FROST INVESTIGATION 1944-1945

—•—

REPORTS ON
OTIS FIELD, SANDWICH, MASS.
AND
HOULTON AIRFIELD, HOULTON, MAINE

CORPS OF ENGINEERS, U.S. ARMY
U.S. ENGINEER OFFICE, BOSTON, MASS.
JUNE 1945

APPENDICES 3 AND 4
TO COMPREHENSIVE REPORT
DATED JUNE 1945

WAR DEPARTMENT
U. S. ENGINEER OFFICE
BOSTON, MASSACHUSETTS

APPENDIX 3

REPORT ON
OTIS FIELD
SANDWICH, MASSACHUSETTS

FROST INVESTIGATION
1944 - 1945

JUNE 1, 1945

FROST INVESTIGATION

TABLE OF CONTENTS

FROST INVESTIGATION

LIST OF TABLES

LIST OF PLATES

FROST INVESTIGATION
1944 - 1945

APPENDIX 3

REPORT ON
OTIS FIELD, SANDWICH, MASSACHUSETTS

1. Authorization. The general frost investigation program was authorized by the Chief of Engineers by letter to the Division Engineer, New England Division, dated 7 July 1944, subject, "Frost Investigation" and subsequent indorsements; and by the Chief of Engineers by letter to the Division Engineer, New England Division, dated 30 June 1945, subject "Funds and Completion Dates for Investigational Projects" and subsequent indorsements.

2. Purpose. The purpose of this investigation has been the determination of the development of frost in the soils underlying airfield pavements as affected by various conditions of weather, soils and groundwater.

3. Scope. This report presents the results of the frost investigation conducted at Otis Field, Sandwich, Massachusetts during the period from 30 November 1944 through 23 April 1945. The investigation at Otis Field includes one test area in which observations were made of frost penetration, ice segregation, water content, and density. In place C. B. R. tests were made on the subgrade soil. Atterberg limits and mechanical analysis tests were performed on representative samples. The climatic and other general conditions related to the frost investigation at Otis Field also are included in this report.

4. Definitions. The description of the tests and analyses of results involve a specialized use of certain terms and words. These words and terms are defined for use in this report as follows:

a. Test Area. The test area is the portion of the airfield selected for investigations and observations.

b. Pavement. The term pavement is defined as a covering of a prepared or manufactured product superimposed upon a subgrade or base to serve as an abrasion and weather resisting structural medium.

c. Base. The term base applies to the course of specially selected soils, mineral aggregates or treated soils placed and compacted on the natural or compacted subgrade.

d. Subgrade. The term subgrade applies to the natural soil in place or to fill material upon which a pavement or base is constructed.

e. Frozen Soil. Two types of frozen soil are referred to in this report as follows:

(1) Homogeneous Frozen Soil. A soil in which all the water in the voids is frozen is referred to as a homogenenous frozen soil.

(2) Stratified Frozen Soil. A soil in which part of the water in the soil is frozen outside the voids in the form of ice lenses.

f. Ice Crystals. The formation of ice particles found in the pores of homogeneous frozen soil is referred to as ice crystals.

g. Ice Lenses. Ice lenses are the ice formations in stratified frozen soil occurring in repeated layers essentially parallel to each other and normal to the direction of heat loss.

h. Frozen Zone. The limits of depth within which the soil is frozen is referred to as the frozen zone.

i. Frost Penetration. The maximum depth from the surface to bottom of the frozen soil.

j. Frost Action. Frost action is the accumulation of water in the form of ice lenses in the soil or base materials under natural freezing conditions.

k. Frost Heave. Frost heave is the raising of the pavement surface due to the accumulation of ice lenses. The amount of heave in most soils is approximately equal to the cumulative thickness of the ice lenses.

l. Degree Day. Degree Day is the algebraic difference between 32° Fahrenheit and the daily mean temperature. The degree day is plus when the daily mean temperature is below 32° Fahrenheit and minus when above.

m. Degree Day Diagram. Degree Day Diagram is a plot of the cumulative degree days as the ordinate and elapsed time as the absicca (Figure 1, Plate 2).

n. Freezing Index. Freezing index is a measure of the combined duration and magnitude of below freezing air temperature occurring during any given winter.

o. Normal Freezing Index. Normal freezing index is the freezing index computed for normal air temperatures based upon a long period of record usually 10 or more years.

p. Frost Susceptible Soil. Frost susceptible soil is a soil in which frost action is possible. Any soil which contains 3 percent or more by weight of grains smaller than 0.02 mm. in diameter shall be considered a frost susceptible soil.

q. Non-Frost Susceptible Materials. Non-frost susceptible materials are crushed rock, sand, sand and gravel, gravel, slag, cinders or any other cohesionless material in which frost action is not possible.

r. Ground Water Table. Ground water table is the free water surface nearest to the ground surface.

s. Density. Density is the unit dry weight in pounds per cubic foot.

5. General Conditions.

a. Location and Terrain. Otis Field is located within the limits of Camp Edwards, Town of Sandwich, Barnstable County, Massachusetts. Plate 1 shows the geographical location of the airfield in the Boston District. The site is of glacio-fluvial origin and is part of an extensive outwash plain. The area is generally flat; the only change in topography occuring in occasional eroded valleys and kettleholes. An extensive deposit of variable sands and gravels with occasional boulders extends to considerable depths. No bedrock has been encountered by boring explorations and no rock exposures are present in the deep kettleholes or ravines surrounding the area.

b. Drainage. The drainage system consists of paved gutters, ditches, culverts, pipe drains, and catch basins. Surface run-off is generally collected by longitudinal open ditches parallel to the outer edges of the landing strips, taxi strips and shoulders. In addition to the ditches, the landing strip turf shoulders have longitudinal subdrains for surface run-off of closed joint concrete pipe located 150 feet from each side of the runway center line. An open joint underdrain system is parallel to the edges of each runway, warm-up apron and taxiway pavement. Runway underdrains were installed in the spring and summer of 1943. They are 6-inch diameter, open joint, non-reinforced concrete pipe laid parallel to the surface of the runway with the invert 4 feet below the edge of pavement. The permanent groundwater table is located at about 20 to 30

feet below the surface.

c. Types of Pavement. The runways, taxiways, stub-end taxiways and the addition to the service apron are constructed of bituminous concrete. The runway turn-arounds, warm-up aprons, taxiway turn-arounds, hardstandings and original service apron are of cement concrete.

d. Traffic History. Otis Field has been used mainly by medium weight bombers of the 30,000 pound class during operations by the Army from January 1942 to January 1944. Average operations per day were 45 cycles of landings and take-offs. The lighter weight planes of 8,000 pounds made an average of 75 cycles. Occasionally planes of 60,000 pounds used the field at 5 landing and take-off cycles per day. Since May 1944 the airfield has received more intensive use by the Navy. Single engine planes of 12,000 to 15,000 pound gross weight have made 200 to 250 cycles of landings and take-offs per day. The NE-SW Runway received approximately 50 percent of the traffic, the NW-SE Runway 25 percent and the N-S Runway 25 percent.

e. Condition of Pavement. All airfield pavements during the investigation period were generally good with the exception of minor cracking and minor depression on all pavement surfaces. Serious or detrimental frost heave or cracking was not evident during the winter of 1944-1945.

f. Climatic Conditions. Winter temperatures at Otis Field are mild in comparison to severe winters of northern New England. Temperatures below freezing prevail from mid-December to late February or early March. The normal freezing index is 202 based on a 21 year record of the U. S. Weather Station located at East Wareham, Massachusetts approximately ten miles northwest of the airfield. The 1944-1945 freezing index was 512 degree-days or about two and one-half times greater than normal.

The normal total precipitation for the three and one-half month period from 1 September to 15 December is 15 inches. The total precipitation for the same three and one-half months preceding the freezing period for 1944 was 21 inches or about 40 percent above normal. The weather conditions were, therefore, more favorable for frost action to occur in relation to freezing temperature and autumn rainfall. The cumulative snowfall in 1944-1945 was in excess of the previous season. These data are presented in detail in Figures 1 and 3 on Plate 2.

g. Previous Frost Investigations.

(1) Winter 1942-1943. Early in January 1943 frost heaves had developed at several locations on the paved runways, particularly in the test area selected for the 1944-1945 investigation. These heaves became steadily worse until mid-February when differential heaves were as great as 4 and 6 inches and averaging about 3 inches. The most serious heaving occurred in the unsealed portions of the bituminous concrete pavement. Some surface stones in the unsealed areas of the pavement were loosened by frost and picked out by traffic. The following summer the runway pavement was removed and replaced at a few selected areas where the pavement damage was critical. A seal coat was applied to all runway paving which had not been previously sealed.

To investigate the depth of the frost penetration and the character of the subgrade soils in an area of severe frost heaving, a test pit, T500p, was excavated to a depth of 4 feet on 17 February 1943 during a cold

spell (13° Fahrenheit). After removal of the pavement, continuous water contents of the top 8 inches of subgrade were obtained from each of the four sections of the pit. Locations and data from these samples, E-6 to E-17, are listed together with a sketch of the pit in Table 1. The location of T500p is shown on Plate 3. Directly beneath the top 8 inches of subgrade, 12 continuous water contents were taken. Results of tests on samples E-74 to E-85 are listed in Table 1. A few thin frost lenses were observed in the top 8 inches of the subgrade. The thickest and greatest number of ice lenses were found in the lower sandy silt subgrade to a depth of 2 feet which was the depth of maximum frost penetration. These ice lenses varied in size from very thin flakes to a maximum thickness of about 1/8 inch. Sample E-85, showing a low water content of 4.7 percent consisted of clean fine to medium sand and was located at a depth of 36 inches directly beneath the silty layer. A group of 9 observation wells was installed 24 February 1943 during a thaw period, on the NE-SW Runway left of the centerline between stations 41 + 20 and 42 + 20. The wells were installed in the portion of the pavement where frost heaves were most severe. It was observed that a greater quantity of surface water existed on the turf shoulders adjacent to this area than elsewhere along the runway. The underdrains described in Paragraph 4b were not installed on this date which may

explain the high perched water table, 6 to 12 inches below the surface during the 2-day thaw spell. The top 8 inches of material were not frozen during this period although the depth of frost penetration was 2 feet. During several days in the frost melting period, attempts were made to observe the effect of 30,000 pound plane loads on the bituminous concrete pavement. There was no visual evidence of weaving or disturbance of any kind.

(2) Winter 1943-1944. On 20 January 1944, a visual inspection was made of the runways and taxiways at Otis Field to observe the effect of frost heaving of the subgrade. Some slight heaving had occurred at the intersection of the NW-SE and the N-S Runways. Longitudinal cracks approximately 1/16 inches in width were noted at several points. The pavement heave did not interfere with field operations. Inspection of the northeast end of the NE-SW Runway in the area of severe pavement heave during the winter of 1942-1943 showed a few small local heaves. One severe heave of about 4 to 5 inches was observed right of centerline at station 45 + 00. No frost heaves were found at any other part of field.

6. Test Area A.

a. Location and Description. Test Area A is located in a cut section on the NE-SW Runway extending from the runway centerline to the west edge of the pavement between station 40 + 00 and station 52 + 00. The pavement varies in thickness from 5 to 7 inches and consists of a

plant mix, cold laid, partially crushed aggregate bound with emulsified asphalt. The pavement overlies a non-uniform subgrade generally consisting of pockets of sands, silts and gravels so intermixed that several gradations of frost susceptible soil are encountered from about 1.0 to 3.0 feet below the pavement surface. The subgrade at greater depths consists of fine to medium sand with occasional gravel and small amounts of silt.

b. Explorations. A chronological summary of explorations is given in Table 1. A more detailed tabulation which includes the date and result of test pit and auger hole explorations is contained in 5 sheets of Table 2. The explorations in Test Area A, the locations of which are shown on Plate 3, consist of 5 groups as follows:

(1) Preliminary Soils Explorations. Sufficient data on pavement and subsurface conditions were obtained during winter of 1942-1943, particularly in test pit T500p, to assist in selection of Test Area A. The area was observed to be affected by frost action during the past two winters as described in Paragraph 4g.

(2) Explorations Prior to Freezing Period. Seventeen auger holes, T232a to T248a inclusive were excavated to depth of 6.0 feet or to refusal. These explorations were made during period 30 November to 8 December 1944 to determine water content of subgrade soils, to obtain typical samples for grain size analysis, and to define sub-surface conditions.

(3) Explorations During Freezing Period. Test Pit T253p and three auger holes T254a, T255a, and T256a were

excavated 15-16 February 1945 to determine density, water content, and depth of frost penetration in the subgrade.

(4) Explorations During Frost Melting Period. Test Pit T257p and four auger holes T258a to T261a inclusive were excavated 16 March 1945 to determine changes in the subgrade caused by frost and winter conditions. Density, water content, and in place C. B. R. of the subgrade were obtained in the test pit.

(5) Explorations After Frost Melting Period. One test pit, T262p, was excavated 24 April 1945 to determine density and water content of the subgrade after frost had left the ground. Depth of pit was 6.0 feet and it was continued to 13.0 feet by auger hole.

c. Installations. Four observation wells, T249a to T252a inclusive were installed to measure the perched ground water table in the upper subgrade. The wells consisting of 2 inch diameter galvanized iron pipe with a threaded sleeve to which a vented cap was attached were installed 8 December 1944 to depths 1.1 and 1.4 feet. The lower 6 inches of this pipe were perforated with 1/4 inch holes to permit the access of ground water and the bottom of the pipe was sealed with a wooden plug to prevent clogging. The location of these observation wells are shown in plan on Plate 3.

d. Observations and Measurements. The following observations and measurements were made:

(1) Ground Water Table Observations. The wells were dry at all periods during this investigation with the

exception of observations made on 5 February 1945 which showed ice inside the wells at depths 0.3 to 1.3 feet.

(2) Pavement Heave. Level Surveys were made over the entire test area which was divided into a 25-foot grid system. The initial survey was made on 15 December 1944 before frost had entered the ground. The surveys were repeated in mid-winter on 31 January 1945 and after the frost melting period on 15 March 1945. Pavement heave contours based upon the elevation differences indicated by surveys on 15 December 1944 and 31 January 1945 were computed and are plotted on Plate 4. The subsidence of the pavement or return to normal condition after the frost melting period, based upon the elevation differences indicated by surveys on 31 January 1945 and 15 March 1945, are similarly shown by contours on Plate 4.

(3) Depth of Frost Penetration. The depth of frost penetration was measured in one test pit, T253p, and three auger holes, T254a, T255a, and T256a, on 15-16 February 1945. Measurements ranged from 1.4 to 2.2 feet below the pavement surface and the average depth of frost penetration was 1.8 feet. No frost was found during explorations made 8 December 1944 and 16 March 1945. Figure 2 on Plate 2 shows the depth of frost penetration versus time plotted from the above data and partly estimated.

(4) Ice Lens Survey. Observations of ice lenses were made

during the excavation of Test Pit T253p and in three auger holes, T254a, T255a and T256a. The freezing index at the time of excavation on 15-16 February 1945 was 460. Ice lenses were found on these dates generally between 1.0 and 2.0 foot depth in the silt and fine sand layers. The ice lenses were from 1/32 inch to hairline in thickness numbering approximately 63 in a 12-inch depth.

c. Field Tests.

(1) Water Content. Continuous water contents were obtained in the test pits and auger holes excavated during the fall, winter, and spring. The tests were made for the purpose of determining the migration and accumulation of water as the result of frost action. The water content data are plotted in relation to the soil profile in Figures 1 and 2 on Plate 5. All water content results are further summarized in Table 2.

(2) Density. The density and water content of the subgrade were obtained to depth of approximately 6 feet to determine density changes due to frost action. The results of these tests are plotted in Figure 1 on Plate 5 in relation to the soil profile and for comparison with water contents. Figure 3, Plate 5 shows plot of density versus water content for all tests made.

(3) California Bearing Ratio. On 16 March 1945, in place C. B. R. tests were made on the surface of the sub-

grade and 23 inches below the surface of the subgrade in Test Pit T257p. The results of these tests are presented in Table 3.

f. Laboratory Tests. The following laboratory tests were performed:

(1) Mechanical Analysis and Atterberg Limits. Tests were made for classification purposes in accordance with procedures given in Appendix 14. All materials are classified using the Casagrande Classification. Range in graduation of the several subgrade materials encountered is shown in Figures 4 and 5 on Plate 5. Summary of all mechanical analysis, Atterberg limit tests and soil classification is shown in Table 2.

g. Summary of Results.

(1) Soils. In general, the subgrade soil is frost susceptible as more than 3 percent of grains by weight are smaller than 0.02 mm. in diameter. However, an occasional layer of sand and gravel and gravelly sand was encountered which is not frost susceptible.

(2) Freezing Index and Precipitation. The freezing index of 1944-1945 was 512 or 2-1/2 times more severe than the normal freezing index. The rainfall during 3-1/2 months preceding the freezing period was 20 inches or approximately 40 percent above normal.

(3) Ground Water. On 16 March 1945, an explored depth of 15 feet did not reach ground water. The well installations were intended to show perched water table

conditions in the upper subgrade. Except on 5 February 1945, when ice was found in each well, the wells were dry.

(4) Pavement Heave. The effect of frost action during 1944-1945 on pavement heave is considered negligible. The maximum heave measured was 0.16 feet and this occurred in a small circular area along the edge of pavement adjacent to the turf. In general, the pavement heave was 0.10 feet and the heaved area was predominately closer to the edge of runway pavement. The subsidence of the pavement measured on 15 March 1945 indicated that the pavement did not return completely to the original elevations.

(5) Depth of Frost Penetration. The depth of frost penetration averaged 1.8 feet below the pavement surface and ranged in depth from 1.4 to 2.2 feet when observed on 15-16 February 1945. No frost was found during explorations made on 8 December 1944 and 16 March 1945.

(6) Ice Segregation. Ice lenses were found to range in thickness from 1/32 inch to hairline. Lenses were found in a zone approximately 12 inches thick and above the lower limit of frost penetration.

