placing of more gravel fill, when needed, and the promotion by every possible means of the drainage of both the fill and the adjacent silt. It was satisfactory to note, during the 1954 visit, that a good number of locations that were "soupy" in 1952 had dried up quite satisfactorily and appeared to be giving no further trouble in maintenance. At other places, however, standing water was still to be observed close to the road; as long as it is there, it will be a possible source of further trouble.

Naturally, there are many experiments which the Division of Building Research would like to try out on this pioneer road, if only it was nearer to Ottawa! One experiment has been tried with the assistance of DNR staff: it will be described at a later point in this Report. The chief "value" of the road from the research point of view is the striking confirmation it gives of the existence of permafrost at Uranium City, and of the behaviour of road fill placed on permafrost, as well as of the difficult characteristics of glacial silt as a material of construction.

One unusual geological feature was noted, in 1952, along the road. It is described in Appendix A since it is of academic interest only. It is included in this Report, however, in case any readers may know of any similar occurrences, in which case the writer would greatly appreciate hearing from them.

Correspondingly, it should be recorded that Mr. Herbert (Road Foreman in 1954) advised the writer that he had encountered in 1954 blocks of clear ice, firmly buried in the silt, one striking case having been seen on the Rix Road. It is unfortunate that samples of such blocks were not obtained but this was obviously impossible.

(13) AIRFIELD AT STONY RAPIDS

Useful and relevant information was obtained during journeys to Uranium City in 1952 and 1953 at the airfield at Stony Rapids (Fig. 1). This simple field, consisting of two intersecting strips about 3000 feet long and 300 feet wide was made in the summer of 1951 by the simple expedient of bulldozing the muskeg and trees over the area to the sides of the strips and allowing the underlying silt first to thaw out and then to dry out, as exposed.

Fortunately, it was possible to do this before the field was used by planes, with the result that a hard sun-baked crust was available for use when the first light planes landed early in the summer of 1952. When examined by the writer at this time the surface consisted of compact glacial silt identical in appearance with that at Uranium City (Sample 37-10 noted in Table 1, shows that the similarity was real). A few depressions were noted, some basin-shaped, suggesting the thawing-out of ice lenses. A few drainage channels had cut themselves across the area and, as noted in Appendix A, similar holes to those found on the road were noted.

Grading had been carried out before the visit of 1953 and drainage ditches had been constructed around the

perimeter of the field, removing the slight blemishes of 1952 and converting the field into one of the best simple airports of the north country.

PART THREE

SOIL TEMPERATURES

(14) A GENERAL NOTE

One result of the early inquiry from Mr. Bereskin was an offer, by the Division, to lend to the Department two of its temperature recording instruments. These were accordingly shipped from Ottawa in November 1951 and installed at the townsite of Uranium City (by the Department) in December 1951. Their locations are detailed in following notes.

The instruments record on weekly circular charts by means of three ink-pens, using different coloured inks. Since the original installation at Uranium City was made, it has been found from experience there, and elsewhere, that the instruments are not very satisfactory for outside use under such rugged conditions as are created by Canadian winters. Despite all difficulties, however, the instruments in question have been faithfully operated by DNR staff (notably Mr. George Langford and Mr. Earl Shannon) and the Division is indeed grateful for this assistance.

(15) INSTRUMENTS

The instruments used were Taylor Temperature Recorders, 76J series. They consist of special metal bulbs, mercury filled, connected through stainless steel compensating capillary tubes to a recording mechanism which actuates the three pens, registering on a circular chart, rotated by a clockwork mechanism. The instruments were calibrated before leaving Ottawa but have not been checked since. The blue ink pens, in particular, gave a lot of trouble.

(16) INSTRUMENT A

This was first installed (in 1951) attached to a silver birch tree close to what is now the intersection of Uranium Road and Fission Avenue, at about an elevation of 175 feet above Martin Lake, i.e., in the upper part of the

townsite. During the installation, the vegetal ground cover was removed and not replaced, and a wooden cover and fence were used to keep snow off the ground over the buried bulbs. Initial results, therefore, may be unduly cold.

Consequent upon the start of construction work in the locality of the instrument, it was moved in August 1952 and reinstalled in a new location in the boulevard of Frenette Road, close to the intersection with 2nd Street N., and conveniently situated with respect to the DNR office. Readings started again in August 1952 and have continued up to the time of writing this revised Report, except for the first part of 1953.

(17) INSTRUMENT B

This was first installed at a point at the low part of the townsite, to the South of Uranium Road in lot 2 of Block B9. It was in use here from December 1951 until the time of the writer's 1952 visit. Just before that time (July 1952) a wood working building had been erected very close to the tree to which the instrument was attached. It was therefore decided to move it and to reinstall it on Ice Hill to see if something could be learned about the effect of the road fill on the permafrost known to exist at this location.

During his visit, therefore, the writer saw the bulbs removed, the excavation being carried out by local Indians. The bulbs were "well and truly" buried at the stated depths in clean dry uniform sand. The subsequent reinstallation at Ice Hill was done by DNR staff. During Mr. Handegord's visit of August 1953, it was found that the instrument had been damaged: it was repaired as well as could be managed and has been operating since that time. Details of the installation at Ice Hill are shown in Fig. 6.

(18) A GENERAL NOTE

From experience gained by the Division at Uranium City and elsewhere with clockwork-operated soil temperature recorders, it has been found that they are not really satisfactory for such rugged outside duty. There is no easy way of calibrating the instruments nor of checking their accuracy when once they have been installed. Further, although they give a continuous temperature record, this is not really necessary since ground temperatures (even near the surface) change relatively so slowly. Accordingly, the Division is turning to electrical measuring devices, such as thermo-

couples, for its country-wide soil temperature observations. It is hoped to replace the two instruments at Uranium City with one thermocouple installation soon after the completion of this Report. (This has now been done: 1955.)

(19) DISCUSSION OF RESULTS

The records obtained during the two-year period of observation have been summarized in Figs. 7 to 12. Although plotted to a relatively small scale, these diagrams permit of a general study of soil temperature variations.

Figures 7 and 8 show the records obtained in the first half of 1952 at the first two installations, both instruments being located on the townsite. The installation at the top of the hill had the three bulbs at depths of 6, 9 and 12 feet respectively. Minimum winter temperatures were about 24°F, 26°F and 29°F respectively. Figure 7 shows the usual time lag with increasing depth, minimum temperature at the 12-foot depth not occurring until the second week of June.

The temperatures in July are puzzling, alike because of the rather rapid rise for the 6- and 12-foot depths and the very small rise in the temperature at 9 feet. Although these final records are of doubtful value, the winter values should be reliable since the instruments had been carefully calibrated immediately before leaving Ottawa.

The soil temperatures at the foot of the hill follow the same pattern although they are surprisingly higher. Minimum temperatures at depths of 8, 10, and 13 feet were respectively 31°, 32°, and 37°F. The usual time lag is again apparent; the July temperatures, showing a small rise only, are in line with the usual slow change in soil temperature pattern.

The difference between the two locations may be explained, in part, by the difference in soil type. At the foot of the hill, the bulbs were in damp, uniform, compact sand whereas at the top of the hill, the bulbs were located in dry sand and gravel.

Figures 9 and 10 show the record over a two-year period for the new location for the instrument previously at the top of the hill. The new location was at about the same elevation as the first location at the foot of the hill, but to the north of this, adjacent to the Mines Branch office. Bulbs were now at depths of 2, 4, and 8

feet respectively, so that the temperature range is much greater than in Figs. 7 and 8, the time lag being much shorter. Unfortunately, the pen recording the temperature at the 2-foot depth has not been operating satisfactorily but minimum temperatures for the 4- and 8-foot depths respectively were 16° and 20°F. Summer temperatures are well above freezing.

