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I. INSTALLATION OF STEEL PILES - 1972

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PREFACE

Field studies of uplift forces on structures resulting from frost action have been carried out in Ottawa for some five years. Papers describing the results of this work are available from the Publications Section of the Division of Building Research, National Research Council of Canada.

The installation at Thompson, Manitoba, now described is similar to one at Ottawa and is the first of an expanded program for studying the influence of climate, soil type, and moisture regime. These are thought to be significant factors in the uplift problem.

Ottawa
July 1973

N. B. Hutcheon
Director

It was decided to do these further studies at Thompson, Manitoba, where the Division of Building Research had established a field station in 1966 to provide support for permafrost investigations in northern Manitoba. Thompson lies within the discontinuous permafrost zone where unfrozen areas separate islands or patches of perennially frozen ground (permafrost). Lacustrine soils are widespread and the climate is significantly more severe than that of Ottawa. The mean annual air temperature at Thompson is 24.9°F (FI 5300 degree-days) and the mean annual precipitation based on data 1968-72 is 17.56 inches (13.01 in. rain, 45.5 in. snow).

SITE SELECTION AND PREPARATION

Several factors had to be considered in selecting a suitable test area. Power would be required and, as daily visits would have to be made to the site, a power line and a main road should be reasonably close to avoid lengthy power and road connections. Bedrock should be no more than 20 to 25 ft below the ground surface to avoid costly drilling and long anchor rods for the reaction frames.

The overburden soils should be reasonably uniform over the site. It was anticipated that the maximum frost penetration might be as much as 10 to 12 ft, depending on whether the snow cover was removed from the area during the test period and also the thermal influence of the piles on the ground thermal regime. Therefore the overburden should be a minimum of 12 to 15 ft thick to ensure that the frost line stayed within the mineral soil. It was also desirable that the area be reasonably well drained to avoid water problems during the snow melt period in spring and from rainfall during the summer. Finally, it was decided to choose a site free of permafrost i.e., subject to seasonal freezing only, so as to avoid the problems created by changes in the ground thermal regime (thawing) and subsidence of the ground and to reduce the complexity of analysis introduced when rheological behaviour of warm temperature permafrost soils must be taken into account as part of the forces resisting uplift.

In 1971, following preliminary examinations of several potential sites at widely separated locations in the Thompson area, a site about 2 miles south of the town near an already established Division of Building Research permafrost test site was selected. It was adjacent to Provincial Road #391 which is also a power line route.

The test site selected lies within the Plant Site Area of the International Nickel Company of Canada Ltd. (which covers a large area around the mine and Thompson townsite) and permission to use this site (about 200 ft square) was obtained from INCO. Auger drilling conducted in October 1971 showed that bedrock underlay the site at depths of from about 12 ft in the N. E. corner to 20 ft in the S. W. corner. The soils are typical of those encountered in the Thompson area (5). A layer of peat from 3 to 12 in. thick covers varved clays (stratified clay and silt layers) that become more silty with depth. These overlie bedrock or 1 to 2 ft of sandy silt containing random pebbles over bedrock.

The undisturbed site was covered with a dense growth of spruce. Arrangements were made to have the City of Thompson hand-clear and burn the tree cover and carry out grubbing operations during March 1972. The peat and tree roots were removed by bulldozer and piled in previously selected areas on the edges of the clearing well away from the boundaries of the test site. A 12-in. layer of pit run gravel was placed directly on the clay soil. At the same time, a 500-ft-long gravel access road was constructed from Provincial Road #391 to the site. A power line approximately 300 ft long was constructed in April.

Auger drilling to determine depths to bedrock and level surveys to obtain surface elevations at nine locations on the test site were carried out in May 1972.

During late July and early August 1972 larger stones in the pit run gravel were removed around each pile location and a 6- to 9-in. layer of select graded sand and gravel was added to the east half of the site. Following compaction of the sand layer this part of the test site was surfaced with a 3- to 4-in. layer of asphaltic concrete to provide a good working surface for the heavy equipment used during pile and anchor installation operations.

The general layout and dimensions of the site, the locations of exploratory boreholes, edge of clearing, paved and unpaved sections are shown in Figure 1. Bedrock elevations are given in Figure 2 properly referenced to BM No. 1 shown in Figure 1. Elevation contours of the paved surface are given in Figure 3. All elevations are based on an assumed datum of 100.000 ft for permanent BM No. 1.

INSTALLATION OF STEEL PILES AND INSTRUMENTATION

(a) Steel Pipe Piles

All nine steel pipe piles (three 6-in. dia., three 12-in. dia. and three 18 in.-dia.) were prepared for installation as follows. The outside of the piles were sand blasted to remove the surface anti-corrosion treatment (50 per cent varnish, 50 per cent thinner) which might influence the strength of the bond between the frozen soil and the pile. Both ends of the pile were capped by welding a 1-in. steel plate to the upper end and a 1/2-in. steel plate to the lower end (Figure 4a). Pile dimensions are given in Table 1.

Three of the steel piles (S6A, S12A and S18A - one of each diameter) were instrumented with 20-gauge copper-constantan thermocouple wire to determine depth of frost penetration. The lead wires were placed inside 3/4-in. steel conduits welded to the outside of the piles and at one-ft intervals the thermocouple was embedded with epoxy resin in a 6-in. long x 1/4- x 1/4-in. groove cut on the outside surface of the pile at right angles to its long dimension as shown in Figure 4b. The conduit served to protect the thermocouple wires from damage and to lead the thermocouple wires to the ground surface in an orderly array.