(7) Subgrade Soil Conditions.

(a) Water Content and Density. From the limited amount of data obtained for the non-uniform subgrade soil, there appears to be no correlation between the change in water content and density

with respect to tests made during the normal and frost melting periods.

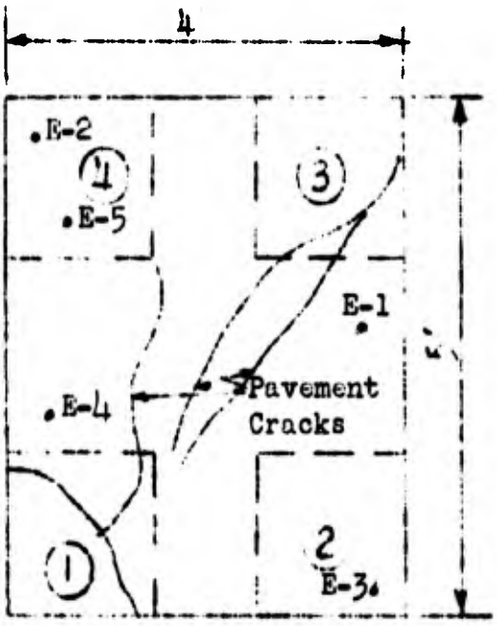
(b) California Bearing Ratio. The in place C. B. R. tests made 16 March 1945 on the subgrade show results ranging from 7 to 31 percent at 0.1 inch penetration. Tests made in November and December 1943, prior to this investigation, show a higher C. B. R. value of 44 percent for the subgrade.

h. Conclusion. It is believed that the history of pavement heave at Otis Field furnishes an example of the beneficial results obtained after the installation of an open joint subsurface drainage system or probably more specifically after the application of a bituminous seal coat on the runway pavement. Prior to these two corrective measures, pavement heaves of about 6 inches developed during the winter of 1942-1943. The following winter of 1943-1944, with a lower freezing index, the pavement heave developed was negligible. For winter of 1944-1945 with very severe temperature and rainfall conditions in comparison to the previous two winters, the pavement heave was also negligible.

FROST INVESTIGATION

FROST DATA FROM TEST PIT T500p

17 FEBRUARY 1943



PLAN OF TEST PIT T500p
NE-SW Runway
Station 51 + 00
40' left of ℄

BITUMINOUS PAVEMENT SAMPLES
(Locations show on Plan)

Sample No.	Depth in Inches	Water Content % Dry Weight
E-1	2 - 4	5.3
E-2	2 - 4	5.9
E-3	2 - 5	5.3
E-4	2 - 6	4.7
E-5	2 - 6	4.2

Average Thickness of Pavement 6.0"

Average Depth of Frost Penetration 24.6"

Sandy Silt from 14" to 36"

Clean Sand below 36"

Section	Sample No.	Depth in Inches	Water Content % Dry Weight	
1	E-6	6 - 9	28.7	
	E-7	9 - 11	23.6	
	E-8	11 - 14	17.7	
2	E-9	6 - 9	10.5	
	E-10	9 - 11	11.7	
	E-11	11 - 14	11.9	
3	E-12	6 - 9	11.5	
	E-13	9 - 11	11.0	
	E-14	11 - 14	19.1	
4	E-15	6 - 9	11.8	
	E-16	9 - 11	15.1	
	E-17	11 - 14	13.7	
Center of Pit	E-74	14 - 16	18.8	
	E-75	16 - 18	30.6	Ice
	E-76	18 - 20	39.1	Lenses
	E-77	20 - 22	48.8	
	E-78	22 - 24	45.9	
	E-79	24 - 26	16.35	
	E-80	26 - 28	15.1	Frost
	E-81	28 - 30	15.7	Line
	E-82	30 - 32	18.4	
	E-83	32 - 34	19.7	
	E-84	34 - 36	24.7	
	E-85	36 - 38	4.7	

TABLE 1

CHRONOLOGICAL SUMMARY

EXPLORATIONS AND OBSERVATIONS

OTIS FIELD

SANDWICH, MASS.

DATE	WEATHER	OPERATION	REMARKS
1944			
Nov. 30 to Dec. 8	Cold, windy, clear - no freezing.	Auger Holes T232a to T248a excavated to about 6 ft. Observation wells T249a to T252a installed in base.	
Dec. 15		Initial level survey on 25' grid system on test area.	
1945			
Jan. 31		Second survey of test area.	
Feb. 5	Cold, windy clear	Observation wells read.	
Feb. 14 to Feb. 17	Cold, foggy. Freezing at night. Windy occasional snow	Test Pit T253p and auger holes T254a to T256a excavated. Observation & measurement of ice formations. Water content and density obtained. Observation wells read.	Heaves observed around holes excavated in Nov.-Dec. 1944.
Feb. 21	Clear, warm	Visual inspection of heaves and cracks on all runways.	
Mar. 15		Third survey of test area.	
Mar. 19	Foggy, windy, moderate temperature.	Test Pit T257p excavated. Water content, density and field CBR tests performed. Auger holes T258a to T261a excavated and water content obtained. No ice lenses or frost in ground. Observation wells read.	Heaving subsided in areas previously observed.
Apr. 23	Partly cloudy, warm. Frost at night.	Test Pit T262p excavated. Water contents and density tests performed. Observation wells read.	Observation well T251a damaged beyond use.

R DEPARTMENT

FROST INVESTIG
SUMMARY OF SOIL TE

OTIS FIELD. SANDW

PLORA-TION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRA-TION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN SI % Finer than indica				
								0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.
-500p	17 Feb. 1943	A	Bit. Concrete	0.0-0.5								
			Subgrade	0.5-0.8			SP					
				0.8-0.9			"				24	
				0.9-1.2			"					
				1.2-1.3			"					
				1.3-1.5			ML					
				1.5-1.7			"					
				1.7-1.8			"					
				1.8-2.0	2.0	>3.2	"					
				2.0-2.2			"					
				2.2-2.3			"					
				2.3-2.5			"					
				2.5-2.7			"					
				2.7-2.8			"					
				2.8-3.0			"					
				3.0-3.2			"					
-216p	25 Nov. 1943	A	Bit. Concrete	0.0-0.6	0	>4.0						
			Subgrade	0.6-4.0			SP					
-230p	9 Dec. 1943	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-0.8			SF					
				0.8-1.1	0	>4.0	GP					
				1.1-2.7			"					
				2.7-3.6			SP					
				3.6-4.0			"					
-231p	9 Dec. 1943	A	Bit. Concrete	0.0-0.4								
			Subgrade	0.4-0.7			SC					
				0.7-1.0	0	>4.0	SP					
				1.0-1.6			"					
				1.6-2.5			"					
				2.5-4.0			"					
232a	30 Nov. 1944	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-0.9			GP					
				0.9-1.0	0	>5.6	SP					
				1.0-3.8			SF					
				3.8-5.6			"					
233a	30 Nov. 1944	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-0.7			SF					
				0.7-0.8	0	>5.8	"					
				0.8-2.7			"	4	12	30	37	
				2.7-5.8			"		15	46	61	
		A										

NVESTIGATION
SOIL TEST DATA

SANDWICH, MASS.

SOIL DATA									FIELD IN-PLACE TESTS			REMARKS
Y GRAIN SIZE r than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY	DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.					
										15.6		
	24	36	82	88	94					15.4		
										15.6		
										18.8		
										30.6		
										39.1		
										48.8		Numerous ice lenses from 1/8" to hair line thickness from 1.2'-2.0'.
										45.9		
										16.4		
										15.1		
										15.7		
										18.4		
										19.7		
										24.7		
										4.7		
												Refusal due to gravel.
									126	13.0	44	
									122	3.3	44	
									126	10.7		
30	37	47	73	78	85							
46	61	71	80	84	95							

B

FROST INVESTI
SUMMARY OF SOIL T

OTIS FIELD. SANDV

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN S % Finer than indic				
								0.005 mm	0.02 mm	0.05 mm	0.10 mm	
T-234a	1 Dec. 1944	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-2.0	0	> 6.0	SF					
				2.0-3.2			"					
				3.2-6.0			"					
T-235a	2 Dec. 1944	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-0.9			SF					
				0.9-1.9	0	> 5.2	GP	0	1	1	2	
				1.9-3.5			"				0	
				3.5-5.2			"		0	2	5	
T-236a	2 Dec. 1944	A	Bit. Concrete	0.0-0.4								
			Subgrade	0.4-1.1			SF	2	9	20	27	
				1.1-1.5	0	> 6.0	"	1	8	17	21	
				1.5-2.4			SP		0	1	4	
				2.4-6.0			GP			0	1	
T-237a	2 Dec. 1944	A	Bit. Concrete	0.0-0.4								
			Subgrade	0.4-0.5	0	> 5.0	SF					
				0.5-1.8			"					
				1.8-5.0			SP					
T-238a	2 Dec. 1944	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-0.7			SP	0	1	2	4	
				0.7-0.9	0	> 5.4	SF					
				0.9-1.5			"	2	7	16	22	
				1.5-5.4			SP			0	1	
T-239a	2 Dec. 1944	A	Bit. Concrete	0.0-0.5								
			Subgrade	0.5-0.9			SW					
				0.9-1.6	0	> 6.0	SF	6	19	40	52	
				1.6-3.4			"	3	11	23	30	
				3.4-6.0			GP				0	
T-240a	5 Dec. 1944	A	Bit. Concrete	0.0-0.6								
			Subgrade	0.6-2.4	0	> 4.6	SF					
				2.4-4.6			SP					
T-241a	5 Dec. 1944	A	Bit. Concrete	0.0-0.4								
			Subgrade	0.4-0.7			SF					
				0.7-0.9	0	> 6.0	SP					
				0.9-2.1			SF	2	9	17	22	
				2.1-6.0			SP	0	1	2	3	

'ESTIGATION
OIL TEST DATA

NDWICH, MASS.

SOIL DATA								FIELD IN-PLACE TESTS			REMARKS
RAIN SIZE un indicated grain size					ATTERBERG LIMITS		SPECIFIC GRAVITY	DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.					
											Small roots from 2.0'-2.5'.
2	7	48	57	66							
0	9	52	56	62							Refusal due to boulder.
5	17	58	68	89							
27	37	70	77	86							
21	32	73	79	89							
4	18	79	82	88							
1	8	59	71	81							
											Few small roots at 1.5'. Refusal at 5' due to gravel.
4	11	59	71	85							Refusal at 5.4' due to coarse gravel.
22	29	76	83	93							
1	9	57	63	76							
52	63	84	88	96	23.9	19.3					Small roots found from 1.0'-1.5'.
30	42	77	82	92							
0	16	58	64	75							
											Refusal at 4.6' due to coarse gravel.
									9.0		
									4.9		
22	41	81	87	99					7.1		
3	12	63	72	87					1.9		

WAR DEPARTMENT

FROST INVEST
SUMMARY OF SOIL

OTIS FIELD. SAND

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN % Finer than in			
								0.005 mm	0.02 mm	0.05 mm	0.1 mm
T-242a	5 Dec. 1944	A	Bit. Concrete	0.0-0.4							
			Subgrade	0.4-0.8			SP	1	1	4	6
				0.8-0.9	0	> 6.0	SP				
				0.9-1.1			SP				
				1.1-1.6			SF		12	24	30
				1.6-6.0			SP				0
T-243a	5 Dec. 1944	A	Bit. Concrete	0.0-0.4							
			Subgrade	0.4-1.2			SF	1	4	8	12
				1.2-3.8	0	> 6.0	SP				0
				3.8-6.0			GP			0	1
T-244a	6 Dec. 1944	A	Bit. Concrete	0.0-0.4							
			Subgrade	0.4-0.7			SF	2	10	28	39
				0.7-1.7	0	> 6.0	"				
				1.7-2.0			"	5	18	52	69
				2.0-3.4			"				
				3.4-6.0			SP	1	3	7	12
T-245a	7 Dec. 1944	A	Bit. Concrete	0.0-0.5							
			Subgrade	0.5-0.6			SF				
				0.6-0.8	0	> 6.0	"				
				0.8-2.0			"	0	2	6	11
				2.0-6.0			SP			0	1
T-246a	7 Dec. 1944	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-0.7			SF				
				0.7-0.9			"				
				0.9-1.3	0	> 6.0	SP	0	1	2	3
				1.3-1.8			SF	2	13	29	40
				1.8-2.6			ML	6	25	60	71
				2.6-6.0			SP	0	1	2	3
T-247a	7 Dec. 1944	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-0.9	0	> 6.0	SF				
				0.9-4.8			SP				
				4.8-6.0			SP				
T-248a	6 Dec. 1944	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-0.7			SF				
				0.7-0.9			"	2	6	13	17
				0.9-2.1	0	> 6.0	SP				
				2.1-3.2			"		0	1	2
				3.2-4.7			SF	0	5	14	20
				4.7-6.0			"				

INVESTIGATION
SOIL TEST DATA

SANDWICH, MASS.

SOIL DATA									FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE finer than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY	DENSITY LBS./CU. FT.	WATER CONTENT	CBR 0.1" PEN.	
0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.					
4	6	17	70	79	90					2.6		
24	30	43	87	91	97	17.7	15.6			9.4		
	0	12	81	88	95					2.1		
8	12	23	64	70	77					7.8		
	0	16	87	90	91							
0	1	10	53	61	74							
28	39	52	78	83	91					10.3		
52	69	84	91	93	99	None				11.5		
										14.5		
										24.1		
7	12	27	77	84	92					3.0		
										6.8		
6	11	17	60	67	78					3.9		
0	1	7	72	86	91							
										6.5		
2	3	12	63	71	83					2.4		
29	40	47	75	81	86					10.0		
60	71	79	94	96	99	25.7	21.0			15.8		
2	3	16	82	86	92					22.3		
										10.3		
										4.0		
13	17	29	83	92	98					3.9		
										8.5		
1	2	17	81	88	94					12.0		
14	20	28	77	86	96					7.6		

FROST INVESTI
SUMMARY OF SOIL T

OTIS FIELD. SANDW

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN S % Finer than indic 0.005 mm	0.02 mm	0.05 mm	0.10 mm
T-249a	8 Dec. 1944	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-0.9	0	>1.4	SF				
				0.9-1.4			SP				
T-250a	8 Dec. 1944	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-0.9	0	>1.4	SP				
				0.9-1.4			"				
T-251a	8 Dec. 1944	A	Bit. Concrete	0.0-0.5							
			Subgrade	0.5-0.8	0	>1.1	SF				
				0.8-1.1			SP				
T-252a	8 Dec. 1944	A	Bit. Concrete	0.0-0.5							
				0.5-0.7	0	>1.1	SF				
				0.7-1.1			SP				
T-253p	15 Feb. 1945	A	Bit. Concrete	0.0-0.2							
			"	0.2-0.6							
			Subgrade	0.6-0.9			GW				
				0.9-1.3			ML	19	36	63	70
				1.3-2.3			"				
				2.3-3.3	2.0	>12.0	GP				
				3.3-3.8			"				
				3.8-4.6			"				
				4.6-4.9			SP				
				4.9-5.5			"	0	1	1	1
				5.5-6.0			"				
				6.0-12.0			"				
T-254a	15 Feb. 1945	A	Bit. Concrete	0.0-0.2							
			"	0.2-0.6							
			Subgrade	0.6-1.0	1.8	>2.0	SF	8	25	45	55
				1.0-1.8			"	3	10	21	28
				1.8-2.0			SP	0	1	1	2
T-255a	16 Feb. 1945	A	Bit. Concrete	0.0-0.2							
			"	0.2-0.6							
			Subgrade	0.6-1.2	2.2	>4.5	SF	7	13	30	38
				1.2-2.6			ML	8	33	50	58
				2.6-4.5			SP	0	1	2	5
T-256a	16 Feb. 1945	A	Bit. Concrete	0.0-0.2							
			"	0.2-0.6	1.4	>5.0					
			Subgrade	0.6-1.4			SF				
				1.4-5.0			SP				

INVESTIGATION
SOIL TEST DATA

SANDWICH, MASS.

SOIL DATA									FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE r than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY	DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.					
												Observation well installed at 1.4'.
												Observation well installed at 1.4'.
												Observation well installed at 1.1'.
												Observation well installed at 1.1'.
63	70	80	93	96	98				114.6	21.0		
									99.3	21.8		Ice lenses of 1/32" found throughout from 1.3'-2.3'.
									---	1.3		
									125.7	0.8		
									115.8	0.9		
1	1	6	84	89	96							
									122.6	1.4		
									---	1.8		
45	55	66	89	92	97							Ice lenses of 1/32" found throughout from 1.0'-1.8'.
21	28	40	81	87	97							
1	2	7	30	36	62							
30	38	49	86	92	98							Ice lenses of 1/32" found throughout from 1.2'-2.2'.
50	58	66	76	78	88							
2	5	21	82	87	96							
												Several large boulders.

B

FROST INVESTI
SUMMARY OF SOIL T

OTIS FIELD. SANDV

XPLORA-ATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRA-TION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN S % Finer than indic			
								0.005 mm	0.02 mm	0.05 mm	0.10 mm
T-257p	16 Mar. 1945	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-1.9			SF	7	19	38	47
				2.5							
				1.9-3.7	0	>15.0	SP	1	4	8	11
				3.7-4.5							
				4.5-6.4			SF	3	11	30	49
				6.4-15.0			SP			0	1
T-258a	16 Mar. 1945	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-1.9	0	>3.3	SF	2	13	35	47
				1.9-2.9			SP	0	3	6	8
				2.9-3.3			"		0	1	1
T-259a	16 Mar. 1945	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-1.6	0	>5.0	SF	8	28	57	70
				1.6-3.6			SP			0	1
				3.6-5.0			SP			0	2
T-260a	16 Mar. 1945	A	Bit. Concrete	0.0-0.5							
			Subgrade	0.5-1.6	0	>4.0	SP	1	4	9	12
				1.6-4.0			"			0	1
T-261a	16 Mar. 1945	A	Bit. Concrete	0.0-0.6							
			Subgrade	0.6-1.4	0	>4.0	SF	5	15	37	48
				1.4-4.0			SP			0	1
T-262p	24 Apr. 1945	A	Bit. Concrete	0.0-0.2							
			"	0.2-0.7							
			Subgrade	0.7-1.6			SF				
				1.6-2.1	0	>13.0	"				
				2.1-4.1			"				
				4.1-5.5			ML				
				5.5-6.0			SP				
				6.0-13.0			"				

NVESTIGATION
SOIL TEST DATA

ANDWICH, MASS.