Figures 11 and 12 show the record of temperatures at the Ice Hill, details of the installation being shown in sketch form in Fig. 6. The bulbs at 1- and 2-foot depths were located at the side of the road, that at the depth of 3 feet 8 inches was located under the roadbed, the depth indicated being measured from the road surface. Despite the fact that the record is unfortunately incomplete, enough readings are available to show that:

(a) The temperature on the surface of the permafrost, under the undisturbed cover of muskeg, is almost constant at about freezing point;

(b) The insulating effect of the muskeg is further demonstrated by the relatively small variation in the temperature at 12 inches below the surface (a range of up to 15°F as compared with almost 50°F at 2-foot depth in sand and gravel, as seen in Fig. 10);

(c) The disturbing effect of the road construction, which involved removal of much of the muskeg, is clearly shown by the temperature variation at the 3-foot-8-inch depth, from 36°F to 18°F, despite the fact that the bulb was resting on the original surface of the permafrost.

Finally, Fig. 13 represents an attempt to prepare an average annual chart based on all the records obtained at the townsite, in what has come to be a usual form of graphical diagram for soil temperatures. The significance of this diagram is discussed in the following section, but it must here be noted that it is not to be regarded as a final picture of the soil temperature regime at Uranium City, due to possible inaccuracies already mentioned, but only as a preliminary assessment.

PART FOUR

GENERAL DISCUSSION

(20) SOME GENERAL COMMENTS

The foregoing notes show clearly that this Report is only a statement of progress. Further information must be obtained before any definite conclusions about the pattern of soil temperatures can be reached. In view of practical decisions which may shortly have to be made, however, (see paragraph 22) it is necessary to advance some tentative conclusions, as is so often the case with urgent engineering work. The following paragraphs contain a few suggestions, therefore, which arise from a careful study of the evidence gathered up to the time of writing the final version of this Report. They are all subject to review, and possible correction, when more data on the local soil temperature regime are available.

In the first place, there is no doubt about the existence of permafrost in the area of Uranium City, the exposures along the Bushell - Beaverlodge road being unmistakable. The fact that no permafrost was encountered at the Uranium City site is probably due to the fact that most of the observations there were in excavations in dry sand and gravel. This explanation does not apply, however, to the fact that no perennially frozen ground was encountered in the muskeg swamp which is now surrounded by the town development.

Before the townsite was partially cleared to permit of road construction and building operations, this swamp was the natural "sump" for all the surface run-off from the basin-like area now being used as the main development area. (It still is so, of course, but it now receives subsurface drainage also and the surface drainage is influenced profoundly by the town development.) In its original condition, therefore, the swamp area had been inundated for a very long period during summer months by surface water at a temperature very much above freezing point.

If permafrost, to a relatively shallow depth, had existed at this site, it is easy to imagine how it could have been thawed out, over the years, by this supply of heat from surface water. This possibility is confirmed, to some degree, by the experience in the excavation of the well at Bushell (Section 11b). No frost was here encountered, a fact which can be explained by the proximity of the well to the large volume of lake water which is always at

a temperature above freezing (apart from the winter surface layer of ice), thus providing a source of heat for the slow melting of the permafrost.

For those readers to whom the general pattern of soil temperature is unfamiliar, it may be explained that it is usual to find that the temperature in the ground is unaffected by the annual changes of air temperature at a depth of from 15 to 20 feet below the surface. Above that level, ground temperature will vary throughout the year to an increasing degree as the surface is approached, even diurnal variations of air temperature being reflected by soil temperature variations in the upper few inches of the ground.

Below the depth at which annual air temperature variations cease to have any influence, the temperature of the ground (be it soil or rock) gradually increases, at a sensibly constant rate within measurable distances. Thus, in one of the very few cases in which ground temperatures have been measured in northern regions, McCarthy (5) has shown that at Point Barrow, Alaska, the temperature increased at a rate of about 0.747°C per 100 feet, so that with a temperature of -5.45°C at a depth of 300 feet, "permafrost" extended to a depth of 1030 feet.

Accordingly, since Uranium City is so much to the south of Point Barrow with a correspondingly warmer climate, the depth of permafrost will be very much smaller. Observations already recorded suggest that the depth is of the order of 25 to 30 feet. This is but little more than the depth to which the effect of annual air temperatures may be felt. It follows that the permafrost which does exist in the vicinity of Uranium City can be regarded as "very unstable" permafrost, requiring relatively little heat, in reasonable steady supply, to thaw it out. The situation can also be described by saying that such permafrost as does exist will probably all be at a temperature very close to 32°F.

If the foregoing suggestions are valid, then it may be asked why permafrost is so very pronounced when it is found near Uranium City and correspondingly why so close to the surface, even in high summer, especially at the Ice Hill. In explanation, it may be observed that every case of permafrost so far observed has been under a cover of muskeg. It has always been accepted that muskeg acts as a good insulator to permafrost, minimizing the depth of the so-called active layer in summer seasons. The writer has not encountered such a vivid demonstration of this as at the Ice Hill. Here the muskeg appears to be quite dry and is compact and well-matted i.e., in an

excellent state to act as an insulator. The effect of even a slight disturbance of its natural condition is well shown by the records of temperature obtained under the road-bed at the Ice Hill.

(21) CORRELATION WITH CLIMATE

The influence of local climate on soil temperatures has been described in the foregoing section. Before dealing with the main practical problem which has to be faced in the immediate future, it may be helpful to consider such facts about the local climate as are available.

Unfortunately, but quite naturally, there is not yet a regular meteorological station at Uranium City. Steps have been taken to initiate the necessary procedure for starting such a station but the only local weather records known to be available are a series of daily maximum and minimum temperatures started in 1954 by Mr. Earl Shannon of DNR at Uranium City.

It has been found that records were taken at Fond du Lac (at the east end of Lake Athabasca) from 1905 to 1937. These have been summarized in Fig. 2. They show an average annual air temperature rather lower than would be expected from the recorded soil temperatures, but a good deal of study will have to be made of similar records before any correlative conclusions can be drawn.

(22) PROPOSED UTILITY SYSTEM

The Department of Natural Resources, looking ahead to the further development of Uranium City, has been giving consideration to the provision of public water-supply and sewage systems. (Water for existing buildings comes from wells in a few cases, but more usually by delivery from a motor tank truck. Disposal of sewage is in some cases by septic tanks but in many instances by rather more primitive arrangements.) Messrs. Underwood and McLennan, consulting engineers of Saskatoon, were retained by the Government of Saskatchewan to prepare preliminary plans. The writer has had the privilege of examining their report.

Ground temperatures are clearly of vital importance to the successful operation of a water supply system using buried pipes. Accordingly, Fig. 13 has been prepared as a summary of average soil temperatures obtained from all the measurements made at the townsite, plotted in a convenient form to show clearly changes of temperature with depths throughout the year. Although the chart is based on admittedly insufficient data for a rigorous study of local soil temperatures,

it is at least warrant for suggesting that winter frost penetration at Uranium City will almost certainly extend to 10 feet.

The summary presented in this chart, coupled with the comparative climatic data given in the last section, suggests that the recommendation of the consulting engineers that a circulating system should be used for water supply, with provision for heating the water when necessary, is a wise one. Nothing that has so far been observed at Uranium City suggests that this precautionary design would not be wise, and therefore ultimately economical.

The experience of the towns of Yellowknife (3) and Flin Flon (4), with climates which have already been seen to be comparable with that of Uranium City, both of which have water supply systems of the circulating type, lends useful confirmation to the suggested design for Uranium City.

(23) FUTURE WORK

In view of the obvious importance of observations of soil temperature and permafrost in the area of Uranium City, the Division of Building Research hopes to be able to continue its studies, along the following lines, at least:

(a) It is planned to replace the two clockwork temperature recorders in use at present with a thermocouple installation at the townsite, if possible in the fall of 1954; this should give more accurate measurements of soil temperature with less trouble than at present. (This has now been done: 1955);

(b) Should the proposed water and sewage system be installed, it is hoped that a reasonably complete thermocouple installation can be put in to measure the effect of the system upon the regime of local soil temperatures (as is now being done at Yellowknife jointly by the Division of Building Research and the Federal Department of National Health and Welfare);

(c) It is hoped that, possibly even by the circulation of this Report, more information on the total depth of permafrost may be obtained from those with experience in diamond drilling in the Uranium City area;

(d) Co-operation of the Eldorado Mining Co. Ltd., has been promised in connection with the

possibility of installing a special thermistor-equipped cable in an unused dry drill hole near the main shaft of the Mine, in order to obtain long-term ground temperatures to a depth of (say) 100 feet;

(e) The opening up of the Gunnar Mine is providing new exposures of permafrost within the Uranium City area; it is hoped that these may be observed by members of DBR staff and the co-operation of Gunnar Mines Ltd., in this endeavour has already been promised. (This has been done and will be reported on in due course.)