Before installing the piles a circular section of the asphalt pavement about 10 in. larger in diameter than each pile was cut out and removed. The piles were placed in the centre of machine-augered holes which were 6 in. larger in diameter than the pile (Figures 6 and 7). The piles were centred in the hole and backfilled immediately with the soil removed from the hole to avoid large moisture changes in the soil. The soil was backfilled in layers and well compacted by hand using wooden tampers, but the exact density achieved is not known. The gravel layer was backfilled in the same way. Piles S6A, S18A, S12A and S6C were installed on 23 and 25 August 1972. The remaining five piles were not installed until 10 October 1972 due to a breakdown of the auger drill. Table 2 gives the measured thickness of the asphaltic concrete pavement and the depth of gravel at each pile location. Samples of the gravel at all pile locations were retained for analysis of grain size and moisture content determinations.

(b) Reaction Frames, Anchors and Bench Marks

Each reaction frame was constructed of two 6 I 12.5 steel beams and tied down at the four corners by 3/4-in. anchor rods and 1 1/4-in. expansion shells placed 18 in. into bedrock as shown in Figure 5. A total of 36 anchors (4 anchors for each of the nine reaction frames) were installed between 16 and 31 August 1972.

The procedure followed was to set EW casing with a drill rig approximately 1 to 2 in. into the bedrock, flush out the casing with water and then drill with an XRP (1 1/4 in. OD) diamond set core bit and reaming shell to a depth of about 18-in. into the igneous bedrock. The anchor bolt assembly was then lowered to the bottom of the hole and tightened to refusal by hand with a 24-in. pipe wrench. Each expansion shell was threaded on the end of an 8-ft length of high strength steel (100, 000 psi tensile strength) anchor rod. The 3/4-in. dia. extension rods were 8-, 10- or 12-ft lengths of cold rolled 3/4-in. steel A131, B1112 (62, 500 psi) threaded for 2 in. on each end. Standard "S" type expansion shells and couplings manufactured by Stelco were used throughout.

The rock bolts were cut off about one foot above the pavement surface and threaded. Three-ft lengths of 3/4-in. dia. rod (cold rolled steel) threaded full length were used as extensions above ground for positioning the reaction frames over each pile. Table 3 gives the depth to bedrock and depth of the anchor hole into bedrock for all the anchors installed. Two bench marks were also installed at locations shown in Figure 1. Both consisted of anchor rod assemblies set in bedrock in an identical manner to the reaction frame rock anchors. A 10- to 15-ft length of 1-in. dia. plastic pipe was placed over each BM. The datum point consisted of a ball bearing welded to a coupling screwed on the top end of the rod.

(c) Ground Temperatures

One pile of each diameter (S6A, S12A and S18A) was instrumented with thermocouples as previously described. To determine the thermal influence of the steel pile on the adjacent ground temperature regime multi-conductor thermocouple cables were installed at distances of 0. 5, 1, 2, 4 and 10 feet from each of the three piles. The position of the cables and the depths of the thermocouple points are shown in Figures 1 and 4.

The cables were installed with a drill in holes made by rotating or pushing, or both, an A-cross chopping bit to within 6 in. of the desired depth. The lower end of the cables was then temporarily attached to a 3/4-in. dia. rod, pushed to the required depth and the rod withdrawn. The hole was backfilled with fine grained slag from the INCO mine.

To measure pavement temperatures a 1- x $1\frac{1}{2}$-ft section was cut out at about the centre of the paved area and a thermocouple fixed to both surfaces. The block of pavement was then replaced and the cracks filled with a sealing compound.

(d) Surface Heave Points

The snow cover was not to be removed from the test site. To survey movements of the pavement in the vicinity of piles S6A, S12A and S18A without disturbing the snow cover 1-in. dia. x 2-ft long hardwood dowels were fixed to the pavement surface with $3\frac{1}{2}$-in dia. pipe flanges (Figure 8). The dowels were placed at one-ft intervals to 14 ft on either side of each of the instrumented piles (Figure 9).

(e) Other Instrumentation and Installations

Dillon force gauges placed between the top of each pile and the bottom of the reaction frame were used to measure the uplift forces. In cases where the heave forces were expected to exceed the capacity of a single gauge, two gauges of equal capacity were placed side by side. Details of the gauges and their locations are given in Table 4.

Movement of the piles and reaction frames during active periods of heaving must be known since maximum heave forces developed are dependent on the strain permitted. A survey point consisting of a 1/4-in. long 8-32 self-tapping screw was installed in the centre of the top member of the reaction frame and on the top of each pile cover plate. A completed test installation with a reaction frame over a pile is shown in Figure 10.

It is expected that a satisfactory depth of frost penetration will occur without the removal of the snow cover. Disturbance of the snow cover and hence the ground thermal regime is to be kept at a minimum. To assist in achieving this, an elevated catwalk was constructed along the east row of piles upon which the survey rodman can walk during the weekly level surveys.