SOIL DATA									FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE — finer than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY	DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
0.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.					
38	47	59	78	81	89	23.7	19.7		130.0	6.3	31	
8	11	22	68	73	84				105.0	4.7	7&17	
									89.0	16.0		
30	49	62	86	90	96				112.0	10.1		
0	1	9	74	82	94				---	1.8		
35	47	62	86	89	95							
6	8	14	73	80	93							
1	1	9	52	60	73							
57	70	81	91	93	98							
0	1	10	75	82	92							
0	2	15	76	81	89							
9	12	22	74	83	97							
0	1	12	69	76	88							
7	48	60	86	89	97							
0	1	14	72	85	99							
									125.5	7.8		
									138.5	8.6		Refusal at 13.0' due to boulder.
									112.0	14.5		
									87.4	23.5		
									113.8	2.6		
									---	2.0		

B

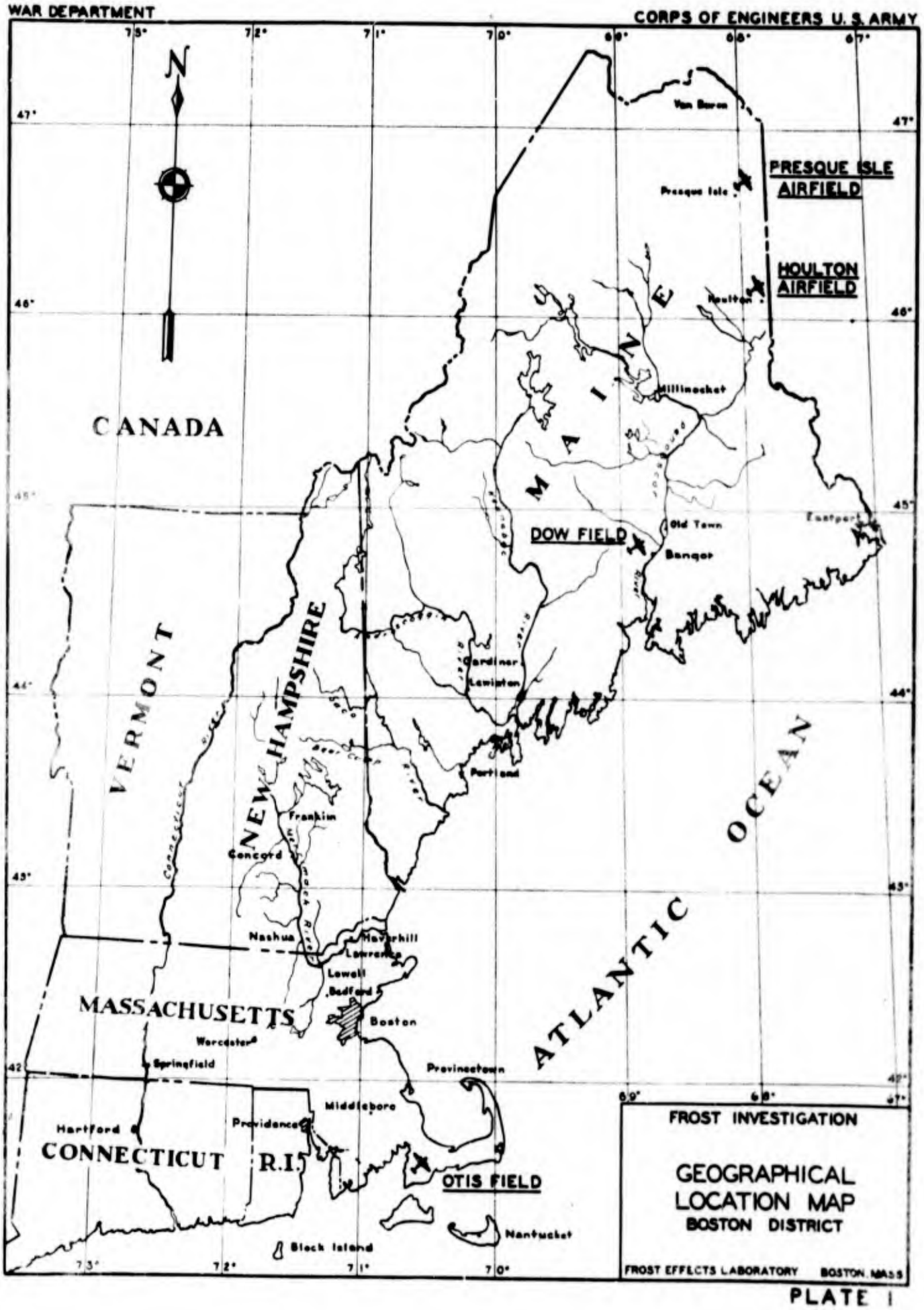

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
N
CANADA
MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
CONNECTICUT
R.I.
ATLANTIC OCEAN
PRESQUE ISLE AIRFIELD
HOULTON AIRFIELD
DOW FIELD
OTIS FIELD
Van Buren
Presque Isle
Houlton
Millinocket
Old Town
Bangor
Eastport
Gardiner
Lewiston
Portland
Franklin
Concord
Nashua
Haverhill
Lawrence
Lowell
Bedford
Boston
Worcester
Springfield
Provincetown
Middleboro
Providence
Hartford
Nantucket
Block Island
47°
46°
45°
44°
43°
42°
75°
72°
71°
70°
69°
68°
67°
FROST INVESTIGATION
GEOGRAPHICAL LOCATION MAP
BOSTON DISTRICT
FROST EFFECTS LABORATORY BOSTON, MASS

PLATE I

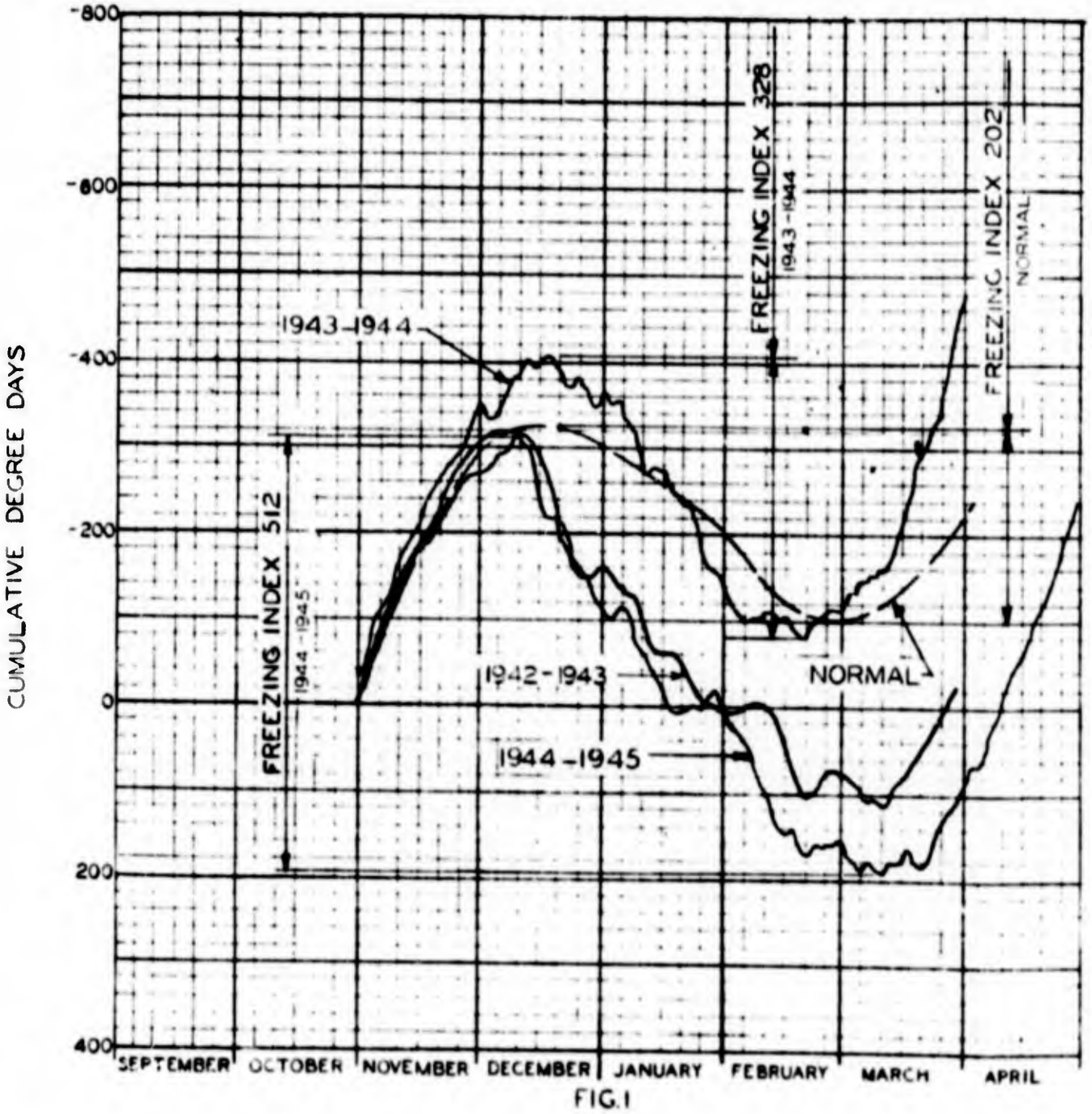

CUMULATIVE DEGREE DAYS
-800
-600
-400
-200
0
200
400
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
1943-1944
FREEZING INDEX 328
1943-1944
FREEZING INDEX 202
NORMAL
FREEZING INDEX 512
1944-1945
1942-1943
NORMAL
1944-1945

FIG. 1

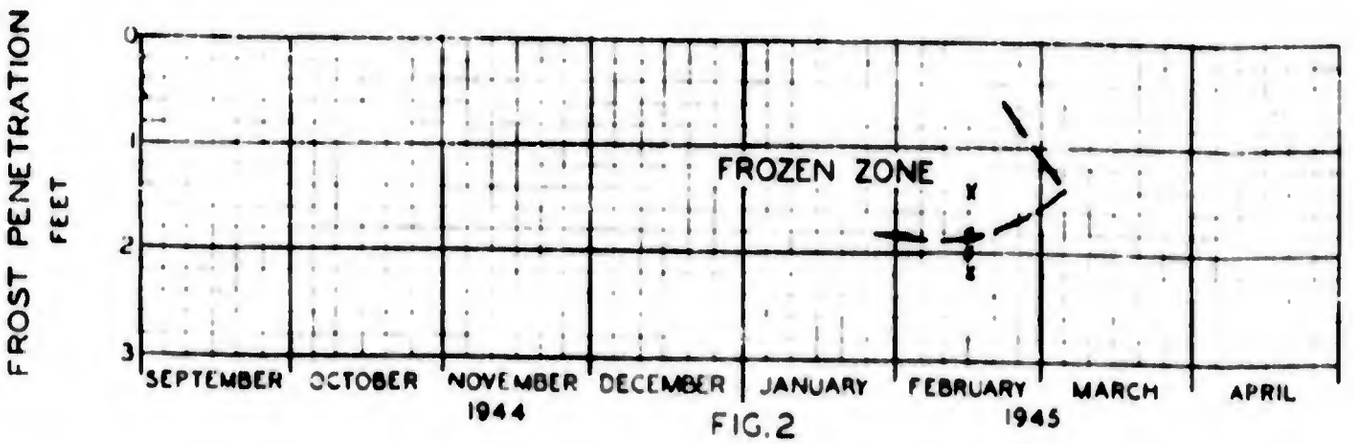

FROST PENETRATION
FEET
0
1
2
3
FROZEN ZONE
SEPTEMBER
OCTOBER
NOVEMBER
1944
DECEMBER
JANUARY
FEBRUARY
1945
MARCH
APRIL

FIG. 2

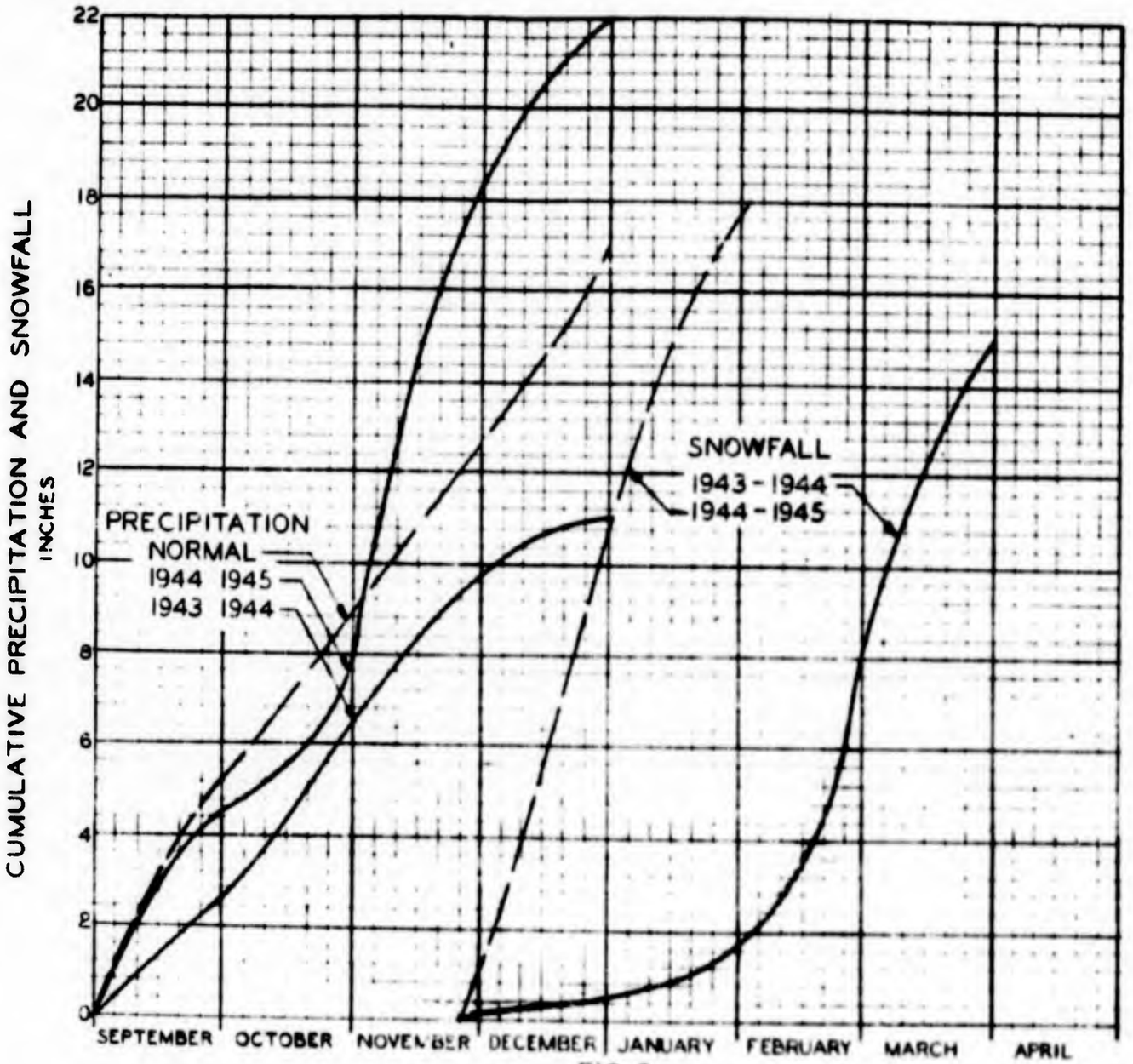


FIG. 3

NOTES

Weather data for 1944-1945 from Weather Officer USNAAF, Otis Field.
All other data from US Weather Bureau, East Wareham, Mass.
In FIG. 2 dotted line is estimated.

FROST INVESTIGATION
OTIS FIELD, SANDWICH, MASS.