(24) A FINAL NOTE

Although this Report, being essentially a statement of progress, can properly have no formal conclusion, a final note must be added if only to acknowledge, on behalf of the Division of Building Research, the valuable assistance which the writer and his associates have received from all with whom they have discussed the matter examined in this Report, and the encouraging interest which has similarly been shown in their studies. So many have been consulted that in the paragraph headed "Acknowledgments" an attempt has been made to list all who thus lent their assistance rather than mentioning only selected names. Even with care, the list may still not be complete.

The Report itself will have demonstrated the essentially dual character of the DBR studies. The practical application of the results is fairly obvious. The fact that Uranium City appears definitely to be on the southern fringe of the permafrost in Canada gives to the study a scientific interest, the full significance may be fully apparent only when more information is available.

(25) ACKNOWLEDGMENTS

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Mr. G.C. Langford, Road Construction Supervisor, Construction Branch
Mr. G.J. Darychuk, Administrator, Uranium City.
Mr. E.N. Shannon, Conservation Officer, Uranium City.
Mr. R. Herbert, Road Foreman, Uranium City.

Eldorado Mining and Smelting Co. Ltd.

Mr. P. Sexsmith, Manager, Beaverlodge (1952)
Mr. R.E. Barrett, Manager, Beaverlodge (1954)
Mr. W. Macdonald, Geologist, Beaverlodge.
Mr. W. Spice, Construction Supervisor, Beaverlodge.
Mr. R.M. Way, Consultant, Toronto.

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2. A. M. Christie. Goldfields - Martin Lake Map-Area Saskatchewan. Geological Survey Department of Mines and Technical Surveys, Ottawa, 1952. Memoir 269.

3. Hall, N. M. Water and sewerage systems for Yellowknife. The Engineering Journal Vol. 34, No. 3, p.164-170. March 1951.

4. Roche, M. A. Water and sewerage in the North. Unusual Distribution System at Flin Flon, Man. Public Works Vol. 79, No. 9, p. 21-22 and 24. August 1948.

5. McCarthy, G. R. Geothermal investigations on the Arctic slope of Alaska. Trans. Am. Geo. Union Vol. 33, No. 4, p. 589-593. August 1952.

APPENDIX A

A NOTE ON UNUSUAL CAVITIES FOUND IN THE GLACIAL SILT

When examining the freshly exposed silt along the road from Bushell to Uranium City, the writer noticed a number of cavities in the surface of the silt which were of the same size and shape as ordinary rounded boulders. The cavities were obviously natural in character but their sides were so clean-cut that they looked as though they had been artificially excavated. Water was noted in the bottom of some of them and in one case two of the cavities were interconnected by an underground channel.

It seems clear that the cavities represent blocks of ground ice which had been kept as ice by the insulation provided by the muskeg cover and which had melted as soon as exposed to the air. They are, therefore, of great scientific interest. They are noted here so that those who read this Report may know of this significance. Should any reader ever come across any similar examples and will advise the writer of the report, this will be a real service to permafrost research.

APPENDIX B

A NOTE ON SOME HOUSE FOUNDATION PROBLEMS

The attention of the members of the DBR staff who visited Uranium City was drawn to some difficulties which had occurred with house foundations, including basements, at the new housing area developed by the Eldorado Company at Beaverlodge. These were carefully examined and revealed features of great interest (from the research point of view), although of much concern to house residences. The cause of most of the troubles which were seen was obviously the action of frost on the silt upon which the houses were founded. Since these features were not peculiar to Beaverlodge, but were only special examples of troubles which occur elsewhere, it was thought best not to detail them in this Report, since they do not appear to be directly related to the local permafrost problem.

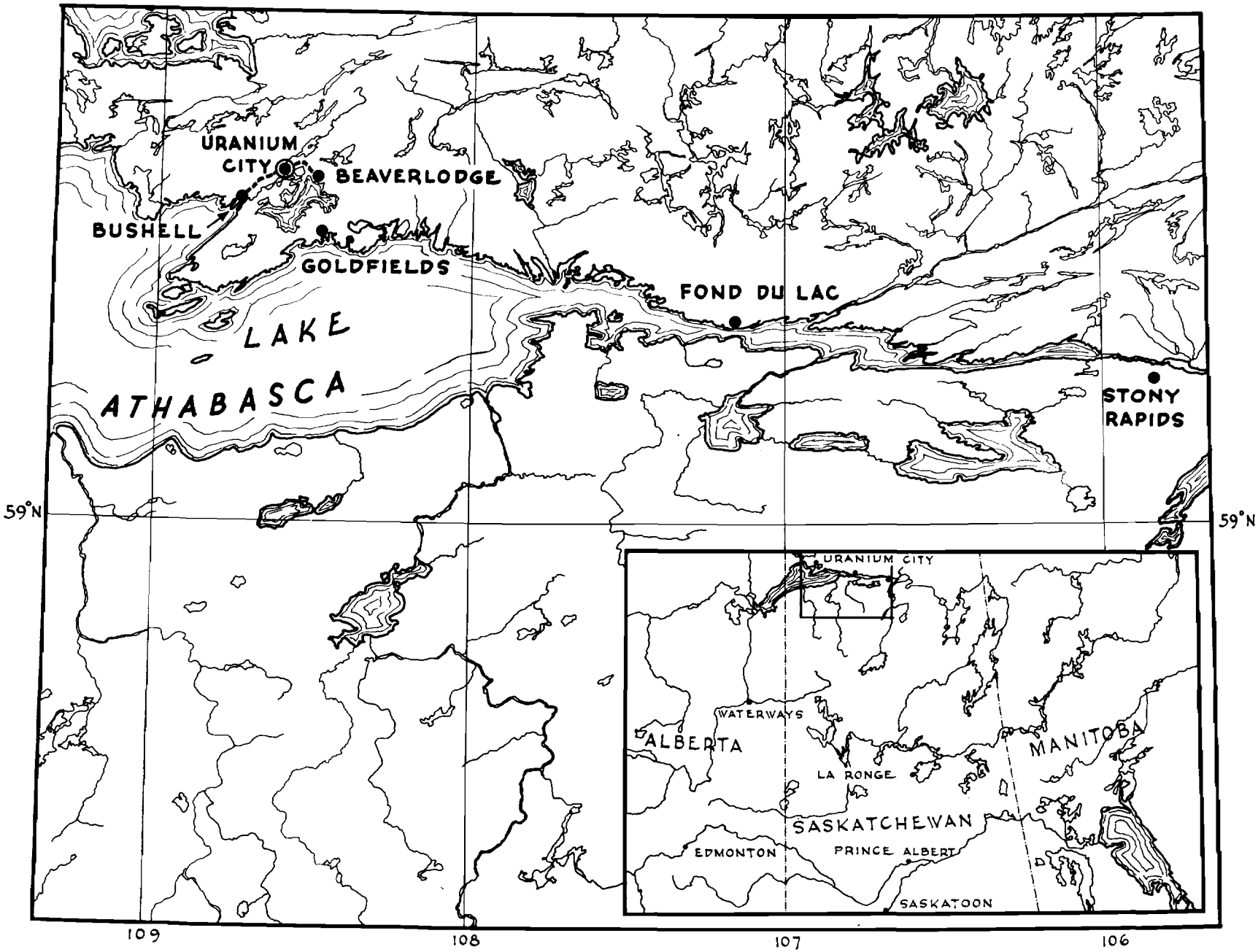
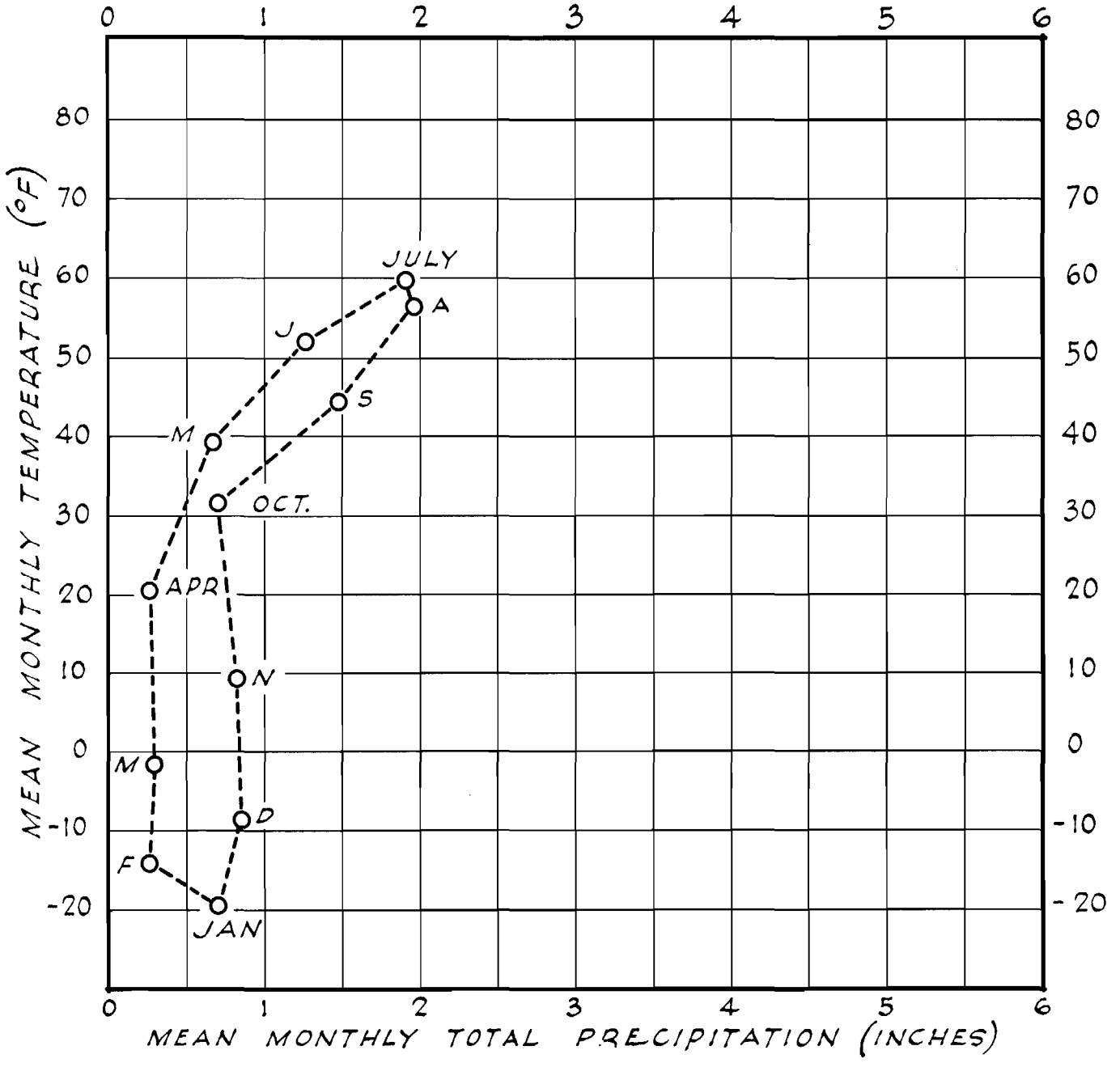