OBSERVATION PROGRAM

Observations were begun in late October 1972. Temperatures on the piles and top and bottom of the pavement are recorded every 2 hours on a multipoint L and N Speedomax Recorder. Ground temperatures adjacent to the three piles are read daily either with the L and N recorder or a digital voltmeter. All EMF signals are preamplified 5 or 10 times, depending on the output level. The temperature measuring instruments were calibrated and are checked weekly for accuracy. The over-all accuracy including instrument error, error of thermocouple placement and general electrical interference are believed to be within $\pm 1/4°C$. The force gauges are read at least once a day and occasionally twice.

Level surveys are made frequently (weekly or bi-monthly) to determine elevations and thus movement of the surface heave gauges, reaction frames and piles. Survey instruments are read to 0.001 ft with an expected accuracy of ±0.002 ft.

A number of points were established on the asphalt surface to ascertain the general heaving characteristics of the test site.

The air temperature is recorded continuously on a thermograph. In addition, standard meteorological maximum and minimum thermometers located in a Stephenson screen on the site are read weekly. The air temperature is also measured by a 20-gauge copper-constantan thermocouple located in the screen and recorded every 2 hours with the other temperature data. Snow depth and snow densities are also measured frequently.

Views of the completed site taken in mid October 1972 are shown in Figures 11 and 12. Water running across the pavement surface resulted from the melting of snow that had accumulated in the NW corner of the site during the final installation phase.

FUTURE WORK

DBR plans to pave the rest of the site and install 9 concrete and 9 wood piles, possibly in 1973. Continuous sampling down to bedrock will be carried out at 2 or 3 locations on the site at that time. Several piezometers and observation wells will also be installed to determine ground water conditions.

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TABLE 1

STEEL PILE DIMENSIONS

Nominal Diameter	Code	Total[1] Length	O.D.	Wall Thickness (in.)
6"	S6A	11' - 0 1/2"	6.647"	0.292
	S6B	11' - 0 1/2"		
	S6C	11' - 0 3/4"		
12"	S12A	10' - 10 1/2"	12.730"	0.377
	S12B	10' - 11 1/4"		
	S12C	10' - 10 1/4"		
18"	S18A	10' - 10"	18.040"	0.379
	S18B	10' - 10"		
	S18C	10' - 9 3/4"		

[1] Includes top (1") and bottom (1/2") steel plates.

TABLE 2

PAVEMENT THICKNESS AND DEPTH OF GRAVEL AT EACH PILE LOCATION

Pipe Pile	Pavement Thickness (in.)	Gravel Layer Thickness (in.)
S6A	4	21 + 6" peat
S6B	3	17
S6C	4	14
S12A	4	20
S12B	3	18
S12C	3	18
S18A	4	16
S18B	3	19
S18C	3	17

TABLE 3

THICKNESS OF OVERBURDEN AT THE REACTION FRAMES AND DEPTH OF ANCHOR HOLE INTO BEDROCK

Pile		Depth to Bedrock[1]	Depth into Bedrock
S6A	1. N.E.	13' - 2"	1' - 7"
	2. S.E.	13' - 8 1/2"	1' - 6 1/2"
	3. N.W.	13' - 2 1/2"	1' - 8"
	4. S.W.	13' - 5 1/2"	1' - 6"
S6B	1. N.E.	12' - 3 1/2"	1' - 5"
	2. S.E.	11' - 9 1/2"	1' - 6"
	3. N.W.	12' - 0"	1' - 6"
	4. S.W.	11' - 7 1/2"	1' - 6 1/2"
S6C	1. N.E.	14' - 11"	1' - 7"
	2. S.E.	15' - 1"	1' - 6 1/2"
	3. N.W.	14' - 8"	1' - 6"
	4. S.W.	14' - 7"	1' - 6"
S12A	1. N.E.	15' - 4"	1' - 9"
	2. S.E.	15' - 1"	1' - 6"
	3. N.W.	14' - 5"	1' - 7"
	4. S.W.	13' - 7 1/2"	1' - 5 1/2"
S12B	1. N.E.	15' - 0"	1' - 7 1/2"
	2. S.E.	14' - 3 1/2"	1' - 6 1/2"
	3. N.W.	14' - 3 1/2"	1' - 6"
	4. S.W.	14' - 5 1/2"	1' - 1 1/2"
S12C	1. N.E.	13' - 4 1/2"	1' - 7"
	2. S.E.	14' - 2 1/2"	1' - 7 1/2"
	3. N.W.	13' - 4 1/2"	1' - 8"
	4. S.W.	13' - 3"	1' - 6"
S18A	1. N.E.	15' - 3"	2' - 0"
	2. S.E.	14' - 9"	1' - 3"
	3. N.W.	14' - 2"	1' - 10"
	4. S.W.	14' - 8"	2' - 0"
S18B	1. N.E.	14' - 0"	1' - 6"
	2. S.E.	13' - 5"	1' - 10"
	3. N.W.	14' - 0 1/2"	1' - 5 1/2"
	4. S.W.	13' - 9 1/2"	1' - 5"
S18C	1. N.E.	16' - 8 1/2"	2' - 4"
	2. S.E.	16' - 3 1/2"	1' - 10"
	3. N.W.	16' - 9 1/2"	2' - 3 1/2"
	4. S.W.	16' - 9 1/2"	1' - 5 1/2"

S.E. #2 →. .← S.W. #4
N.E. #1 →. .← N.W. #3

[1] From surface of pavement at anchor rod hole.