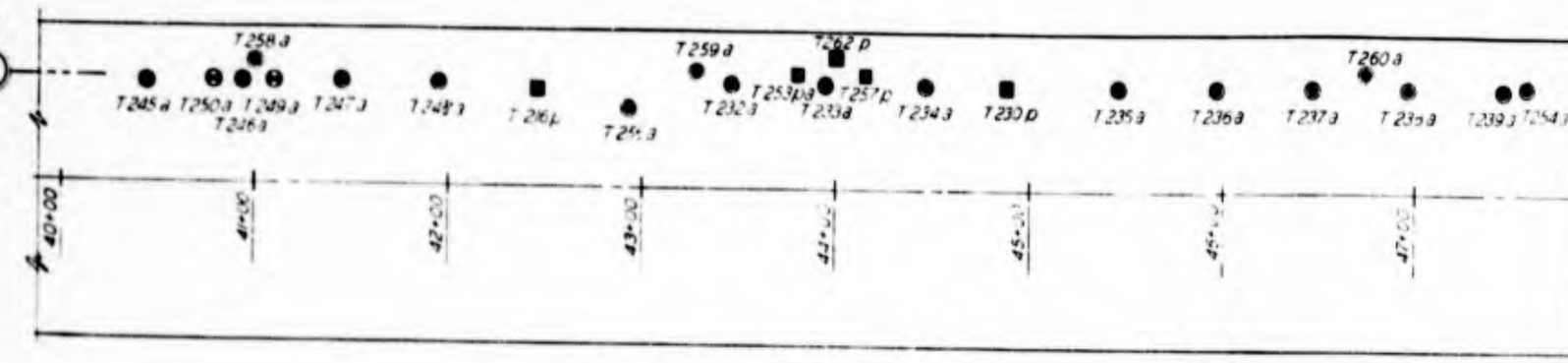
WEATHER AND FROST PENETRATION DATA

JUNE 1945

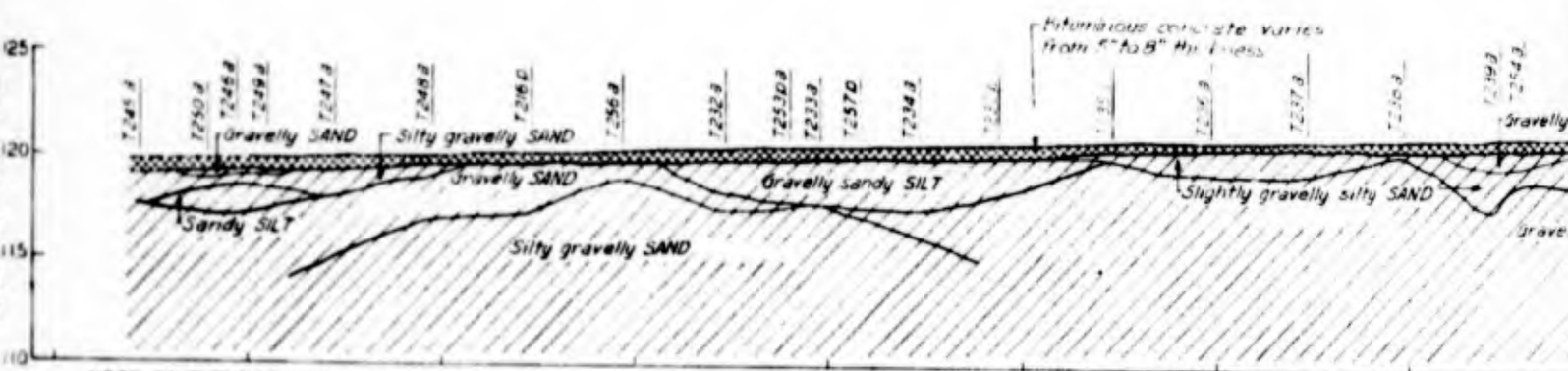
FROST EFFECTS LABORATORY BOSTON, MASS

B

PLATE 2

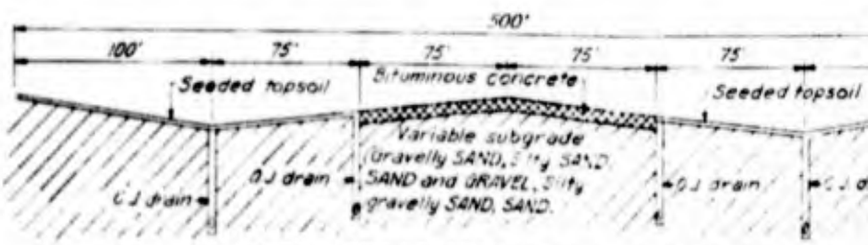


PLAN



NOTE PAVEMENT CONSTRUCTED DIRECTLY ON COMPACTED SUBGRADE

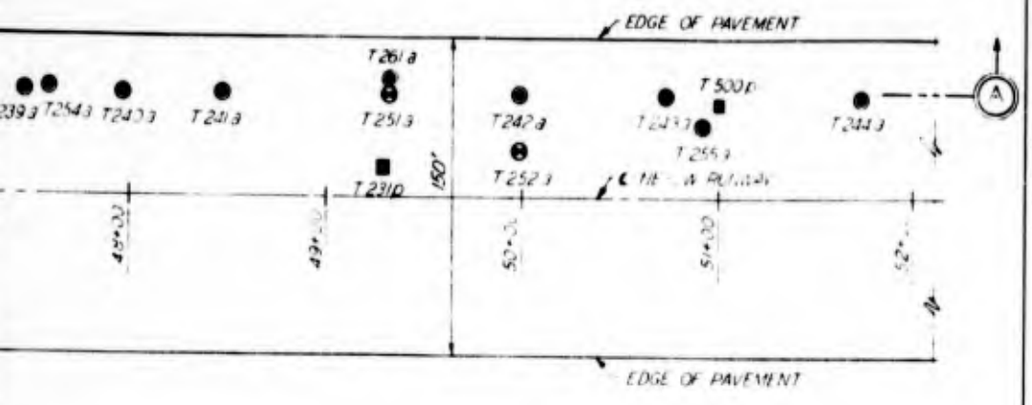
SECTION A-A

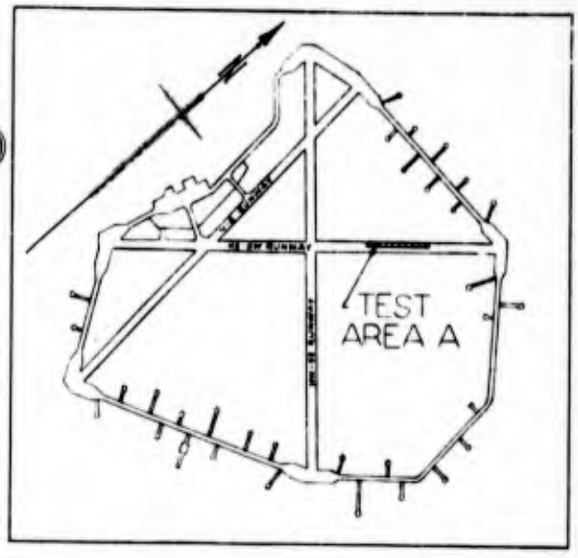


TYPICAL CROSS SECTION OF LANDING STRIP

NO SCALE

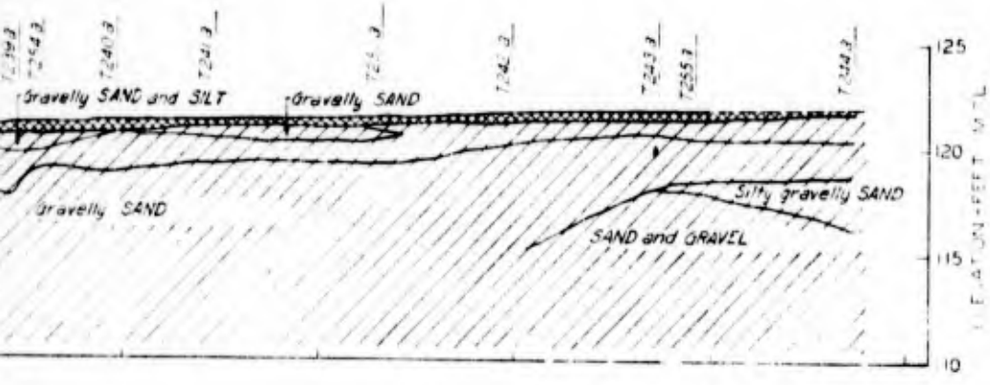
TEST AREA A



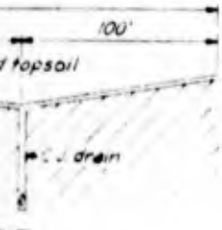


SITE PLAN

SCALE IN FEET



LEGEND
- Auger hole
- Test pits
- Observation well



RIP

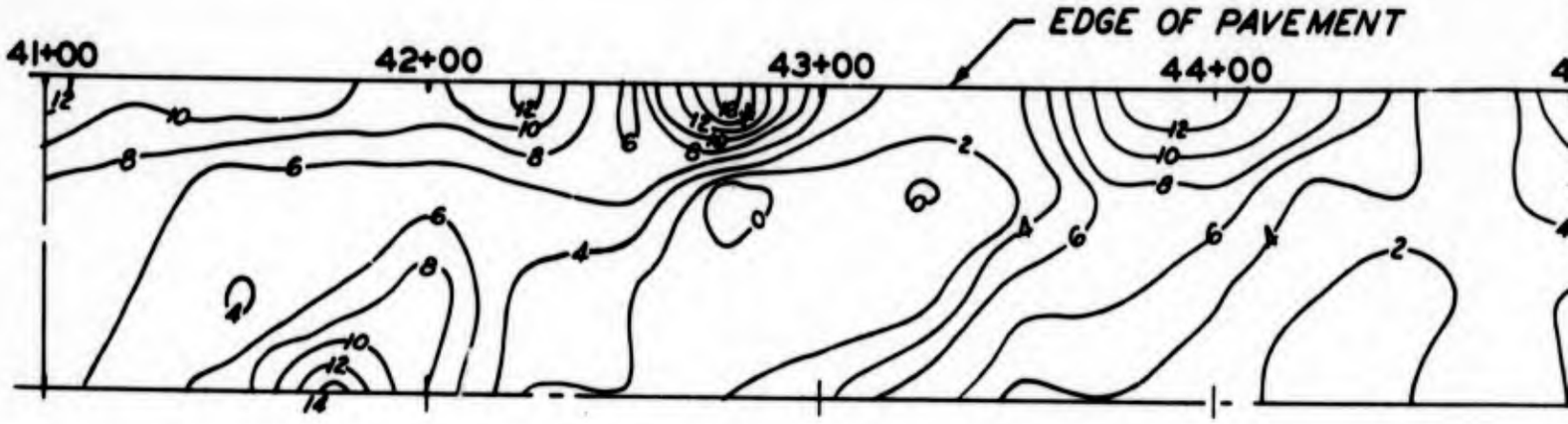
FROST INVESTIGATION
OTIS FIELD, SANDWICH, MASS.

PLAN AND PROFILE
TEST AREA A

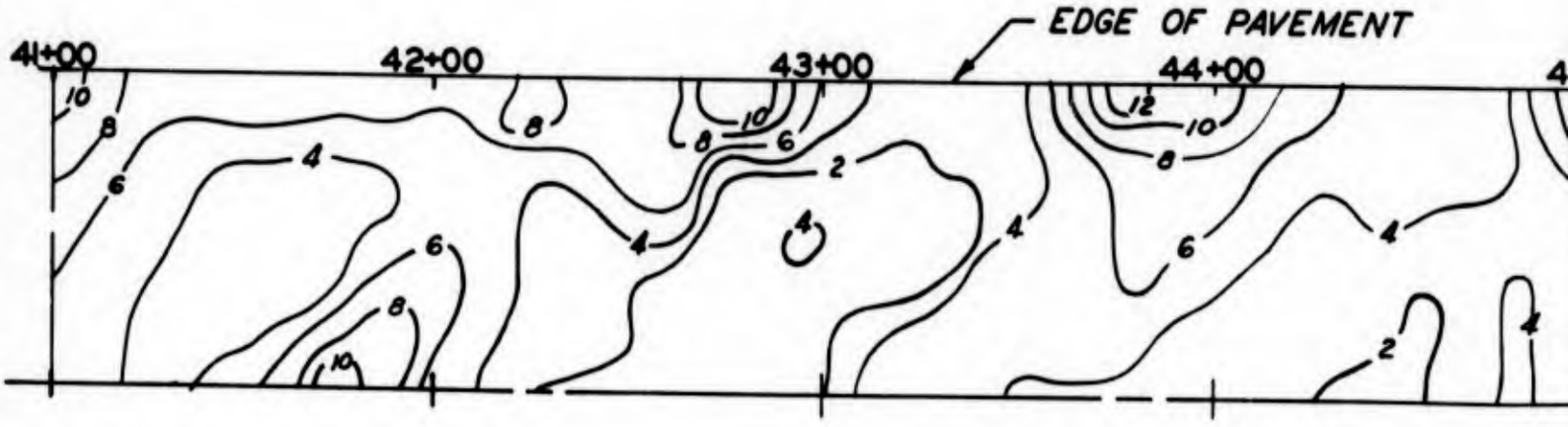
SCALE IN FEET

FROST EFFECTS LABORATORY, BOSTON, MASS. JUNE 1945

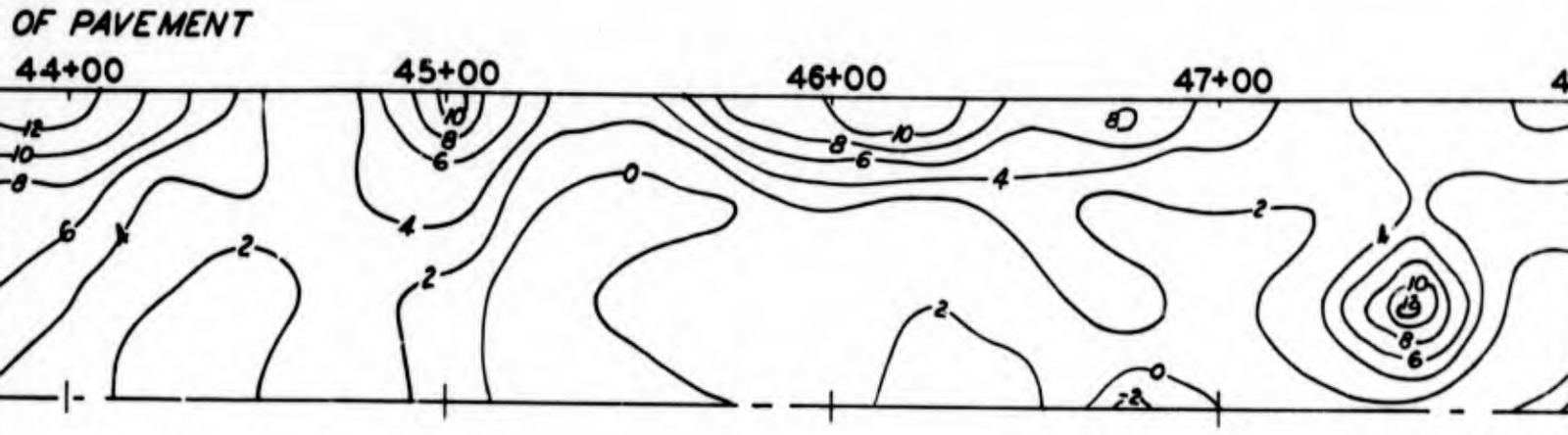
PLATE


EDGE OF PAVEMENT
41+00
42+00
43+00
44+00

SUR

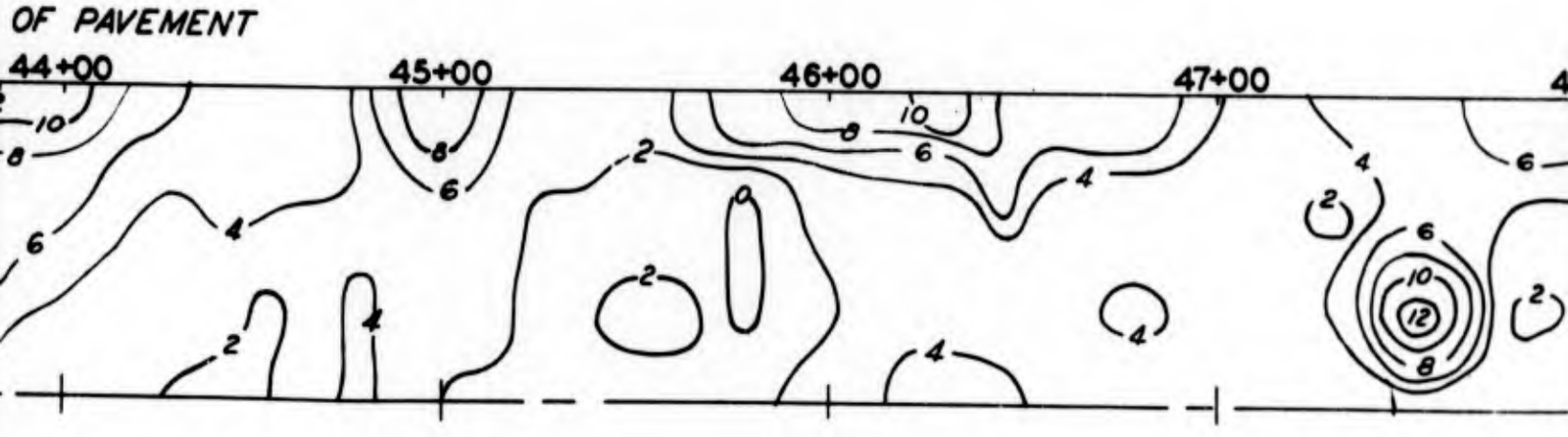

EDGE OF PAVEMENT
41+00
42+00
43+00
44+00

SU



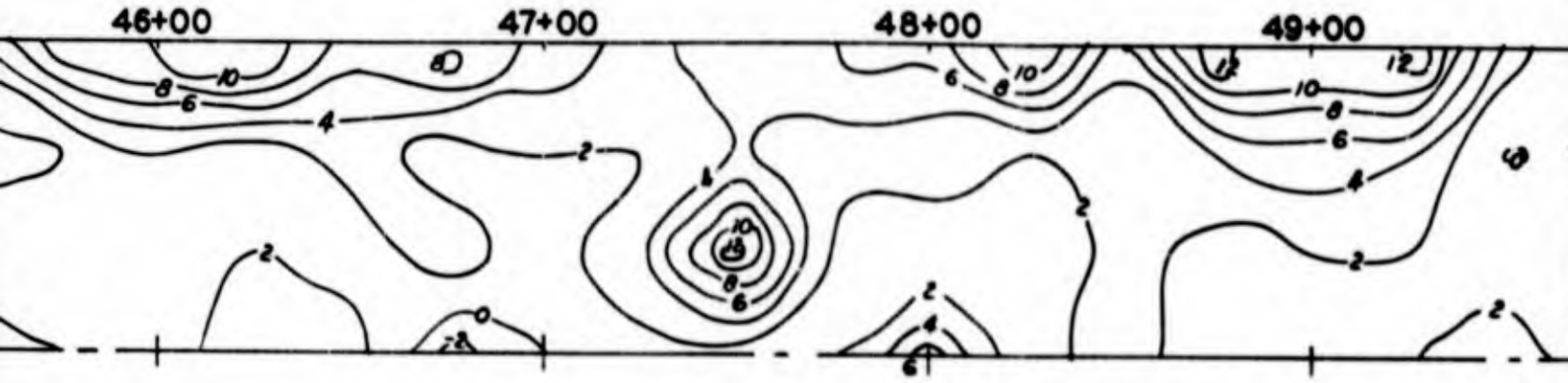
SURVEY: 15 DECEMBER 1944 — 31 JANUARY 1945