FIGURE 1

DBR REPORT 60



(A GRAPHICAL PRESENTATION of THE LOCAL CLIMATE BASED ON RECORDS FROM 1905 to 1937)

FIGURE 2
HYTHERGRAPH for FOND DU LAC, SASK.

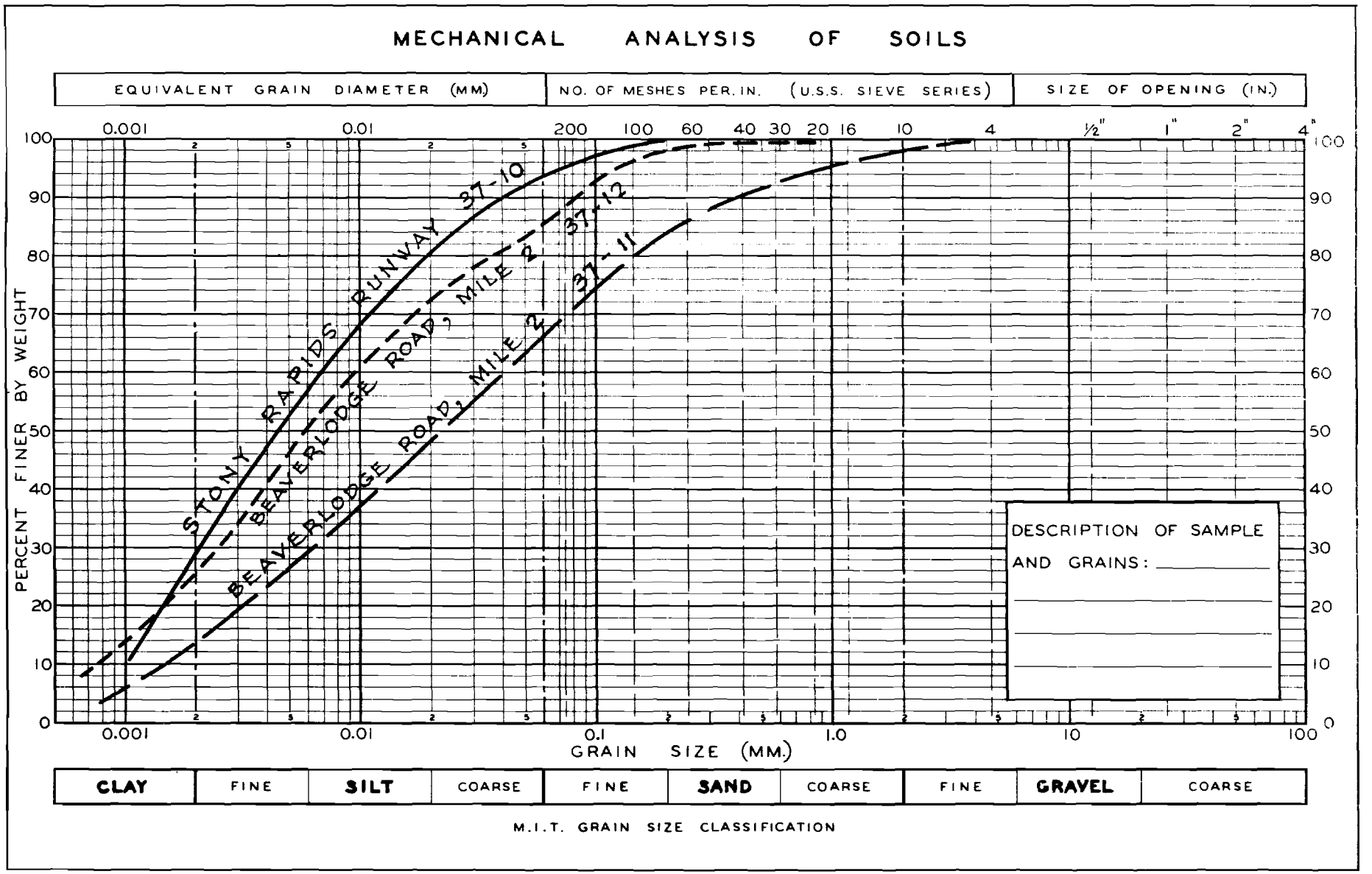

MECHANICAL ANALYSIS OF SOILS
EQUIVALENT GRAIN DIAMETER (MM.)
NO. OF MESHES PER. IN. (U.S.S. SIEVE SERIES)
SIZE OF OPENING (IN.)
0.001
0.01
200
100
60
40
30
20
16
10
4
½"
1"
2"
4"
PERCENT FINER BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
STONY RAPIDS RUNWAY 37-10
BEAVERLODGE ROAD, MILE 2 37-12
BEAVERLODGE ROAD, MILE 2 37-11
DESCRIPTION OF SAMPLE AND GRAINS:
0.001
0.01
0.1
1.0
10
100
GRAIN SIZE (MM.)
CLAY
FINE
SILT
COARSE
FINE
SAND
COARSE
FINE
GRAVEL
COARSE
M.I.T. GRAIN SIZE CLASSIFICATION