TABLE 4

DILLON FORCE GAUGES INSTALLED ON STEEL PILES

Pile	Gauge Serial No.	Gauge Range	Calibration Factor
S6A	18157	0 - 25000	0.9217
S6B	19362	#1 0 - 10000	0.9756
	19361	#2 0 - 10000	0.9412
S6C	18156	0 - 25000	0.9217
S12A	18155	#1 0 - 25000	0.9302
	18158	#2 0 - 25000	0.9050
S12B	19359	#1 0 - 25000	0.8658
	19360	#2 0 - 25000	0.8639
S12C	18382	0 - 50000	0.8824
S18A	18366	#1 0 - 50000	0.9852
	18369	#2 0 - 50000	0.9390
S18B	18367	#1 0 - 50000	0.9756
	15029	#2 0 - 50000	
S18C	19358	#1 0 - 50000	0.9917
	18368	#2 0 - 50000	0.9828

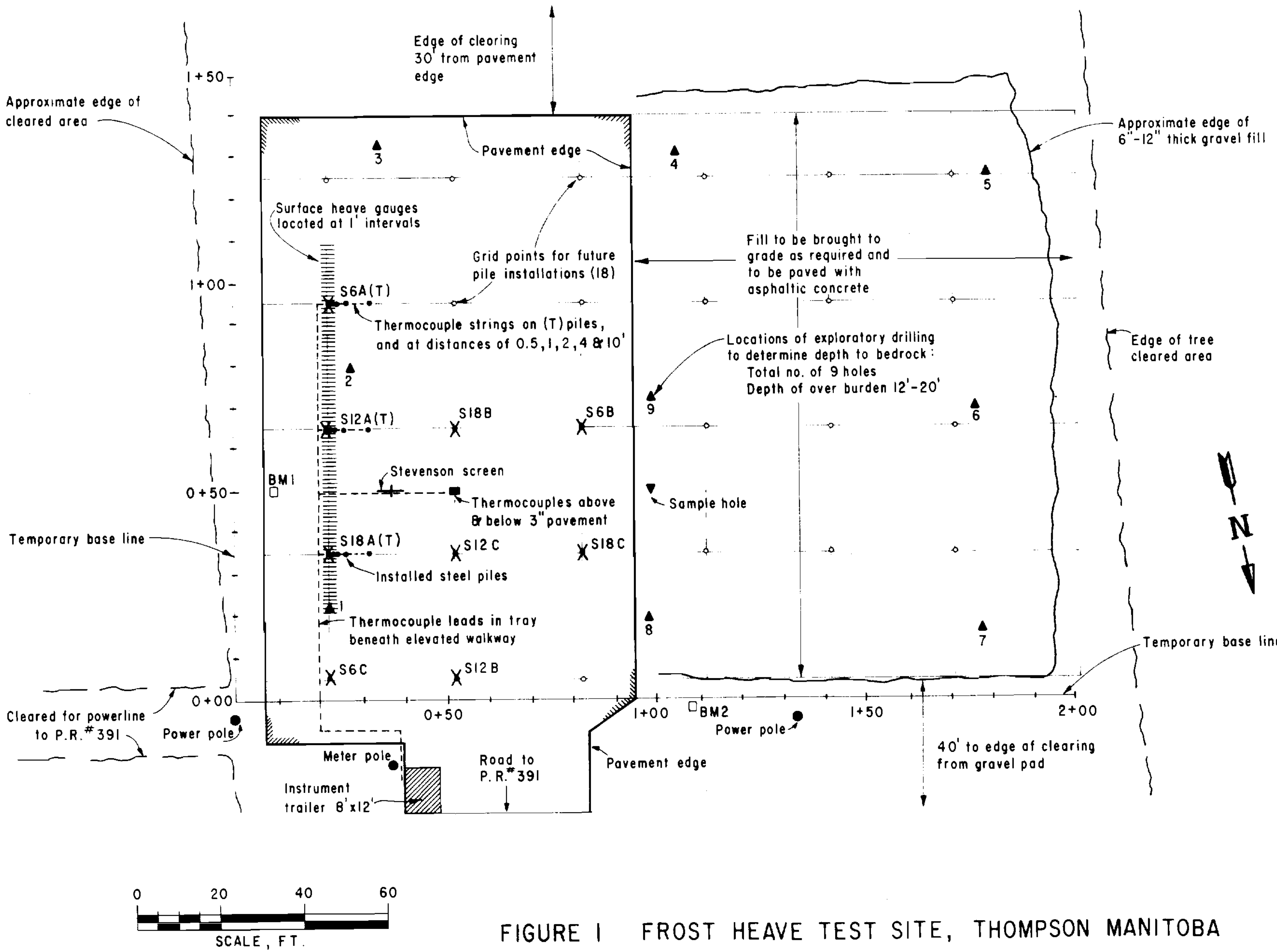
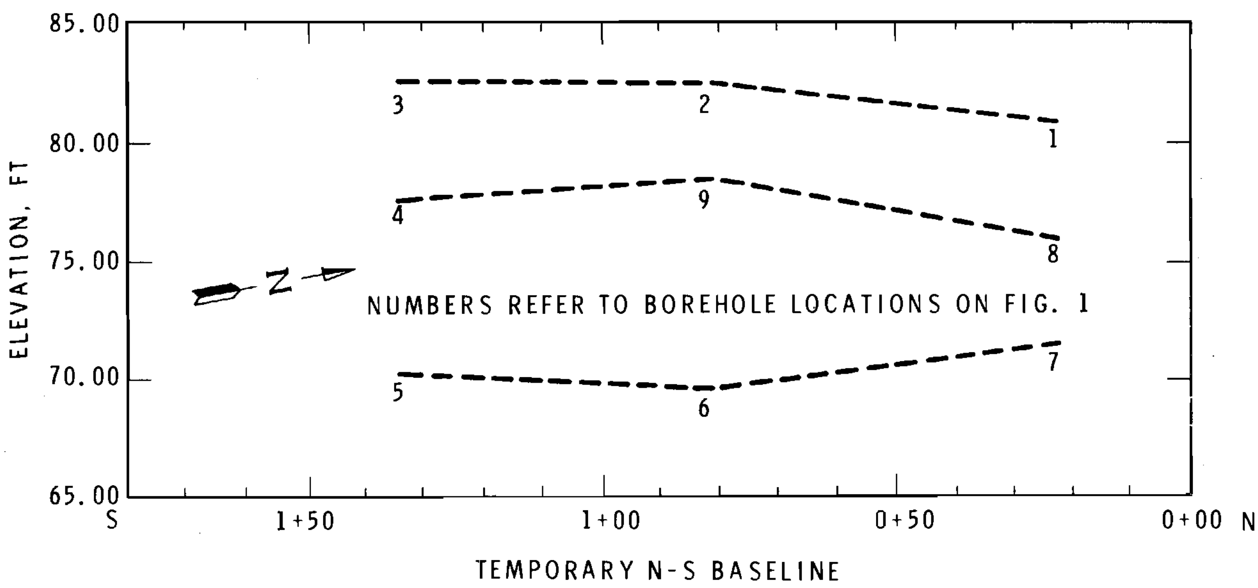
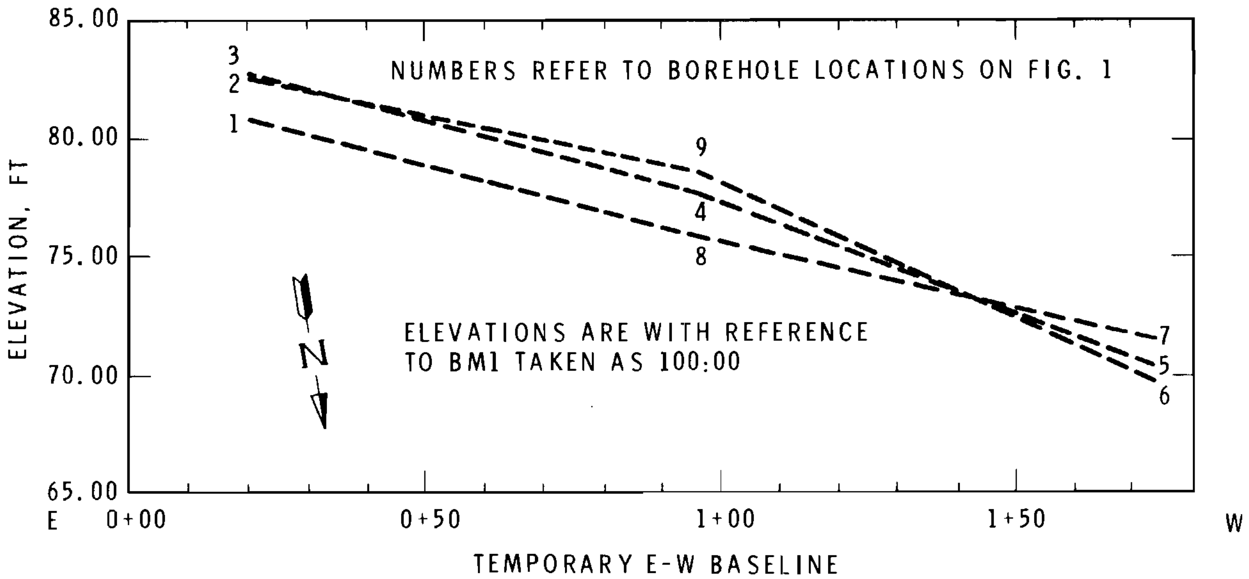