HEAVE CONTOURS



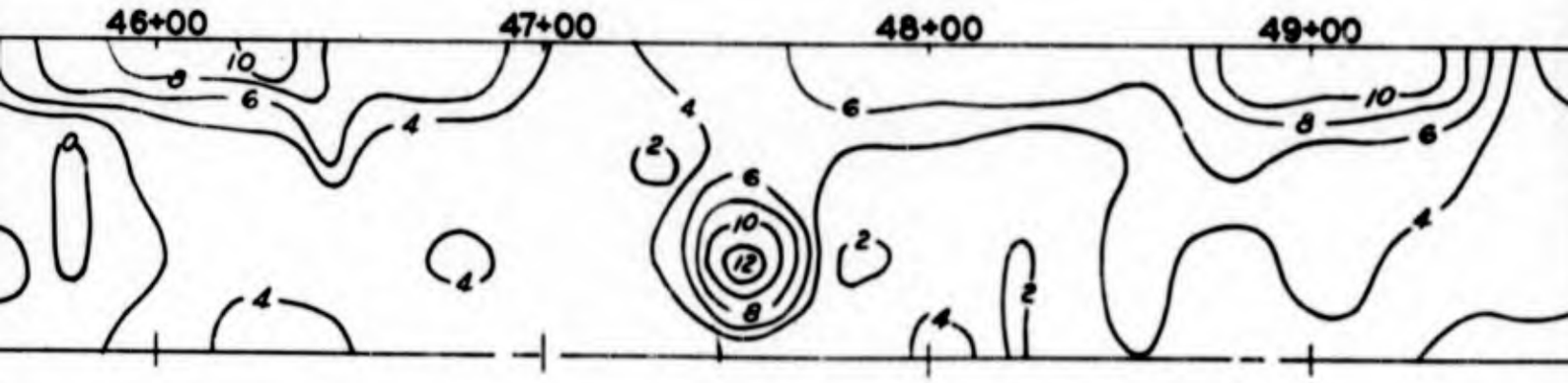
SURVEY: 31 JANUARY 1945 — 15 MARCH 1945

SUBSIDENCE CONTOURS



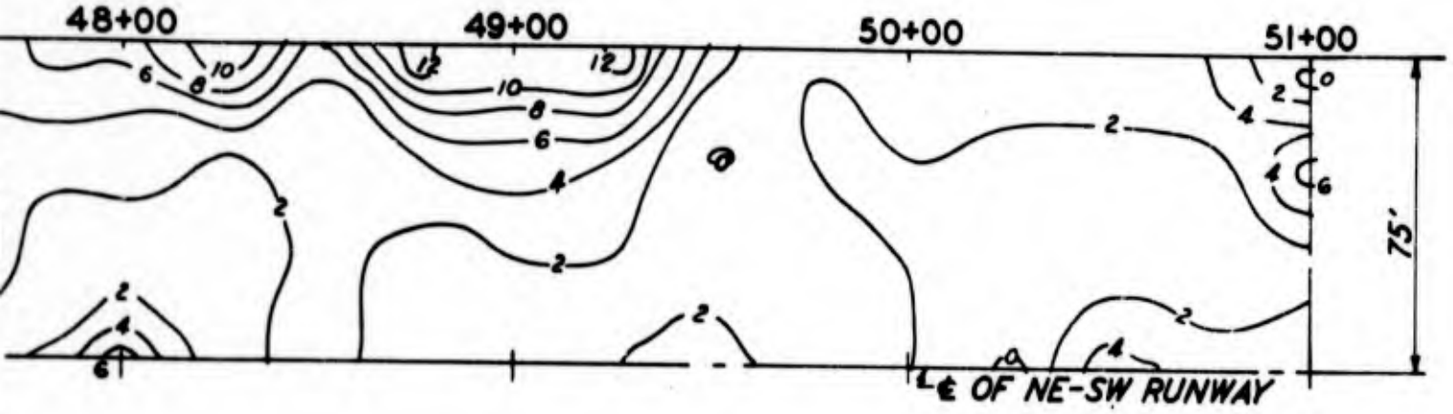
EMBER 1944 — 31 JANUARY 1945

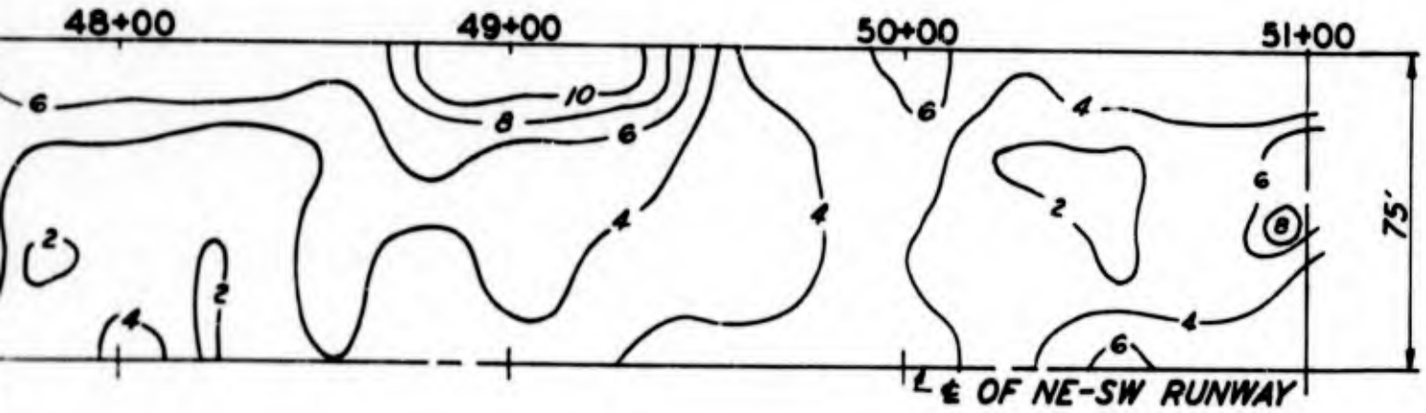
HEAVE CONTOURS



NUARY 1945 — 15 MARCH 1945

UBSIDENCE CONTOURS





NOTES

CONTOURS IN HUNDREDTHS OF FEET

CONTOUR INTERVAL = 0.02'

FROST INVESTIGATION
OTIS FIELD, SANDWICH, MASS.

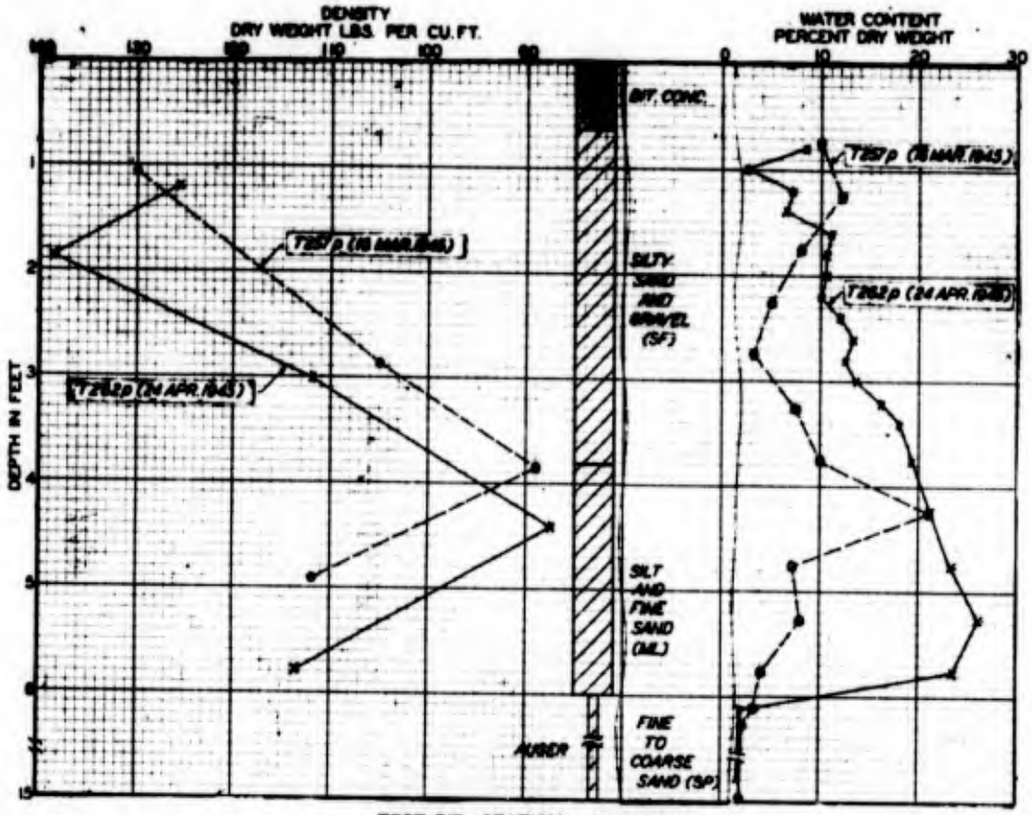
FROST HEAVE CONTOURS

TEST AREA A

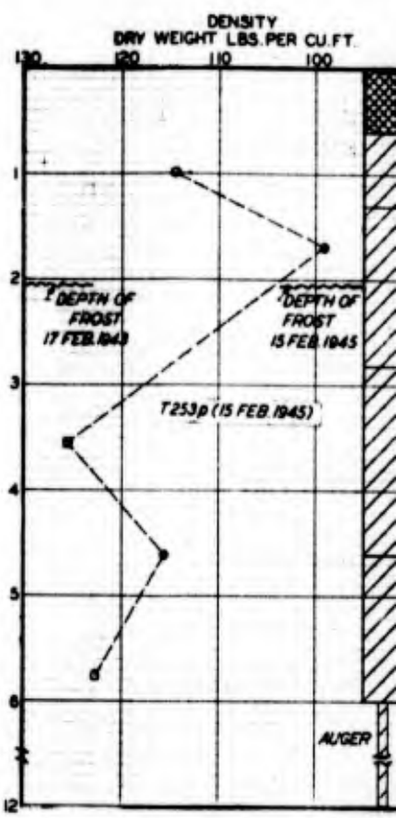
JUNE 1945 SCALE: 1"=50'

FROST EFFECTS LABORATORY, BOSTON, MASS.

D

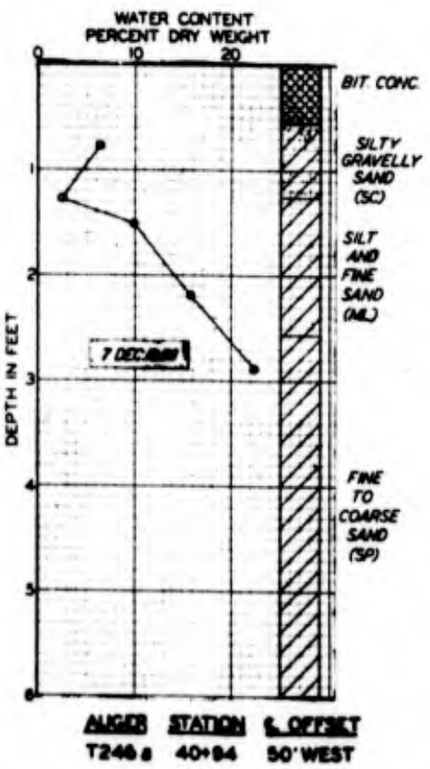


TEST PIT	STATION	& OFFSET
T257p	44+15	55' NORTH
T262p	44+00	62' NORTH

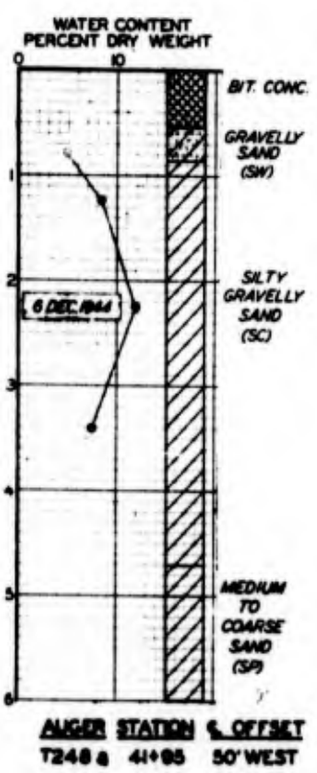


WATER CONTENT-DENSITY-SOIL PROFILE

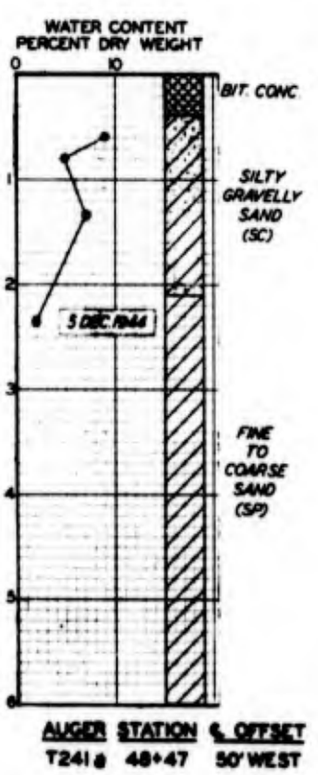
FIG.1



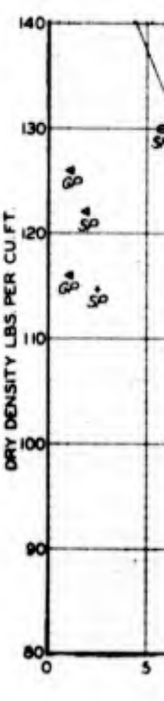
AUGER	STATION	& OFFSET
T248a	40+84	50' WEST