FIGURE 3

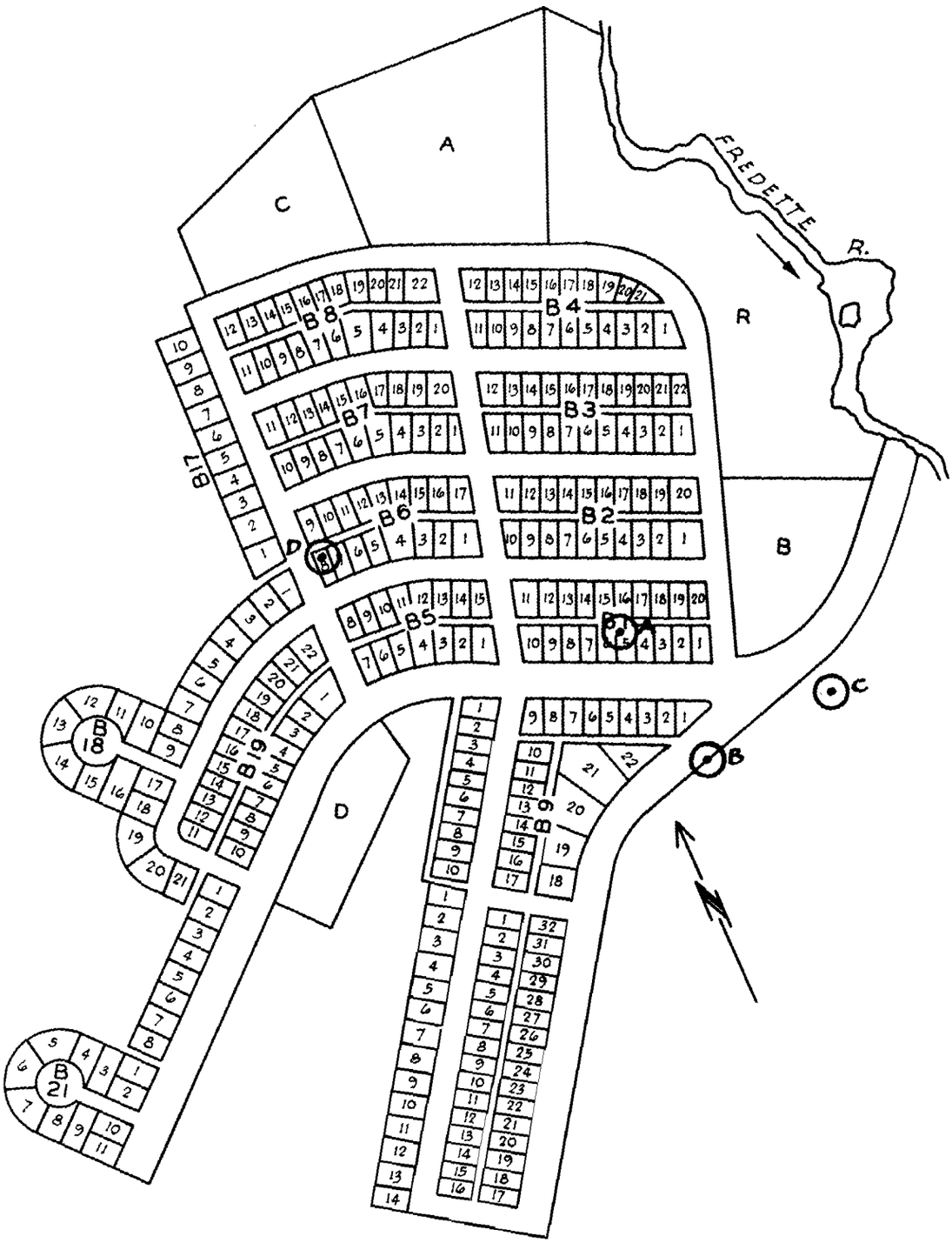


FIGURE 4

SURVEY PLAN OF URANIUM CITY

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FIGURE 5 SILT EXPOSED BY REMOVAL of MUSKEG COVER SHOWING EFFECT of MELTING

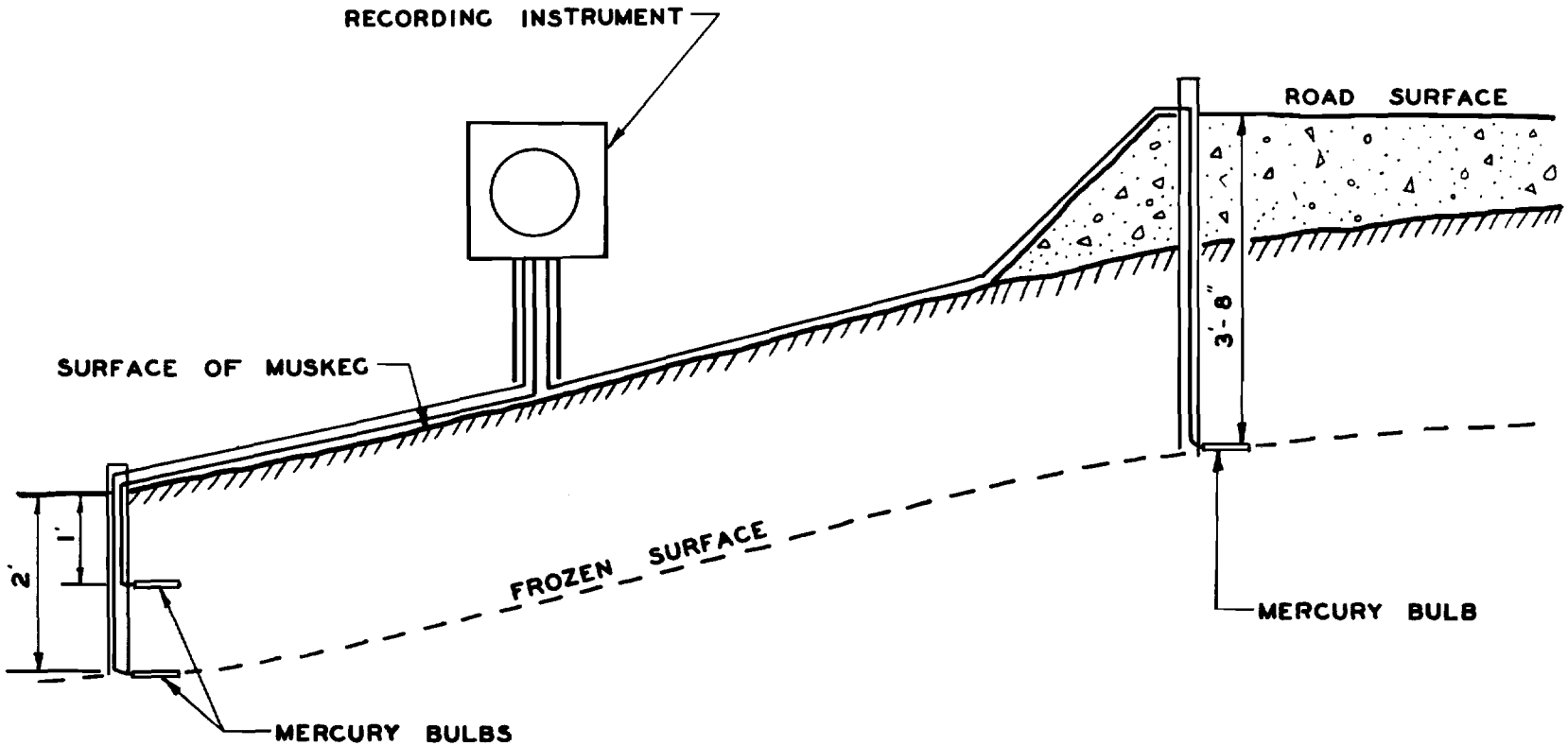
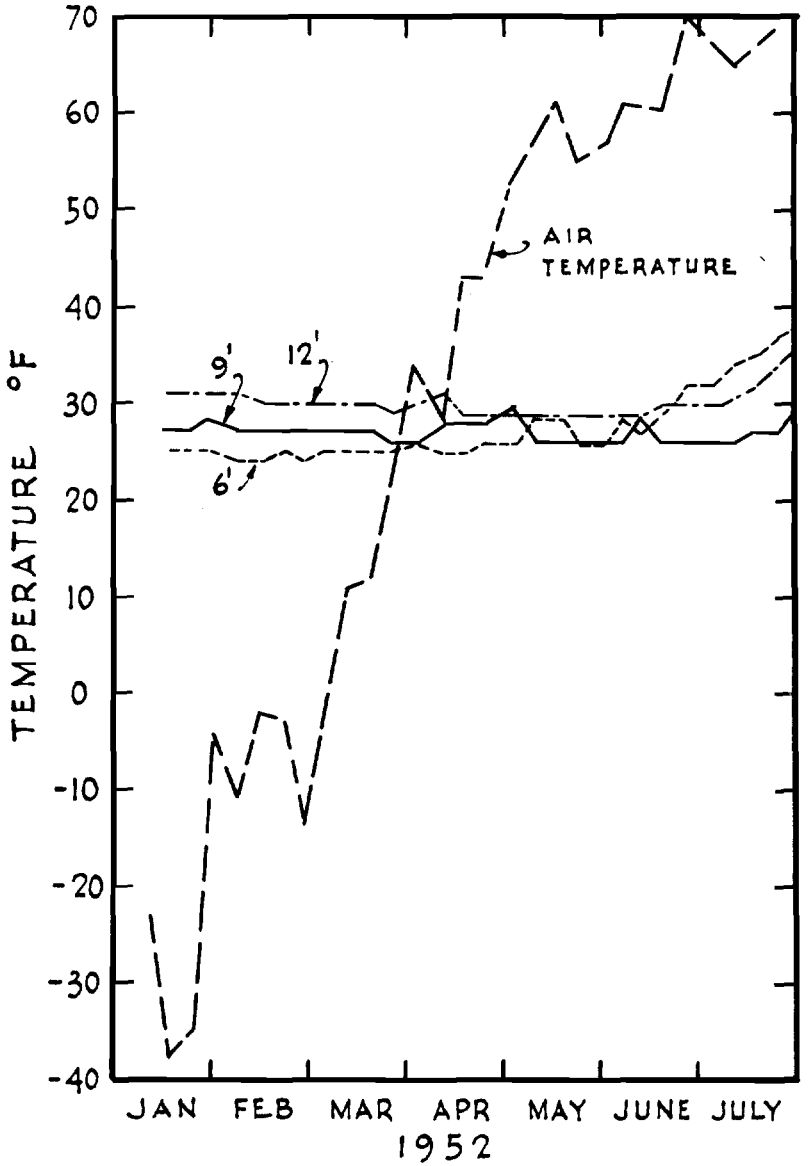