FIGURE I FROST HEAVE TEST SITE, THOMPSON MANITOBA

BR 5007



(a) NORTH-SOUTH BEDROCK PROFILE



(b) EAST-WEST BEDROCK PROFILE

FIGURE 2

BEDROCK ELEVATIONS AT THE FROST HEAVE TEST SITE - THOMPSON, MANITOBA

BR 5036 - 1

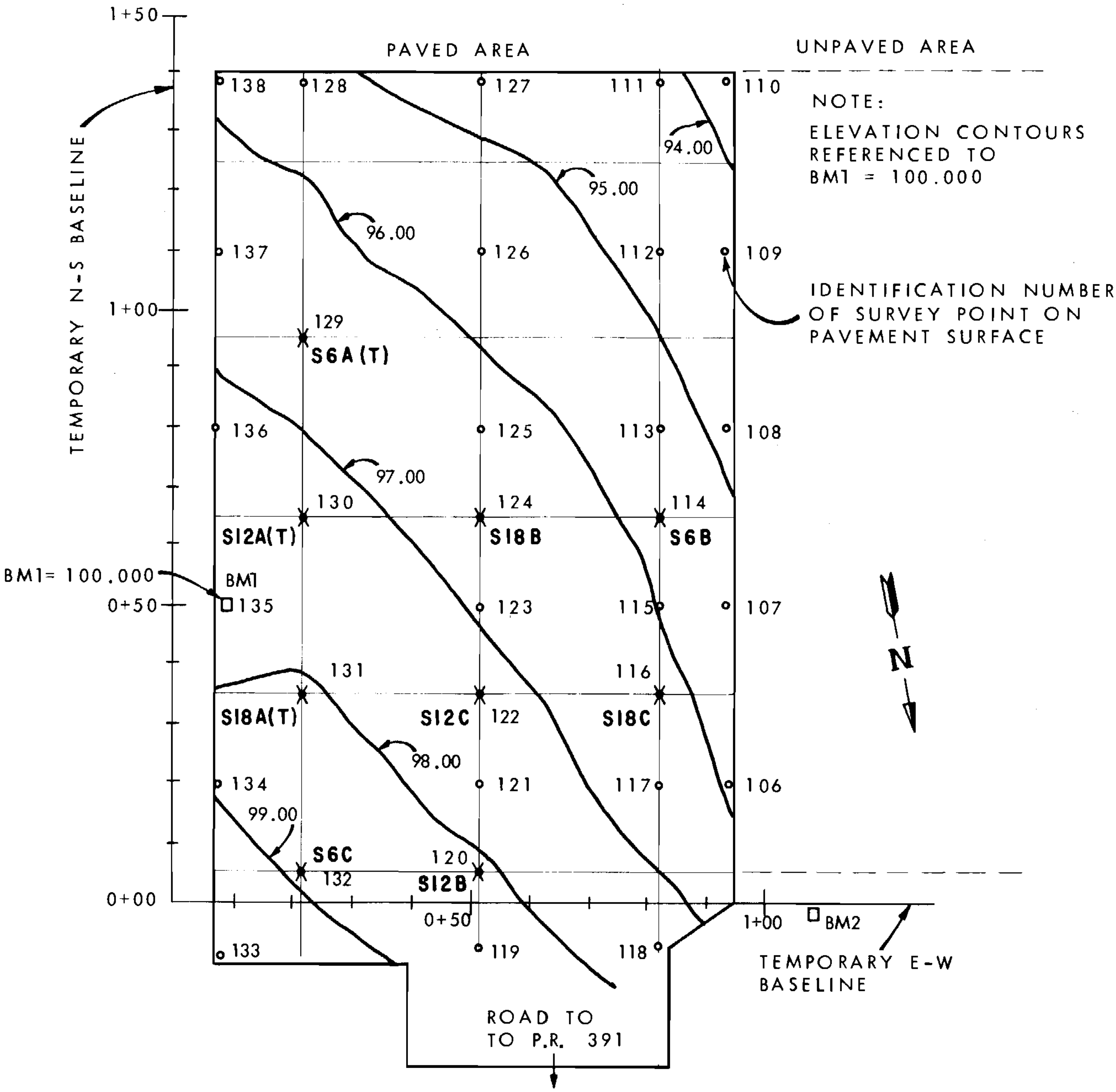
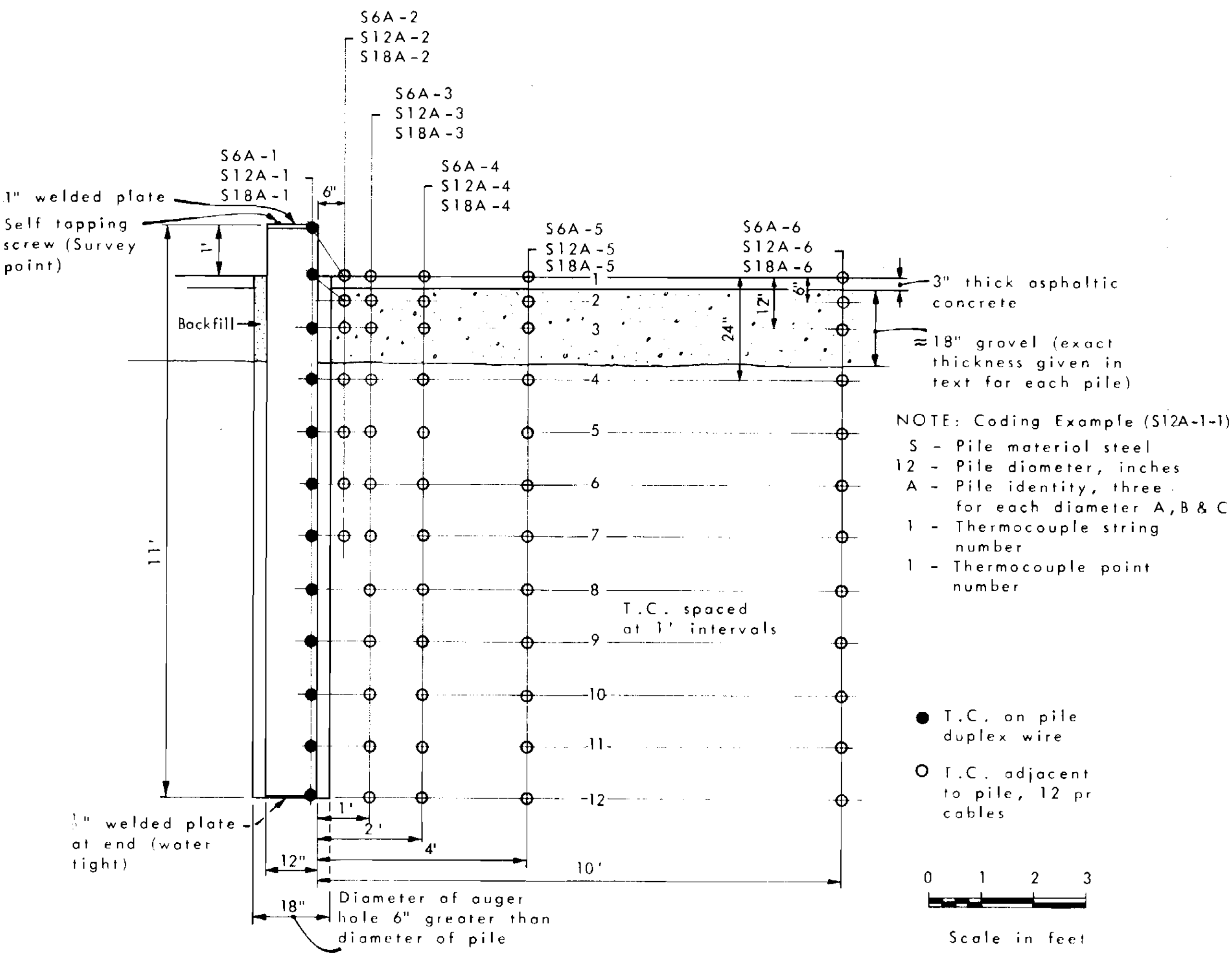