AUGER	STATION	& OFFSET
T248a	41+85	50' WEST

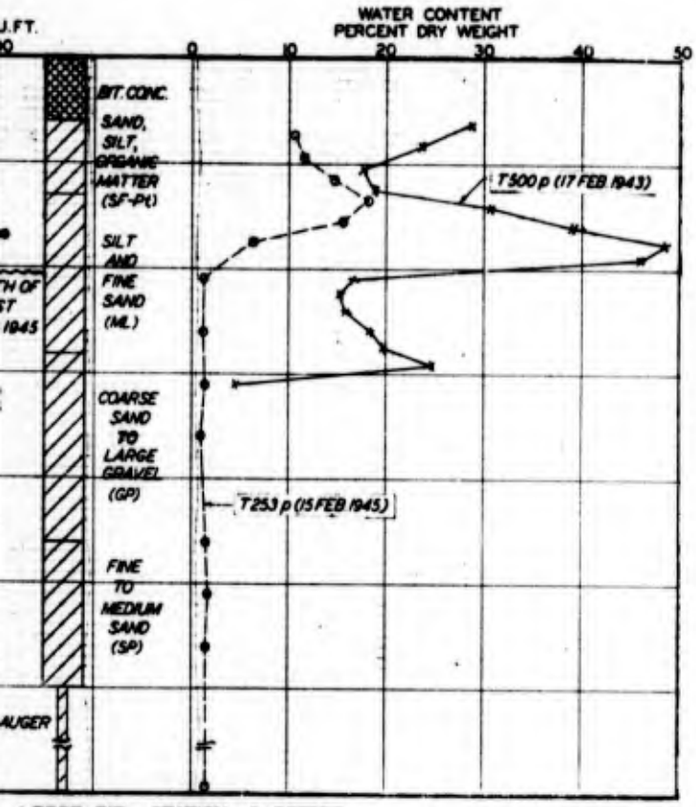


AUGER	STATION	& OFFSET
T241a	48+47	50' WEST

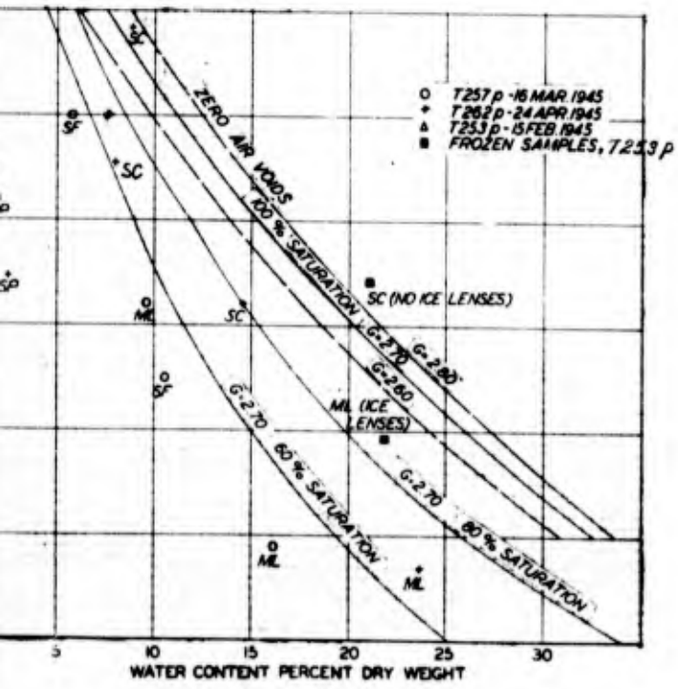


WATER CONTENT-SOIL PROFILE

FIG.2

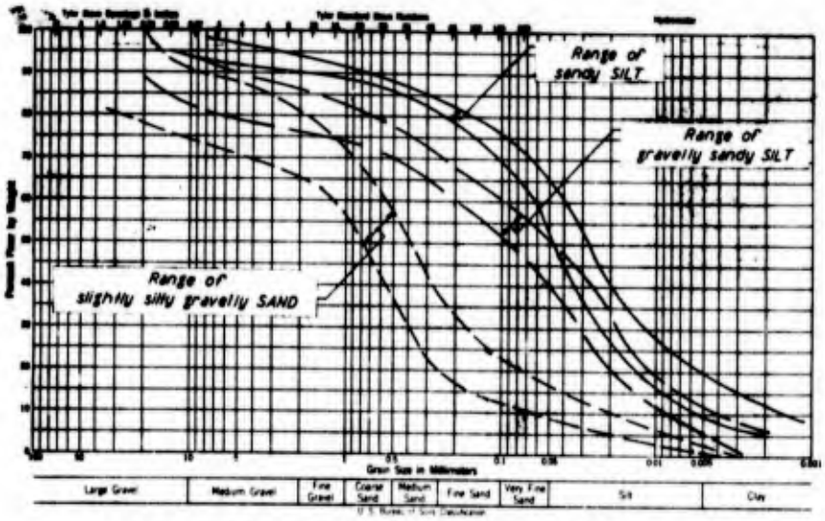


TEST PIT	STATION	& OFFSET
T253p	43+80	55' NORTH
T500p	51+00	40' NORTH



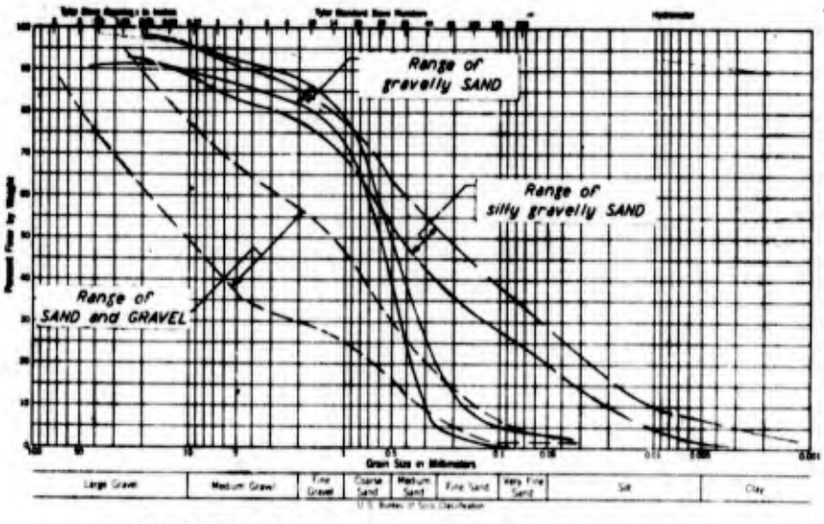
WATER CONTENT-DENSITY

FIG. 3



GRADATION OF SUBGRADE MATERIALS

FIG. 4



GRADATION OF SUBGRADE MATERIALS

FIG. 5

CLASSIFICATION	EXPLORATION NUMBER	DEPTH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
Slightly gravelly, silty SAND (SF)	T236a	1.1'-1.55'		Non-plastic	
Gravelly, sandy SILT (ML)	T239a	0.9'-1.5'	23.9	19.3	4.6
Slightly gravelly, silty SAND (SF)	T242a	1.1'-1.65'	17.1	15.6	2.1
Gravelly SAND (SP)	T244a	1.7'-3.4'		Non-plastic	
Sandy SILT (ML)	T246a	1.8'-2.6'	25.7	21.0	4.7
Gravelly, sandy SILT (ML)	T257p	0.63'-1.9'	23.7	19.7	4.0

FROST INVESTIGATION
OTIS FIELD, SANDWICH, MASS.

SOIL DATA SUMMARY
TEST AREA A

FROST EFFECTS LABORATORY, BOSTON, MASS. JUNE, 1945

B

WAR DEPARTMENT
U. S. ENGINEER OFFICE
BOSTON, MASSACHUSETTS

APPENDIX 4

REPORT ON
HOULTON AIRFIELD, HOULTON, MAINE

FROST INVESTIGATION
1944 - 1945

JUNE, 1945

FROST INVESTIGATION

TABLE OF CONTENTS

FROST INVESTIGATION

LIST OF TABLES

LIST OF PLATES

FROST INVESTIGATION
1944 - 1945

- - APPENDIX 4 - -

REPORT ON
HOULTON AIRFIELD, HOULTON, MAINE

1. Authorization. The general frost investigation program was authorized by the Chief of Engineers by letter to the Division Engineer, New England Division, dated 7 July 1944, subject, "Frost Investigation" and subsequent indorsements; and by the Chief of Engineers by letter to the Division Engineer, New England Division, dated 30 June 1945, subject "Funds and Completion Dates for Investigational Projects" and subsequent indorsements.

2. Purpose. The purpose of this investigation has been the determination of development of frost in the soils underlying airfield pavements as affected by various conditions of weather, soils, and groundwater.

3. Scope. This report presents the results of the frost investigation conducted at Houlton Airfield, Houlton, Maine during the period from 10 November 1944 through 8 May 1945. The investigation at Houlton Airfield includes two test areas in which observations were made of ground water table, frost penetration, ice segregation, water content, and density. In place CBR tests were made on subgrade and laboratory CBR tests were made on remolded representative base and subgrade material. Atterberg limits and mechanical analysis were performed on representative samples. The climatic and other general conditions related to the frost investigation at Houlton Airfield also are included in this report.

4. Definitions. The description of the tests and analyses of re-

sults involve a specialized use of certain terms and words. These words and terms are defined for use in this report as follows:

a. Test Area. The test area is the portion of the airfield selected for investigations and observations.

b. Pavement. The term pavement is defined as a covering of a prepared or manufactured product superimposed upon a subgrade or base to serve as an abrasion and weather resisting structural medium.

c. Base. The term base applies to the course of specially selected soils, mineral aggregates or treated soils placed and compacted on the natural or compacted subgrade.

d. Subgrade. The term subgrade applies to the natural soil in place or to fill material upon which a pavement or base is constructed.

e. Frozen Soil. Two types of frozen soil are referred to in this report as follows:

(1) Homogeneous Frozen Soil. A soil in which all the water in the voids is frozen is referred to as a homogeneous frozen soil.

(2) Stratified Frozen Soil. A soil in which part of the water in the soil is frozen outside the voids in the form of ice lenses.

f. Ice Crystals. The formation of ice particles found in the pores of homogeneous frozen soil is referred to as ice crystals.

g. Ice Lenses. Ice lenses are the ice formations in stratified frozen soil occurring in repeated layers essentially parallel to each other and normal to the direction of heat loss.

h. Frozen Zone. The limits of depth within which the soil is frozen is referred to as the frozen zone.

4. i.

i. Frost Penetration. The maximum depth from the surface to bottom of the frozen soil.

j. Frost Action. Frost action is the accumulation of water in the form of ice lenses in the soil or base materials under natural freezing conditions.

k. Frost Heave. Frost heave is the raising of the pavement surface due to the accumulation of ice lenses. The amount of heave in most soils is approximately equal to the cumulative thickness of the ice lenses.

l. Degree Day. Degree Day is the algebraic difference between 32° Fahrenheit and the daily mean temperature. The degree day is plus when the daily mean temperature is below 32° Fahrenheit and minus when above.

m. Degree Day Diagram. Degree Day Diagram is a plot of the cumulative degree days as the ordinate and elapsed time as the absicca. (Figure 1, Plate 2)

n. Freezing Index. Freezing index is a measure of the combined duration and magnitude of below freezing air temperature occurring during any given winter.

o. Normal Freezing Index. Normal Freezing Index is the freezing index computed for normal air temperatures based upon a long period of record usually 10 or more years.

p. Frost Susceptible Soil. Frost susceptible soil is a soil in which frost action is possible. Any soil which contains 3 percent or more by weight of grains smaller than 0.02 mm. in diameter shall be considered a frost susceptible soil.

q. Non-Frost Susceptible Materials. Non-frost susceptible materials are crushed rock, sand, sand and gravel, gravel, slag, cinders,

or any other cohesionless material in which frost action is not possible.

r. Ground Water Table. Ground water table is the free water surface nearest to the ground surface.

s. Density. Density is the unit dry weight in pounds per cubic foot.

5. General Conditions.

a. Location, Terrain, and Drainage. Houlton Airfield is located approximately 2½ miles east of the town of Houlton, Aroostook County, Maine. Plate 1 shows the geographical location of the airfield in the Boston District. The site is a narrow valley flanked on the sides by relatively high hills extending north and south. The elevation of the airfield is about 475 feet above mean sea level. The maximum difference in elevation within paved areas before grading was about 50 feet. Surface drainage is collected by open French drains and catch basins. Open joint perforated drains are parallel to the edges of runways at a minimum depth of 5 feet. The parking apron has a similar underdrain along the east edge. In cut areas, mainly located at the east and northeast sections of the site, the water table is near the ground surface and receives a continous supply from the adjacent hillside.

b. Types of Pavement. All airfield pavements are of flexible type with the exception of 11,800 square yards of a cement concrete runway turnaround. The runways were designed for a 12 and 18-inch gravel base and 3-inch thickness of bituminous concrete surface. The parking apron was designed for 6 inches of soil cement upon which a wearing course of 1½ inches of bituminous concrete was added at a later date.

c. Traffic History. The airfield received limited operation since 1941, with traffic largely consisting of 12,000 pounds gross weight

5. c.

planes. Approximately 20% of traffic is heavy planes 30,000 to 60,000 pounds gross weight; 30% is medium weight about 27,000 pounds. During the winter of 1942-1943 traffic was moderately heavy, predominately consisting of planes of the 60,000 pounds gross weight class. Traffic is about equally distributed over the two runways.

d. Condition of Pavements. All airfield pavements during the investigation period were generally good with the exception of minor cracking and minor depression on all pavement surfaces.

e. Frost Conditions. The maximum depth of frost penetration observed at the airfield in paved areas cleared of snow ranges from 3 to 4 feet. The subgrade and base soils are considered frost susceptible since over 3 percent of grains by weight are smaller than 0.02 mm. in diameter. No serious heaving of the pavement or pavement failures due to frost action have been noted during the period of operation of the airfield or during this investigation.

f. Climatic Conditions. Winter temperatures at Houlton Airfield are severe. Temperatures below freezing prevail from November to March. The normal freezing index is 1780 based on a 41 year record. The 1944-1945 freezing index is 1605 or 10% less than the normal. The normal rainfall for the three month period of September to November, prior to freezing, is 9 inches. From September 1944 to November 1944 the cumulative rainfall was 17 inches or 90% above normal. The cumulative snowfall in 1944-1945 was in excess of the previous season. The above data are presented in detail in Figures 1 and 3 on Plate 2.

6. Test Area A.

a. Location and Description. Test Area A is located in a shallow fill section of the Parking Apron between station 24 + 48 and station

26 / 48, extending 150 feet to 300 feet east of the centerline. The pavement consists of 1½ inches of bituminous concrete laid on 6 inches of soil cement base. The fill subgrade consists of slightly silty sandy gravel while the underlying natural subgrade is a clayey silt, sand and gravel. Plan and profiles of the test area are shown on Plate 3.

b. Explorations. A chronological summary of explorations is given in Table 1. A more detailed tabulation which includes the date and result of test pit and auger hole explorations is contained in 6 sheets of Table 2. The explorations in Test Area A, the locations of which are shown on Plate 3, consist of five groups as follows:

(1) Preliminary Soils Explorations. Sufficient data on pavement and subsurface conditions were obtained during construction and previous investigations to assist in the selection of this test area.

(2) Explorations Prior to Freezing Period. Two test pits, T132p and T137p, were excavated in November 1944 to determine the density, water content of the subgrade soils and the in place CBR of the subgrade. Six auger borings also were made to define subsurface conditions.

(3) Explorations During Freezing Period. Test pit T161p was excavated 8 March 1945 to determine natural density, water content of the subgrade and depth of frost penetration. Auger hole T163a was made on 10 March 1945 for measuring depth of frost.

(4) Explorations During Frost Melting Period. A large auger hole, T168a, was made on 24 March 1945 to

measure frost penetration and observe ice segregation.

(5) Exploration After Frost Melting Period. Test pits T170p and T173p were excavated 16 and 17 April 1945 and test pit T174p was excavated 8 May 1945 to determine changes in the subgrade caused by frost and winter conditions. Natural density and water content of the subgrade were obtained in these pits.

c. Installations. Installations were made in the pavement area to measure ground water table and heave.

(1) Bench Mark-Observation Wells. Four bench mark-observation wells, T131a, T135a, T138a, and T141a used for determining surface heave and the depth to the ground water table were placed in the pavement prior to 20 November 1944. Locations are shown on Plate 3 and installation details on Plate 4.

d. Observations and Measurements. The following observations and measurements were made in Test Area A:

(1) Ground Water Table Observations. Eleven sets of readings were taken in the observation wells 20 November 1944 to 2 May 1945. The ground water table was below the 6.0 foot depth of observation well installations except at T137p where on 20 November 1944, at time of installation the water table was at 5.2 foot depth. However, test pits T170p and T173p on 16-17 April 1945 had water entering from the sides. Water seeped into test pit T170p along

the bottom of a seam or layer of fill containing organic matter which extended from 1.8 to 3.0 feet below the pavement surface and the rate of infiltration was approximately 1.5 gallons per minute. Water seeped into test pit T173p at a much slower rate. During excavation this pit remained dry, but at 4.5 feet depth the water entered at approximately 0.008 gallons per minute. Table 2 contains the record of depth to ground water table at time of excavation.

(2) Pavement Heave.

(a) Level Readings. Three sets of level surveys were taken on a 25-foot grid system over the entire test area on 14 December 1944, 26 February 1945, and 27 March 1945. Pavement heave contours based upon the elevation differences indicated by surveys on 26 February 1945 were computed and are plotted in Figure 1 on Plate 5.

(b) Wire Line Reading. For wire line readings, extension rods were fitted into the tops of the bench mark-observation wells and a wire was stretched across the pavement between the two bench mark-observation wells. Measurements were made at definite intervals across the pavement from this wire to pavement. Details of bench mark-observation wells and extension rod are shown on Plate 4, Figures 2 and 3 respectively. Wire line readings were used to supple-

ment level readings in the test area. Two transverse wire line sections were used in Test Area A between bench marks T135a and T138a and between T141a and T131a. Eleven readings were made during period of 13 December 1944 to 2 May 1945. This information was used to determine the most advantageous time for obtaining instrument level readings.

(3) Depth of Frost Penetration. The depth of frost penetration was observed to be 4.0 feet on 8 March 1945 in test pit T161p. On 28 March 1945 the depth was measured at 4.1 feet by observation in auger hole T168a. On 16-17 April 1945 no frost was observed in test pits T170p and T173p. The dates at which the depth of frost penetration was observed in Test Area A are shown by points plotted in Figure 2, Plate 2 for comparison with the freezing index. The dashed lines are estimated portions of the curve.

(4) Ice Lens Survey. Observations of ice lenses were made during the excavation of test pit T161p and auger hole T168a. The freezing index at the time of excavation on 8 and 28 March 1945 was approximately 1605. Ice lenses were found on these dates between 3.7 and 4.0 foot depth in the clayey silt, sand and gravel subgrade. The ice lenses were from 1/8 inch to hairline in thickness and from 3 to 4 inches in length. A total of 14 ice lenses were counted in a

vertical section. Ice crystals and minute ice lenses were observed in a large auger hole T168a at depths 0.8 feet to 2.1 feet and from 3.2 feet to 4.1 feet. Ice lenses varied from 1/8 inch to hairline in thickness.

c. Field Tests.

(1) Water Content. Continuous water contents were obtained in the pits excavated during the fall, winter, and spring. The tests were made for the purpose of determining the migration and accumulation of water as the result of frost action. The water content data obtained during November, March, April and May are plotted in relation to the soil profile in Figures 1 and 2 on Plate 6. All water contents obtained are summarized in Table 2.

(2) Density. The density and water content of the subgrade were obtained to depth of approximately 6 feet to determine density changes due to frost action. The results of these tests are plotted in Figures 1 and 2 on Plate 6 in relation to the soil profile and for comparison with water contents. Figure 7, Plate 6 shows plot of density versus water content for all tests made.

(3) California Bearing Ratio. In place CBR tests were made on the surface of the subgrade and 10 inches below the surface of the subgrade in test pit T132p

and in test pit T137p at the surface and at 10 and 25 inches below the surface of the subgrade. The results of these tests are presented in Table 2.

f. Laboratory Tests. The following laboratory tests were performed:

(1) Mechanical Analysis and Atterberg Limits. Tests were made for classification purposes in accordance with procedures given in Appendix 14. All materials are classified using the Casagrande Classification. Range in gradation of subgrade material is shown in Figure 3 on Plate 6. Summary of all mechanical analysis, Atterberg limit tests and soil classification is shown in Table 2.

(2) California Bearing Ratio. A representative sample of subgrade material obtained from test pits T132p and T137p at depth of 2.5 to 6.0 feet was remolded in the laboratory and a series of CBR tests was performed in accordance with procedures outlined in Appendix 14. Results of these tests with related data are shown in Figures 1 and 2 on Plate 7.

g. Conclusions. The following conclusions for Test Area A are indicated from a study of the test data:

(1) Soils. The subgrade soil is frost susceptible as more than 3 percent of grains by weight are smaller than 0.02 mm. in diameter.

(2) Freezing Index and Precipitation. The freezing index of 1944-1945 was 1605 or 10% less severe than

the normal freezing index. The rainfall during 3 months preceding the freezing period was 17 inches or 90% more severe than normal.

(3) Groundwater. Previous explorations indicated a higher water table than was observed during this investigation. The observation wells were not installed to a sufficient depth; therefore, the wells were dry indicating a water table at least below a 6 foot depth. However, during and after the frost melting period, water was observed entering test pits from 1.8 to 4.5 feet below the pavement surface. Explorations in previous years evidently encountered a perched water table condition. The natural subgrade consisting of clayey silt, sand and gravel is more impervious than the overlying fill subgrade consisting of slightly silty sandy gravel, thus creating a perched water table supplied by sidehill drainage, frost melting, and surface seepage.