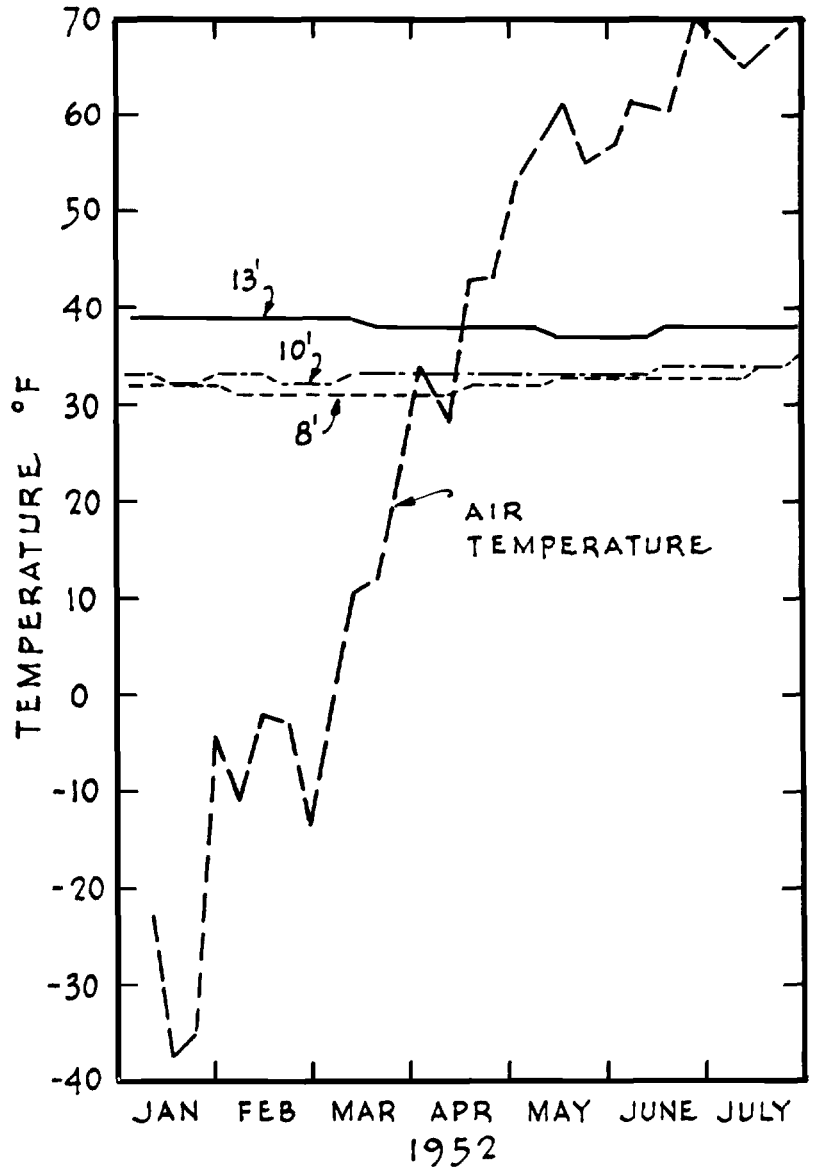
FIGURE. 6.

CROSS SECTION THROUGH SOIL TEMPERATURE INSTALLATION AT "ICE HILL", MILE 5, URANIUM ROAD, URANIUM CITY, SASK.



LOCATION - AT TOP of HILL ON TOWNSITE

FIGURE 7



LOCATION - AT FOOT of HILL NEAR GARAGE

FIGURE 8

AIR AND SOIL TEMPERATURES AT URANIUM CITY, SASK. (WEEKLY AVERAGES)