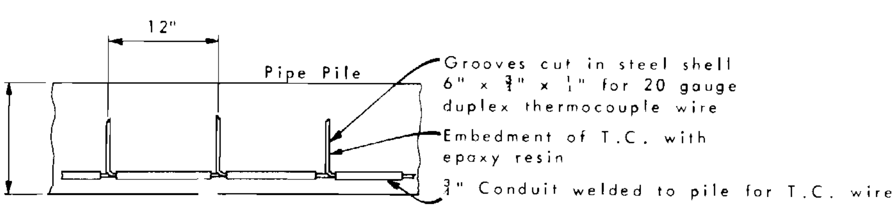
FIGURE 3

ELEVATION CONTOURS OF PAVED SECTION FROST HEAVE TEST SITE-THOMPSON MANITOBA, OCT. 72

BR5036-2



4 (a) Thermocouple positions on 6", 12" and 18" temperature instrumented steel piles and locations of thermocouple strings at various distances from the pile and identification system. Drawing shows 12" pile



4 (b) Installation of thermocouples on steel pipe pile

FIGURE 4 PILE AND THERMOCOUPLE INSTALLATION

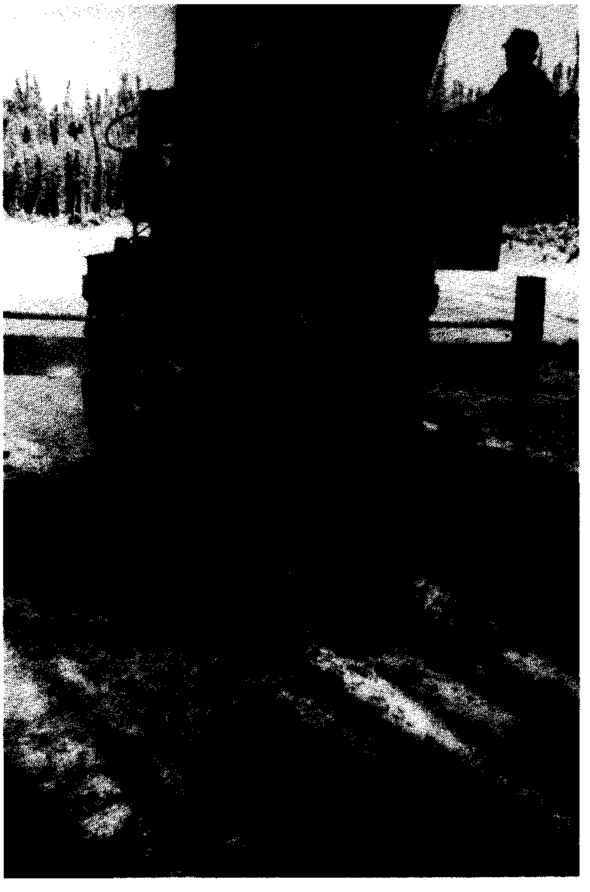