(4) Pavement Heave. The effect of frost action during 1944-1945 on pavement heave is considered negligible. The maximum heave measured was 0.2 feet and this occurred generally in one area comprising about 25 percent of Test Area A. The remaining portion of the test area heaved to a lesser degree ranging from 0.05 to 0.15 feet. These observations were made on 26 February 1945 when heave was generally at its peak for this test area. The accumulated

degree days was 1480 up to this day. The freezing index was 1605 for 1944-1945 and occurred about 15 March 1945. It appears that maximum heave occurs prior to the end of the freezing period because other factors, possibly increased daylight, may influence the effect of continued freezing temperatures.

(5) Depth of Frost Penetration. The depth of frost penetration was approximately 4 feet below the pavement surface when observed on 10 and 28 March 1945. No frost was observed on 14 November 1944 and 16 April 1945. The rate of frost penetration or conditions between the above dates were not determined.

(6) Ice Segregation. Ice lenses were found to range in thickness from 1/8 inch to hairline and from 3 to 4 inches in length. No ice lenses formed where the soil was gravelly. Lenses were found from 0.8 to 2.1 feet in depth and 3.5 to 4.0 feet in depth.

(7) Subgrade Soil Conditions.

(a) Water Content and Density. There appears to be no correlation between the change in water content and density with respect to tests made during November, March, April, and May. The non-uniform character of this subgrade soil offers little opportunity to make companion tests for a reliable comparison of results.

(b) California Bearing Ratio. The in place CBR tests made in November 1944 show results ranging from

5 to 30 percent at 0.1 inch penetration. The presence or absence of gravelly fractions and the appreciable range in water contents at different test locations have considerable influence on these tests. However, the remolded samples of subgrade material tested in the laboratory show the CBR to be 40 percent when compacted at 95 percent modified A.A.S.H.O.

7. Test Area B.

a. Location and Pavement Description. Test Area B is located on the N-S Runway between station -3 + 80 and station -5 + 60 as shown on Plate 3. The pavement consists of 4 inches of bituminous concrete. The base consists of 8 to 18 inches of sand and gravel placed on a natural subgrade of slightly silty sand and gravel which contains boulders or ledge. Plan and profiles of Test Area B is shown on Plate 3.

b. Exploration. A chronological summary of test explorations is given in Table 1. A more detailed tabulation which include the date and result of test pit and auger hole explorations is contained in 6 sheets of Table 2. The explorations in Test Area B, the locations of which are shown on Plate 3, consist of five groups as follows:

(1) Preliminary Soils Explorations. Sufficient data on pavement and subsurface conditions were obtained during construction and previous investigations to assist in the selection of this test area.

(2) Explorations Prior to Freezing Period. Two test pits, T149p and T157p, were excavated 20 November 1944 to determine the water content and density of the base

and subgrade materials and in place CBR of the subgrade. Eight auger holes, T144a, T145a, T146a, T147a, T152a, T154a, T155a, and T158a were made 12-14 November 1944. Most auger holes met refusal because of either ledge or large boulders encountered at depths of 2 to 5 feet.

(3) Explorations During Freezing Period. Test pit, T162p, and auger holes, T164a, T165a, T166a and T167a, were excavated 9 and 10 March 1945. These explorations were intended for measuring depth of frost. However, ledge or boulders were encountered from 1.6 feet to 2.6 feet in depth. Water content and density of the base and subgrade were determined in the test pit.

(4) Exploration During Frost Melting Period. On 24 March 1945 a large auger hole, T169a, was made to observe ice segregation and depth of the frozen zone, but boulder or ledge was encountered at 2.3 foot depth.

(5) Exploration After Frost Melting Period. One test pit, T172p, was excavated 17 April 1945 to obtain natural density and water content of the base and subgrade after the frost had left the ground. No ground water table was encountered to a depth of 8 feet. Auger hole, T171a, was excavated 16 April 1945 to ledge at depth of 4.5 feet. Water content of the base and subgrade was determined.

c. Installation. Installations were made in the pavement area to measure ground water table and heave.

(1) Observation Wells in Gravel Base. Four observation wells, T150a, T153a, T159a and T160a used for measuring ground water table in the gravel base were placed in the pavement prior to 20 November 1944. Locations are shown on Plate 3 and installation details in Figure 1 on Plate 4.

(2) Bench Mark-Observation Wells. Four bench mark-observation wells, T143a, T148a, T151a and T156a used for determining pavement surface heave and ground water table in the subgrade were placed in the pavement prior to 20 November 1944. Locations are shown on Plate 3 and installation details in Figure 2 on Plate 4.

d. Observations and Measurements. The following observations and measurements were made in Test Area B:

(1) Ground Water Table Observations. Eleven sets of readings were taken in the observation wells from 20 November 1944 to 2 May 1945. The ground water table was below the depth of well installations. The presence of boulders and ledge limited the depth of subgrade wells. However, one well T155a was 6.6 feet deep and was dry during observations. Table 2 contains the record of water table in all explorations at time of installation. On 24 March 1945 a slight infiltration of water was observed into auger hole T169a from a sand and gravel pocket located above the upper limit of the frozen zone at 1.6 feet depth.

(2) Pavement Heave.

(a) Level Readings.

Level readings were taken on a 25-foot grid

system over the entire test area. Initial level readings were made 14 December 1944 and were repeated on 26 February 1945 and 27 March 1945. Pavement heave contours based upon the elevation differences indicated by surveys on 26 February 1945 were computed and are plotted in Figure 2 on Plate 5.

(b) Wire Line Readings. For wire line readings, extension rods were fitted into the tops of the bench mark-observation wells and a wire was stretched across the pavement between the two bench mark-observation wells. Measurements were made at definite intervals across the pavement from this wire to pavement. Details of bench mark-observation wells and extension rod are shown on Plate 4, Figures 2 and 3 respectively. Wire line readings were used to supplement level readings in the test area. The transverse wire line sections were used in Test Area B between bench marks T143a and T156a, and between T148a and T151a. Eleven readings were made during period of 13 December 1944 to 2 May 1945. This information was used to determine the most advantageous time for obtaining instrument level readings.

(3) Depth of Frost Penetration. The depth of frost penetration was observed on 9 March 1945 in test pit

T162p to top of ledge or large boulder at 1.6 foot depth. Auger holes, T164a, T165a, T166a and T167a, were made on 9-10 March 1945. The depth of auger holes were limited by ledge or large boulders and may not indicate the full depth of frost. However, the base and subgrade materials were frozen to the top of the ledge or boulder at from 1.5 to 2.6 feet in depth. On 24 March 1945, auger hole T169a indicated the melting of frost below the surface of pavement. The frozen zone existed in a layer 1.6 feet to 2.3 feet in depth below the surface of pavement. Ledge or large boulder was encountered at the lower limit of 2.3 foot depth. The depth of frost in Test Area B is plotted for comparison with the freezing index in Figure 2 on Plate 2. The dashed lines are estimated portions of the curve. The rate of frost penetration could not be observed with accuracy because of difficulty with the rocky subgrade.

(4) Ice Lense Survey. No ice lenses were found in the rocky subgrade.

c. Field Tests.

(1) Water Content. Continuous water content of the base and subgrade were obtained in the pits excavated during the fall, winter, and spring. The tests were made for the purpose of determining the migration and accumulation of water as the result of frost action. The water content data obtained during November and April

are plotted in relation to the soil profile in Figures 5 and 6 on Plate 6. All water contents obtained are summarized in Table 2.

(2) Density. The density and water content of the base and subgrade were determined to depth of approximately 6 feet to determine density changes due to frost action. The results of these tests are plotted in Figures 5 and 6 on Plate 6 in relation to the soil profile and for comparison with water contents. Figure 7, Plate 6 shows plot of densities vs. water content for all tests made.

(3) California Bearing Ratio. In place CBR tests were made on the surface of subgrade in test pit T149p. In test pit T157p, in place CBR tests were made on the surface of the subgrade and 12 inches below the surface. The results of these tests are presented in Table 2.

f. Laboratory Tests. The following laboratory tests were performed:

(1) Mechanical Analysis and Atterberg Limits. Tests were made for classification purposes in accordance with procedures given in Appendix 14. All materials are classified using the Casagrande Classification. Range in gradation of subgrade and base materials is shown in Figure 3 and 4 on Plate 6. Summary of all mechanical analysis, Atterberg limit tests and soil classification is given in Table 2.

(2) California Bearing Ratio. A representative sample of

base material obtained from test pits T149p and T157p at depth of 0.3 to 1.3 feet was remolded in the laboratory and a series of CBR tests was performed in accordance with procedures outlined in Appendix 14. Subgrade material was obtained from Test Area A in test pits T132p and T137p at depth of 2.5 to 6.0 feet and similarly tested for CBR. This material is representative of subgrade material in Test Area B. Results of all laboratory CBR tests with related data are shown on on Plate 7.

g. Conclusions. The following conclusions for Test Area B are indicated from a study of the test data:

(1) Soils. The base and subgrade soils are classified as frost susceptible because more than 3 percent of grains by weight are smaller than 0.02 mm. in diameter.

(2) Freezing Index and Precipitation. The freezing index of 1944-1945 was 1605 or 10% less severe than normal. The rainfall during the preceding 3 months of the freezing period was 17 inches or 90% more severe than normal.

(3) Ground Water. The observation wells in the subgrade were not installed to sufficient depths to indicate ground water table. Installations in the subgrade met refusal due to the presence of ledge or large boulders. The deepest well was 6.6 feet below the pavement surface and was dry when observed during fall, winter and spring. During the frost melting

period a slight infiltration of water was observed entering auger hole, T169a, from above the upper limit of the frozen zone at 1.6 feet depth. The observation wells in the base were also dry when observed.

(4) Pavement Heave. The effect of frost action during 1944-1945 on pavement heave has been negligible. The greatest heave measurement has been 0.05 feet occurring in a small portion of the the test area. The major portion of the test area did not indicate any heave when observations were made on 26 February 1945.

(5) Depth of Frost Penetration. No frost was observed in mid-November 1944 and mid-April 1945. The base and subgrade material were found frozen on 9-10 March 1945 to the top of ledge or boulder encountered at various depths from 1.5 to 2.6 feet below the pavement surface. On the 24 March 1945 the frost melted to a depth of 1.6 feet.

(6) Ice Segregation. No ice lenses were visible in frozen material encountered in this test area.

(7) Subgrade Soil Conditions.

(a) Water Content and Density. There appears to be no correlation between the change in water content and density with respect to tests made during November and April. The non-uniform character of this subgrade soil offers little opportunity to make companion tests for a reliable comparison of results.

(b) The in place CBR tests made in November 1944 on the subgrade shows results ranging from 9 to 28 percent at 0.1 inch penetration. The presence or absence of gravelly fractions and the appreciable range in water contents at different test locations have considerable influence on these tests. However, the remolded samples of subgrade material tested in the laboratory show the CBR to be 40% when compacted at 95% modified A.A.S.H.O. The CBR of remolded samples obtained from the gravel base is 50% at 95% modified A.A.S.H.O.

8. General Conclusions. Following are the general conclusions derived from the investigation of Test Areas A and B:

a. Frost action has caused no substantial pavement heave at either the bituminous concrete pavement on soil cement base of Test Area A or the bituminous concrete pavement on sand and gravel base of Test Area B. The following three conditions existed during the period of the investigation which favored the development of frost action:

(1) A freezing index of 1505.

(2) Rainfall 90% above normal for the three months prior to freezing weather.

(3) A frost susceptible soil in the base and subgrade.

b. The following two conditions retarded the development of frost action:

(1) Ground water table generally below the explored depth of 6 feet.

(2) The rocky nature of the subgrade particularly in Test

Area B.

c. In Test Area A the maximum pavement heave was 0.2 feet. Few ice lenses were found in the subgrade although the frost penetration was approximately 4 feet.

In Test Area B, the maximum pavement heave was 0.05 feet and no ice lenses were found. The absence of ice lenses may be explained by the presence of boulders and ledge rock in the upper subgrade of Test Area B wherein the depth of frost penetration was limited to approximately 3 feet.

d. The more dense subgrade was generally 90 percent saturated. The subgrade with a density less than 120 pounds per cubic foot was less than 80 percent saturated.

e. Due to the non-uniform and rocky nature of the subgrade no data were obtained to determine the reduction in strength of the subgrade during the frost melting period.

f. At no time during this investigation or in previous years has the result of frost action been detrimental to the pavements at Houlton Airfield.

CHRONOLOGICAL SUMMARY
EXPLORATIONS & OBSERVATIONS
HOULTON AIRFIELD
HOULTON, MAINE

DATE	WEATHER	OPERATION	REMARKS
1944			
Nov. 10	Cold, rainy	Two test pits & six auger holes excavated. Four bench mark observation wells installed in Test Area A, Parking Apron.	Difficult operations because of unfavorable weather.
Nov. 20	Occasional Freezing	Two test pits & eight auger holes excavated. Four bench mark-observation wells & four observation wells in base installed in Test Area B, N-S Runway.	
Dec. 13		Initial level survey on 25-ft. grid system of Test Areas A & B.	
1945			
Jan. 15,14		Wire line & observation wells read	
" 26		" " " " "	
Feb. 16		" " " " "	
" 26		" " " " "	
" "		Second level survey Test Areas A & B	
Mar. 8 to Mar. 10	Clear, cold	Test pit T161p & auger hole T163a excavated in Test Area A. Test pit T162p & auger holes T164 to T167 excavated in Test Area B.	
Mar. 22		Wire line & observation wells read	
Mar. 24	Cold, snow & rain	Auger hole T168a excavated in Test Area A. Auger Hole T169a excavated in Test Area B.	
Mar. 27		Third level survey Test Areas A & B	
		Wire line & observation wells read	
Apr. 6		" " " " "	
Apr. 10		" " " " "	
Apr. 16	Clear & Warm	Test pits T170p & T173p excavated	
Apr. 17	Cloudy & Cold	in Test Area A. Test pit T172p	
Apr. 18		excavated in Test Area B.	
Apr. 17		Wire line & observation wells read	
Apr. 26		" " " " "	
May 2		" " " " "	
May 6	Clear & Warm	Test pit T174p excavated in Test Area A.	
May 9	Clear & Cool		

TABLE 1

FROST INVESTI
SUMMARY OF SOIL T

HOULTON AIRFIELD,

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN S % Finer than indic			
								0.005 mm	0.02 mm	0.05 mm	0.10 mm
T-131a	10 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.6							
			Subgrade	0.6-1.6	0	> 6.0	GF	3	9	12	17
				1.6-2.8			"	1	4	6	8
				2.8-4.0			"	2	5	7	8
				4.0-6.0			GC	18	33	39	42
T-132p	14 Nov. 1944	A	Bit. Concrete	0.0-0.2							
			Soil Cement	0.2-0.6							
			Subgrade	0.6-1.2			GF				
				1.2-1.9			"	4	8	12	16
				1.9-2.7	0	> 6.0	"				
				2.7-3.1			"				
				3.1-3.6			GF-GC				
				3.6-4.1			"	6	14	17	20
				4.1-6.0			"				
T-133a	14 Nov. 1944	A	Bit. Concrete	0.0-0.2							
			Soil Cement	0.2-0.8							
			Subgrade	0.8-2.4	0	> 4.3	GF				
				2.4-4.3			GC				
T-134a	14 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.7							
			Subgrade	0.7-2.9	0	> 4.5	GF	3	8	11	14
				2.9-4.5			GC				
T-135a	10 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.5							
			Subgrade	0.5-3.8	0	> 6.0	GF				
				3.8-6.0			GC				
T-136a	14 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.7							
			Subgrade	0.7-3.7	0	> 6.0	GF				
				3.7-6.0			GC				
T-137p	20 Nov. 1944	A	Bit. Concrete	0.0-0.2							
			Soil Cement	0.2-0.6							
			Subgrade	0.6-1.3	0	5.2	GF				
				1.3-2.0			"	2	5	8	11
				2.0-2.5			"				
				3.2							
				2.5-6.0			"	3	8	10	13

ESTIGATION
IL TEST DATA

LD. HOULTON, ME.

SOIL DATA									FIELD IN-PLACE TESTS			REMARKS
AIN SIZE n indicated grain size					ATTERBERG LIMITS		SPECIFIC GRAVITY		DENSITY LBS./CU. FT.	WATER CONTENT	CBR 0.1" PEN.	
0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.	>#4	<#4				
17	24	50	73	91								
8	10	32	52	82								
8	10	26	44	73								
42	50	64	76	92								
									124	15.0		
16	21	41	62	92	33.1	None		2.71			30&9	
									103	21.7		
											5	
20	24	37	48	73					141	13.2	19	
												Refusal due to boulders.
14	20	45	65	84								Refusal due to boulders.
												Refusal due to boulders.
									122	20.1	10	Ground water at 5.2'.
11	22	45	62	92					127	15.5	19	
											7	
13	19	38	55	86	30.4	17.0		2.78				

WAR DEPARTMENT

FROST INVEST
SUMMARY OF SOIL
HOULTON AIRFIELD

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN % Finer than ind			
								0.005 mm	0.02 mm	0.05 mm	0.10 mm
T-138a	10 Nov. 1944	A	Bit. Concrete	0.0-0.2							
			Soil Cement	0.2-0.7							
			Subgrade	0.7-5.0	0	4.1	GF	4	9	14	17
				5.0-6.2			GC	21	38	46	51
T-139a	14 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.7							
			Subgrade	0.7-3.7	0	>6.5	GC	6	12	18	22
				3.7-6.5			GC	24	44	53	60
T-140a	14 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.7							
			Subgrade	0.7-3.2	0	>4.7	GF	6	12	14	17
				3.2-4.7			GC	9	20	26	29
T141a	10 Nov. 1944	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.7							
			Subgrade	0.7-3.2	0	>4.7	GF	0	4	5	7
			Topsoil	3.2-3.4			GC	9	20	24	28
			Subgrade	3.4-4.7			"				
T-142a	14 Nov. 1944	A	Bit. Concrete	0.0-0.2							
			Soil Cement	0.2-0.6							
			Subgrade	0.6-2.0	0	>6.8	GF	1	7	8	10
				2.0-2.7			"				
				2.7-6.8			GC	12	30	39	45
T-143a	12 Nov. 1944	B	Bit. Concrete	0.0-0.1							
			"	0.1-0.4							
			Base	0.4-0.9	0	>4.6	GW	0	1	3	5
			Subgrade	0.9-4.6			GF	4	8	11	14
T-144a	12 Nov. 1944	B	Bit. Concrete	0.0-0.1							
			"	0.1-0.3							
			Base	0.3-0.9	0	>3.9	GW	0	2	4	5
			Subgrade	0.9-3.9			GF	4	8	12	15
T-145a	13 Nov. 1944	B	Bit. Concrete	0.0-0.3							
			"	0.3-0.3							
			Base	0.3-0.7	0	>4.5	GW				
			Subgrade	0.7-1.2			GF				
				1.2-1.7			GF	3	6	8	10
				1.7-4.5			"	3	8	13	16

NVESTIGATION
SOIL TEST DATA

ELD, HOULTON, ME.