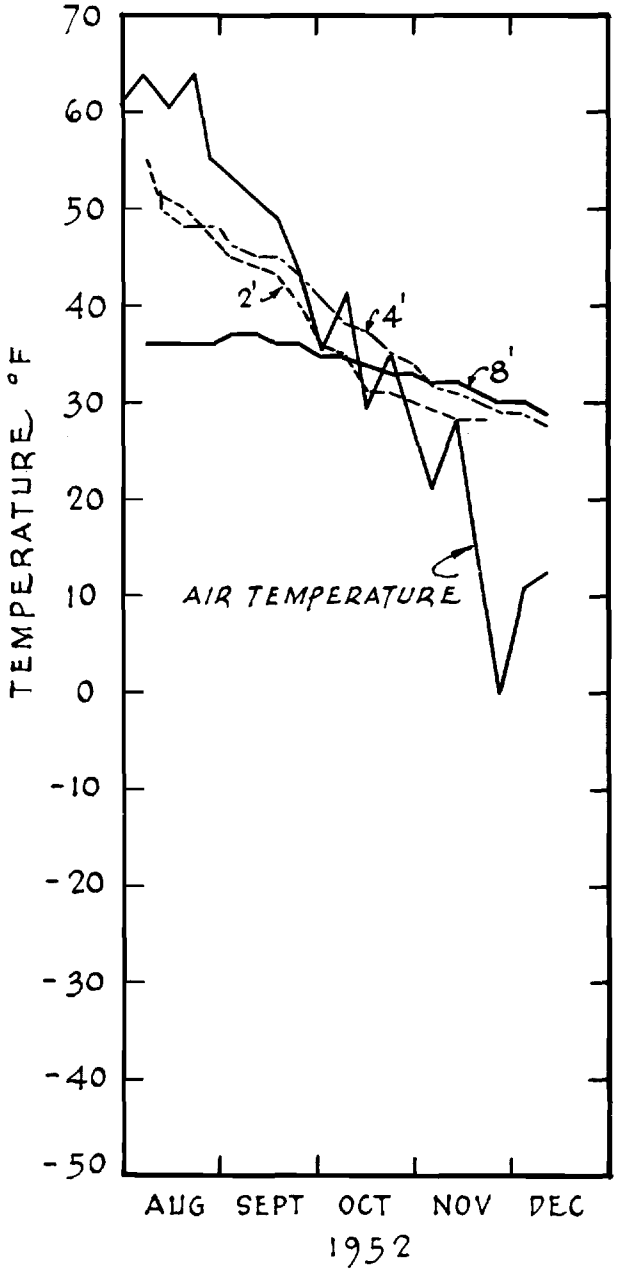


FIGURE 9

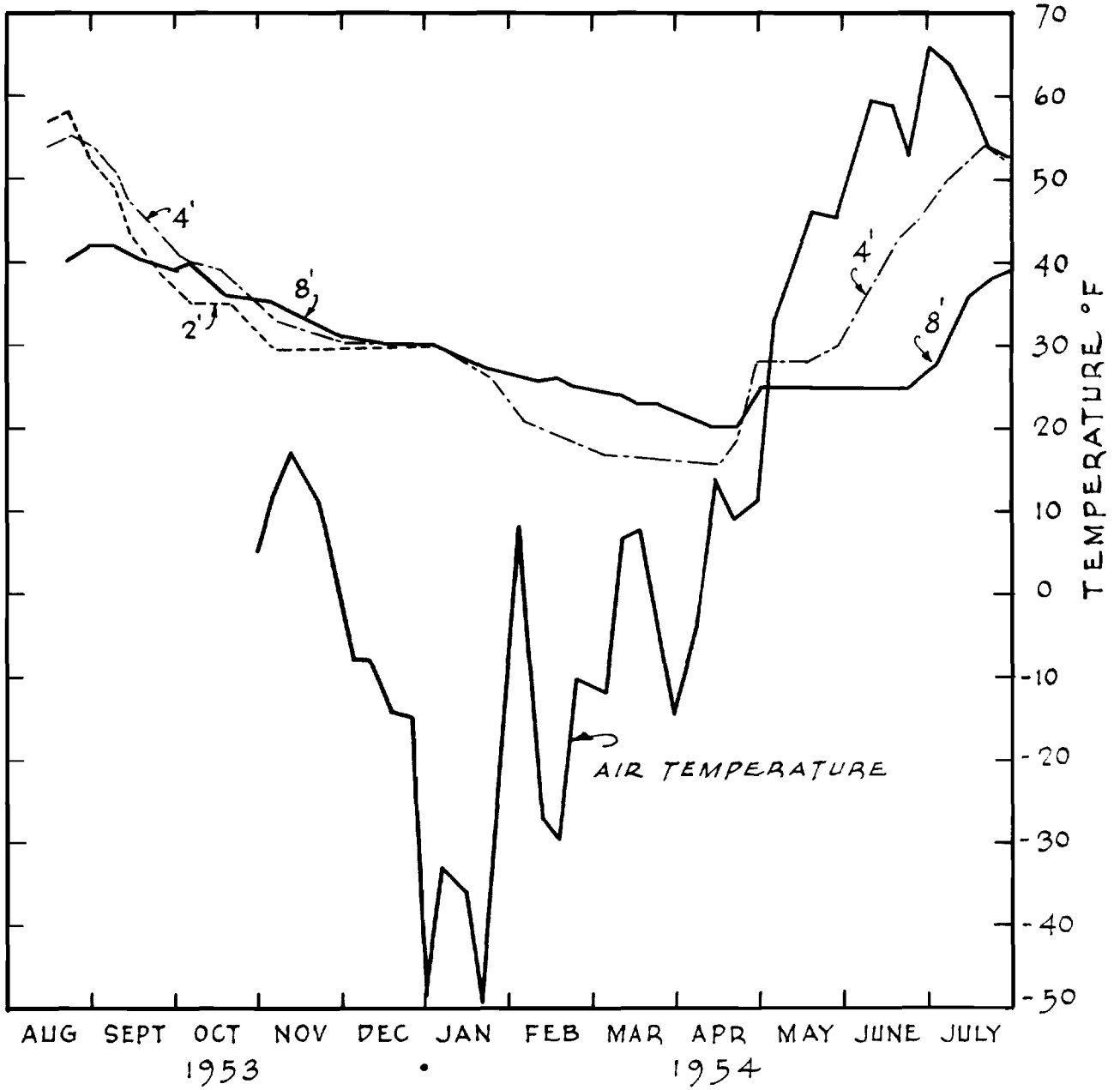
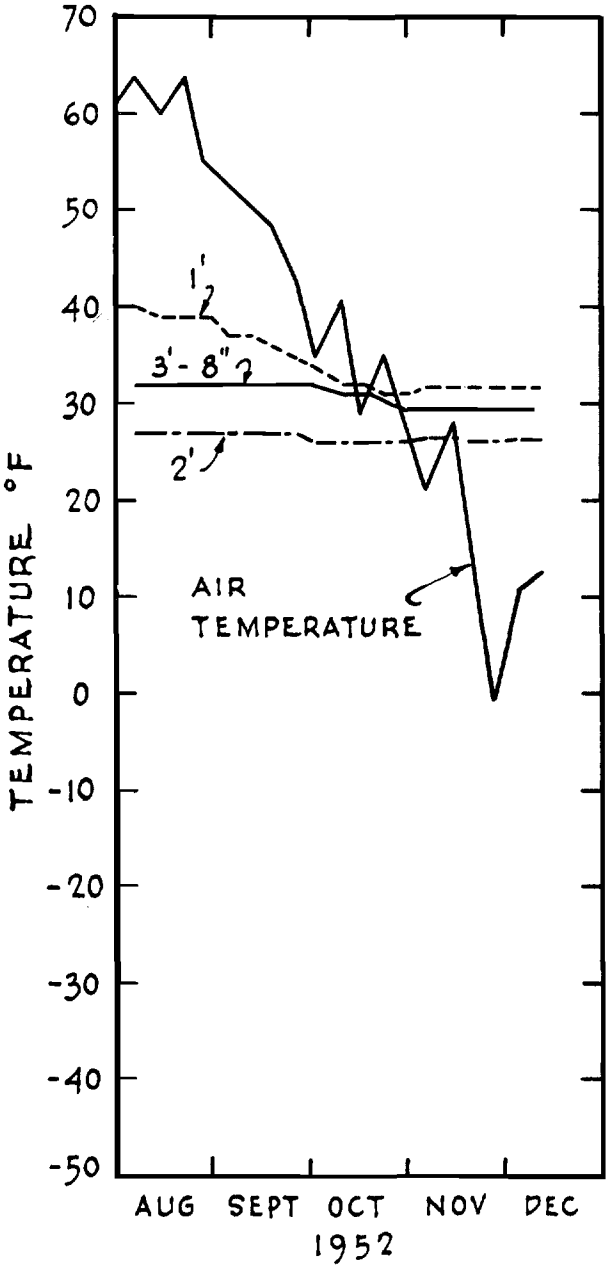