FIG. 6. Augering 24-in. hole for 18-in. diameter pile

FIG. 7. Centering the steel pile in the machine-augered hole

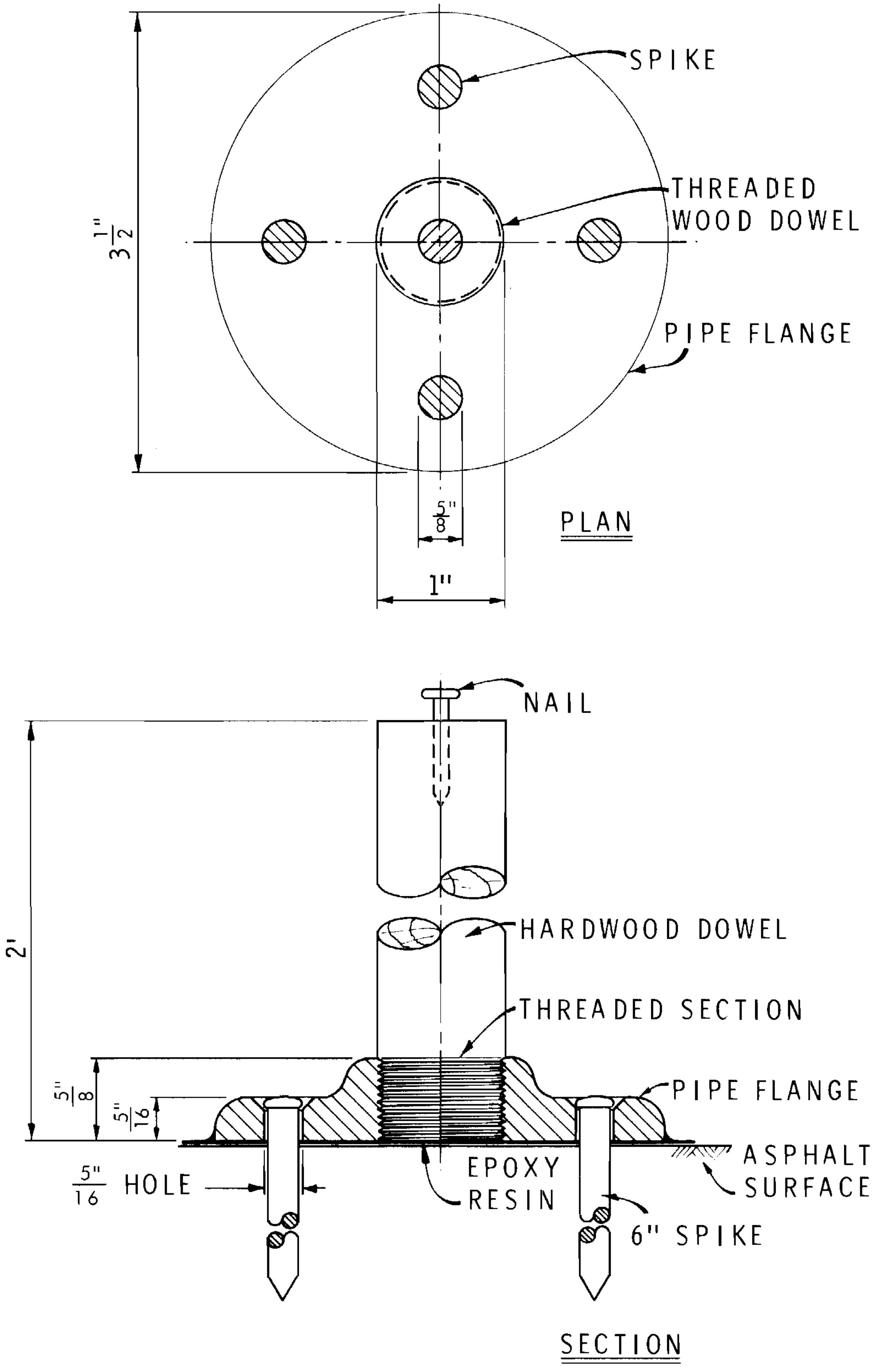


FIGURE 8 SURFACE HEAVE GAUGE

BR5036-4

FIG. 10. Eighteen-in. diameter pile with force gauge and reaction frame in place

FIG. 11. Elevated walkway to prevent snow disturbance during weekly level surveys

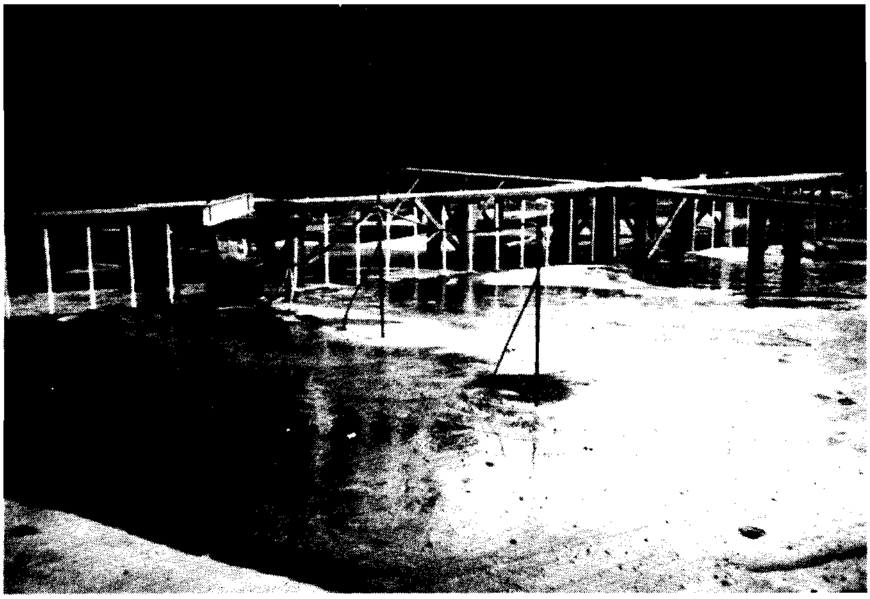


FIG. 12. View of installed pile and thermocouple installations at various distances from pile