FIGURE 10

LOCATION: TOWNSITE NEAR MINES BRANCH OFFICE

AIR AND SOIL TEMPERATURES AT URANIUM CITY SASK. (WEEKLY AVERAGES



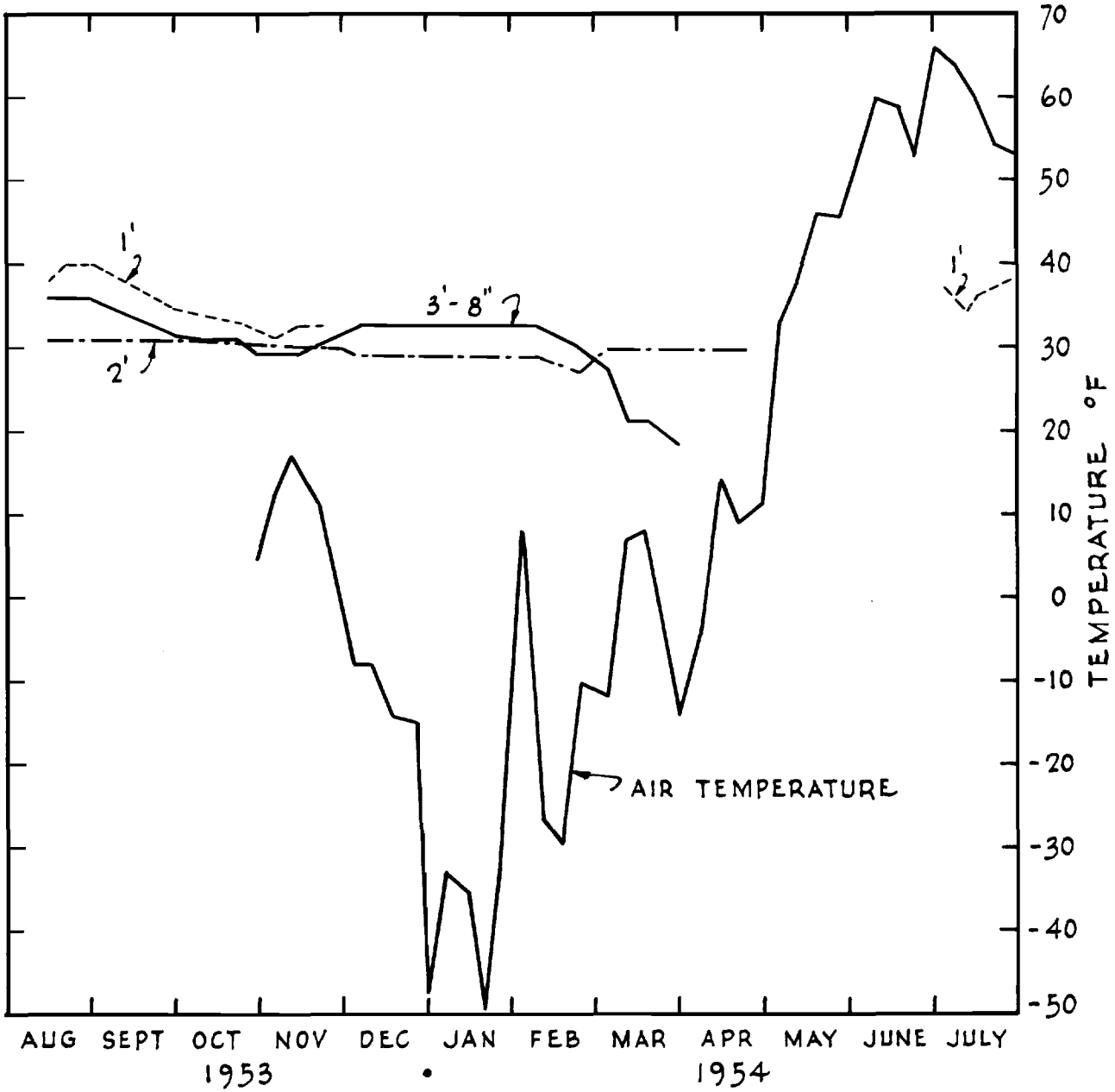


FIGURE 11

FIGURE 12

AIR AND SOIL TEMPERATURES AT "ICE HILL" MILE 5 URANIUM CITY, SASK.

(WEEKLY AVERAGES)

DBR REPORT 60

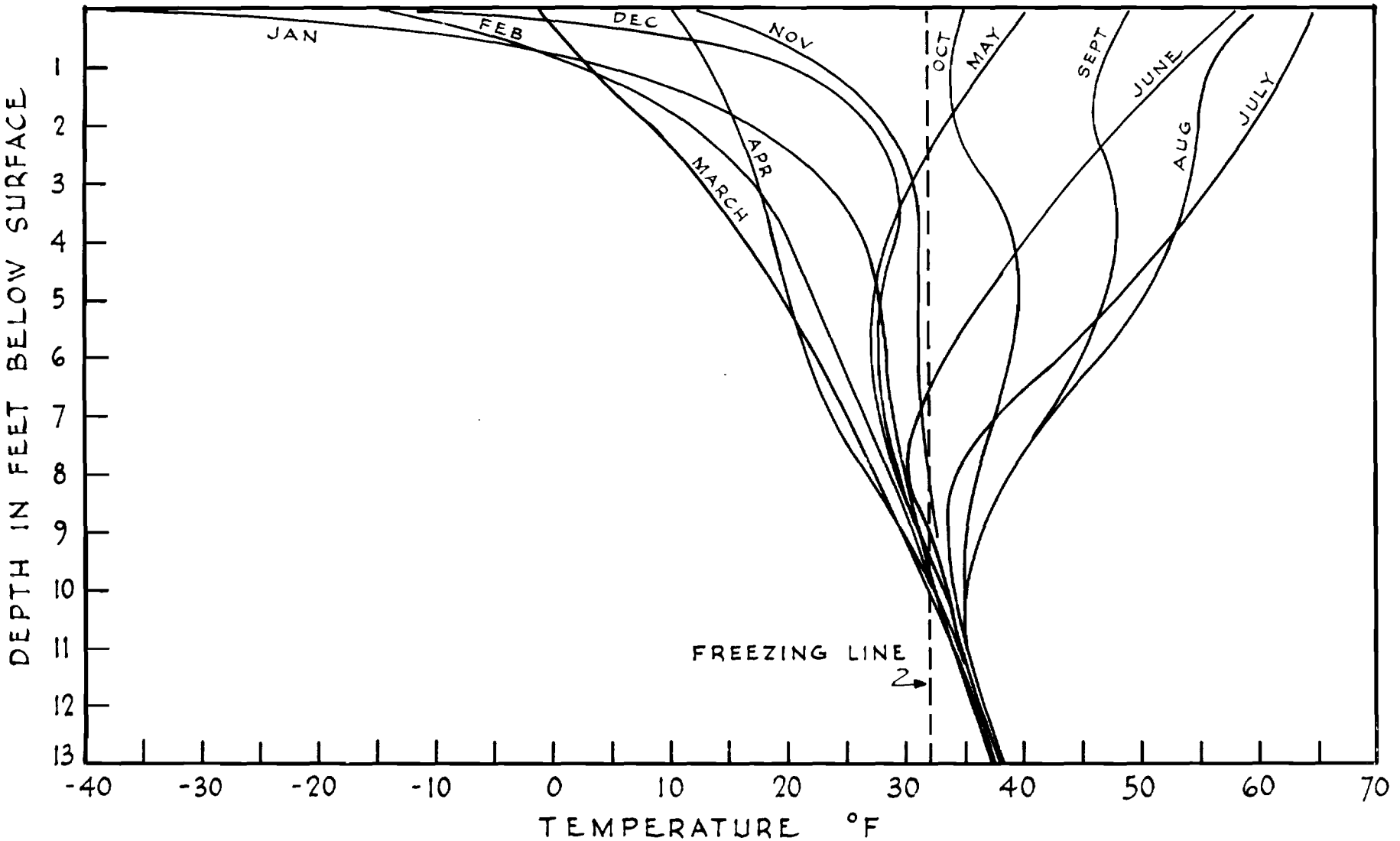


FIGURE 13

RECONSTRUCTED SOIL TEMPERATURE PROFILE - URANIUM CITY