SOIL DATA										FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE % finer than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY		DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.	>#4	<#4				
14	17	24	48	64	90								Ground water at 4.1' three hours after excavation, may be surface run-off as rain fell during excavation.
46	51	57	71	79	94								
18	22	29	60	78	99								
53	60	69	82	89	97								
14	17	24	53	77	97								Refusal due to boulder.
26	29	36	52	65	89								
5	7	9	30	49	82								Refusal due to ledge or boulder.
24	28	35	54	69	93								Large stones & boulders throughout.
8	10	15	47	59	87								
9	45	53	68	76	91								
3	5	7	26	47	80								Rock fragments and boulders encountered in subgrade.
1	14	18	34	45	71								Refusal probably due to boulder.
4	5	6	29	52	90								Refusal due to boulder or ledge.
2	15	19	35	47	82								
8	10	15	31	41	74								Numerous rocks and boulders in subgrade. Refusal due to boulder.
3	16	22	40	52	77								

R DEPARTMENT

FROST INVESTIGA
SUMMARY OF SOIL TES

HOULTON AIRFIELD, H

PLORA-ATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN SIZE % Finer than indicate				
								0.005 mm	0.02 mm	0.05 mm	0.10 mm	0.2 m
-146a	13 Nov. 1944	B	Bit. Concrete	0.0-0.3								
			"	0.3-0.4								
			Base	0.4-0.8			GW					
			"	0.8-1.0	0	>4.7	"	2	6	9	10	1
			"	1.0-1.4			"					
			Subgrade	1.4-4.7			GF	6	9	12	16	2
-147a	13 Nov. 1944	B	Bit. Concrete	0.0-0.2								
			"	0.2-0.3								
			Base	0.3-0.9	0	>2.4	GW	3	13	19	22	2
			"	0.9-1.1			GW					
			Subgrade	1.1-2.4			GF	4	9	14	16	2
-148a	13 Nov. 1944	B	Bit. Concrete	0.0-0.2								
			"	0.2-0.3								
			Base	0.3-0.9	0	>5.9	GW	3	7	9	12	1
			"	0.9-1.3			GW					
			Subgrade	1.3-5.9			GF	4	11	15	17	2
-149p	20 Nov. 1944	B	Bit. Concrete	0.0-0.1								
			"	0.1-0.3								
			Base	0.3-1.3	0	>6.0	GW					
			Subgrade	1.3-6.0			GF					
-150a	14 Nov. 1944	B	Bit. Concrete	0.0-0.4								
			"	0.4-0.5								
			Base	0.5-1.5	0	>3.2	GW					
			Subgrade	1.5-3.2			GF					
-151a	13 Nov. 1944	B	Bit. Concrete	0.0-0.3								
			Base	0.3-0.8								
			Subgrade	0.8-1.2	0	>5.5	GW					
				1.2-1.4			GF					
				1.4-5.5			"					
-152a	14 Nov. 1944	B	Bit. Concrete	0.0-0.3								
			Base	0.3-0.7	0	>4.0	GW	6	11	15	19	2
			Subgrade	0.7-4.0			GF	4	12	16	19	2
-153a	14 Nov. 1944	B	Bit. Concrete	0.0-0.3								
			"	0.3-0.4	0	>6.0						
			Base	0.4-1.2			GW					
			Subgrade	1.2-6.0			GF					

ESTIGATION
OIL TEST DATA

LD. HOULTON, ME.

SOIL DATA									FIELD IN-PLACE TESTS			REMARKS
RAIN SIZE in indicated grain size					ATTERBERG LIMITS		SPECIFIC GRAVITY		DENSITY LBS./ CU. FT.	WATER CONTENT	CBR 0.1" PEN.	
0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.	>#4	<#4				
												Rock fragments and boulders in subgrade. Refusal due to boulder.
10	15	43	56	80								
16	21	39	54	87								
22	28	44	55	81								Refusal due to boulder.
16	22	39	52	82								
12	17	37	50	78	20.7	17.5						Rock fragments in subgrade.
17	22	40	54	83	22.0	17.5						
								2.70	142	7.0		18" diameter boulders encountered.
									132	10.6	20	
												Refusal due to boulders. Observation well installed.
												Shale and rock fragments in subgrade. Refusal due to boulder.
19	24	44	54	77								Refusal due to boulders.
19	26	43	59	86								
												Observation well installed.

WAR DEPARTMENT

FROST INVEST
SUMMARY OF SOIL

HOULTON AIRFIELD.

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN % Finer than indi			
								0.005 mm	0.02 mm	0.05 mm	0.10 mm
T-154a	14 Nov. 1944	B	Bit. Concrete	0.0-0.3							
			Base	0.3-1.0	0	>3.4	GW				
			"	1.0-1.3			GW				
			Subgrade	1.3-3.4			GF				
T-155a	12 Nov. 1944	B	Bit. Concrete	0.0-0.1							
			"	0.1-0.2							
			"	0.2-0.3	0	>6.6					
			Base	0.3-1.0			GW				
			"	1.0-1.2			GW				
			Subgrade	1.2-1.8			GF				
				1.8-2.1			GF				
				2.1-6.6			GF				
T-156a	13 Nov. 1944	B	Bit. Concrete	0.0-0.2							
			"	0.2-0.3							
			Base	0.3-1.0	0	>5.9	GW	4	11	18	21
			"	1.0-1.1			GW				
			Subgrade	1.1-5.9			GC	8	16	21	24
T-157p	21 Nov. 1944	B	Bit. Concrete	0.0-0.1							
			"	0.1-0.3							
			Base	0.3-1.3	0	>6.0	GW	1	4	5	6
			Subgrade	1.3-1.8			GF				
				1.8-2.3			GC	4	12	19	24
				2.3-6.0			GF	6	9	14	17
T-158a	14 Nov. 1944	B	Bit. Concrete	0.0-0.2							
			"	0.2-0.3							
			Base	0.3-1.3	0	>4.5	GW				
			Subgrade	1.3-4.5			GF				
T-159a	20 Nov. 1944	B	Bit. Concrete	0.0-0.1							
			"	0.1-0.3	0	>0.8					
			Base	0.3-0.8			GW				
T-160a	20 Nov. 1944	B	Bit. Concrete	0.0-0.2	0	>0.6					
			Base	0.2-0.6			GW				
T-161p	8 Mar. 1945	A	Bit. Concrete	0.0-0.1							
			Soil Cement	0.1-0.8							
			Subgrade	0.8-2.0			GF				
				2.0-3.0	4.0	>7.8	"				
				3.0-4.0			GC				
				4.0-5.0			"				
				5.0-6.0			"				
				6.0-7.8			"				

VESTIGATION
SOIL TEST DATA
ELD, HOULTON, ME.

SOIL DATA										FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE finer than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY		DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.	>#4	<#4				
													Refusal due to boulders.
													Shale and rock fragments in subgrade.
													Loamy topsoil.
8	21	29	42	53	72								Rock fragments from 1.1-5.9 Roots at 1.8-2.1
1	24	29	42	51	79								
5	6	9	34	49	80	23.0	None	2.65	2.74	150	7.1		Rocks 12" to 16" diam. and shale in subgrade.
										119	16.8	15&28	
9	24	29	44	56	76	40.6	8.3		2.69				
4	17	21	35	43	66							9&21	
													Refusal due to boulder or ledge.
													Observation well installed at 0.7' depth.
													Observation well installed at 0.6' depth.
										113.3	16.3		Ice lenses from 1/8" to hairline in thickness.
						30.5	22.1		2.78	108.0	15.3		Ice lenses from 3.7'-4.0'.
										112.4	14.0		
										133.8	8.3		Refusal due to ledge or boulders.
						26.4	15.8		2.76	127.6	10.1		
										103.5	10.1		

FROST INVEST
SUMMARY OF SOIL

HOULTON AIRFIELD

EXPLORATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRATION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN % Finer than ind			
								0.005 mm	0.02 mm	0.05 mm	0.10 mm
T-162p	9 Mar. 1945	B	Bit. Concrete Base Subgrade	0.0-0.3 0.3-1.0 1.0-1.6	1.6+	>1.6	GW GF				
T-163a	10 Mar. 1945	A	Bit. Concrete Soil Cement Subgrade	0.0-0.1 0.1-0.7 0.7-3.7 3.7-6.0	4.0	>6.0	GF GC				
T-164a	9 Mar. 1945	B	Bit. Concrete Base	0.0-0.4 0.4-2.5	2.5+	>2.5	GW-GF	4	11	12	17
T-165a	9 Mar. 1945	B	Bit. Concrete Base	0.0-0.4 0.4-1.5	1.5+	>1.5	GW	2	6	7	9
T-166a	10 Mar. 1945	B	Bit. Concrete Base Subgrade	0.0-0.4 0.4-1.6 1.6-2.6	2.6+	>2.6	GW GF-GC	3 6	9 13	11 18	13 22
T-167a	10 Mar. 1945	B	Bit. Concrete Base Subgrade	0.0-0.4 0.4-1.3 1.3-2.2	2.2+	>2.2	GW GW-GF	1 4	2 10	4 15	5 18
T-168a	24 Mar. 1945	A	Bit. Concrete Soil Cement Subgrade	0.0-0.2 0.2-0.8 0.8-2.1 2.1-3.2 3.2-4.5	4.1	>4.5	GF w GC				
T-169a	24 Mar. 1945	B	Bit. Concrete Base	0.0-0.4 0.4-2.3	2.3	>2.3	GF				
T-170p	16 Apr. 1945	A	Bit. Concrete Soil Cement Subgrade	0.0-0.1 0.1-0.7 0.7-1.8 1.8-3.0 3.0-4.2	0	3.0	GF Org. Mat. GF				

VESTIGATION
OIL TEST DATA

LD. HOULTON, ME.

SOIL DATA										FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE (than indicated grain size)						ATTERBORG LIMITS		SPECIFIC GRAVITY		DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
5	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.	>#4	<#4				
									2.71	124.9	8.7		Refusal due to boulders. Frost penetration to point of refusal.
									2.61	?	11.4		
2	17	22	47	61	89								Refusal due to ledge. Frost penetration to refusal.
7	9	14	47	62	87								Refusal due to ledge. Frost penetration to refusal.
1	13	21	38	49	78								Refusal due to ledge. Frost penetration to refusal.
3	22	26	47	59	86								
4	5	6	42	54	80								Refusal due to ledge. Frost penetration to refusal.
5	18	24	41	54	80								
													6" to 12" cobbles encountered. Ice crystals and ice lenses from 0.8'-4.1'.
													Refusal due to ledge. Frost from 1.6' to 2.3' depth with ice crystals throughout. Water seepage above frost line.
													Straw & roots encountered from 1.8' to 3.0'. Water entered pit at 3.0' at rate of 1½ gal. per minute.
										125	14.7		
										111	16.7		

FROST INVESTIG
SUMMARY OF SOIL TE

HOULTON AIRFIELD, H

XPLORA-ATION NO.	DATE	TEST AREA	TYPE	DEPTH (FT.)	FROST PENETRA-TION (FT.)	DEPTH TO WATER TABLE (FT.)	SOIL CLASS.	GRAIN SIZ % Finer than indicat 0.005 mm	0.02 mm	0.05 mm	0.10 mm	0. m
T-171a	16 Apr. 1945	B	Bit. Concrete	0.0-0.4								
			"	0.4-0.5								
			Base	0.5-1.5	0	>4.5	GW					
			Subgrade	1.5-1.9			Org. Mat.					
				1.9-4.5			GF					
T-172p	17 Apr. 1945	B	Bit. Concrete	0.0-0.4								
			"	0.4-0.5								
			Base	0.5-1.5			GW					
			Subgrade	1.5-2.2			GF					
				2.2-2.6	0	>8.0	"					
				2.6-3.2			"					
				3.2-4.0			"					
				4.0-4.5			"					
				4.5-5.5			"					
				5.5-6.0			"					
				6.0-8.0			"					
T-173p	17 Apr. 1945	A	Bit. Concrete	0.0-0.2								
			Soil Cement	0.2-0.7								
			Subgrade	0.7-1.2			GF					
				1.2-2.0			"					
				2.0-2.5			"					
				2.5-3.0	0	4.5	"					
				3.0-3.5			"					
				3.5-4.0			"					
				4.0-4.5			"					
				4.5-5.0			GC					
				5.0-5.5			"					
				5.5-6.0			"					
				6.0-8.3			"					
T-174p	8 May 1945	A	Bit. Concrete	0.0-0.3								
			Soil Cement	0.3-0.7								
			Subgrade	0.7-1.3			GF					
				1.3-1.8			"					
				1.8-2.4			"					
				2.4-2.6	0	7.3	GC					
				2.6-3.4			"					
				3.4-3.7			"					
				3.7-4.2			"					
				4.2-4.9			"					
				4.9-5.4			"					
				5.4-6.0			"					
				6.0-7.5			"					

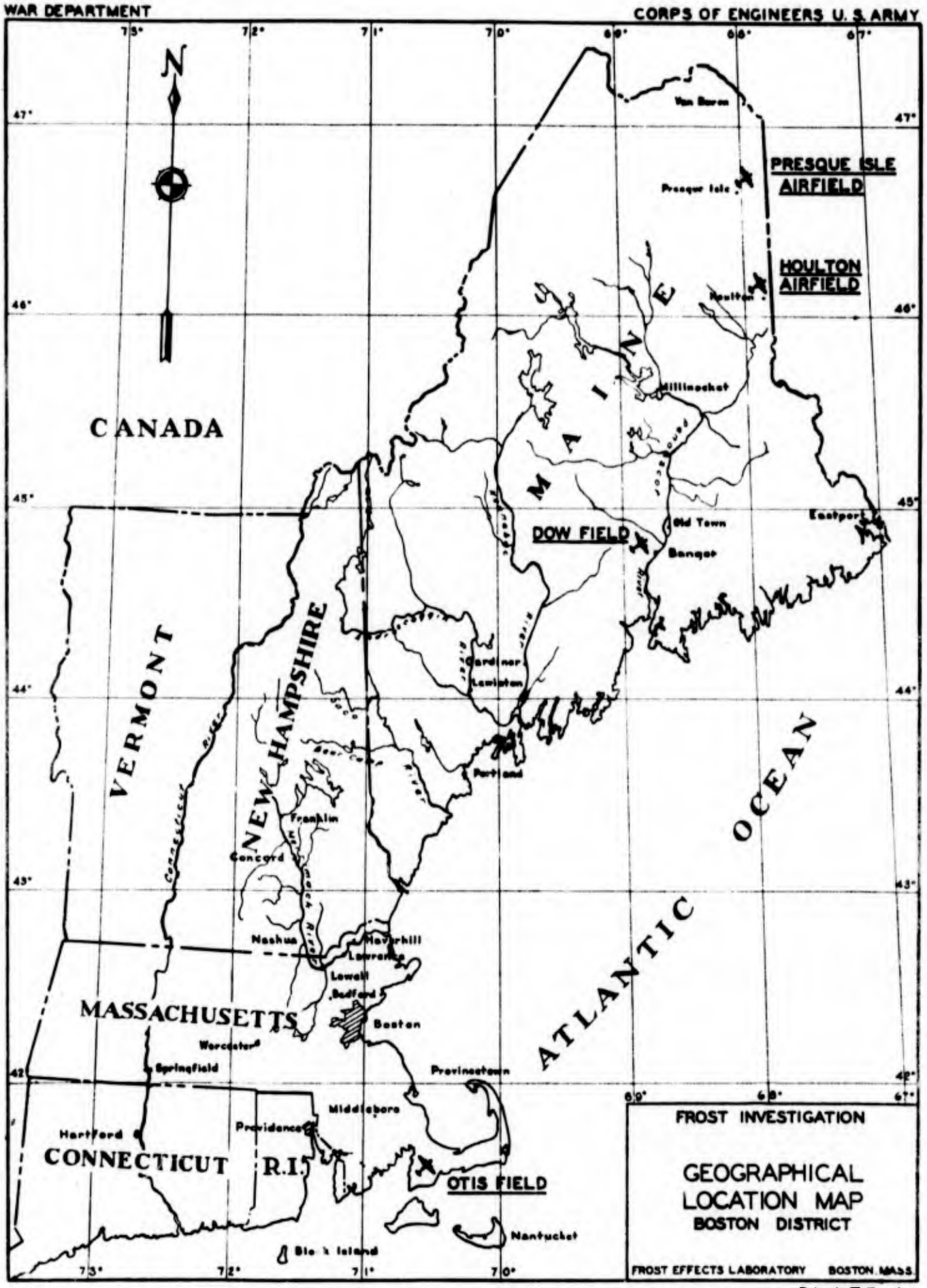
NVESTIGATION
SOIL TEST DATA

ELD, HOULTON, ME.

SOIL DATA										FIELD IN-PLACE TESTS			REMARKS
GRAIN SIZE finer than indicated grain size						ATTERBERG LIMITS		SPECIFIC GRAVITY		DENSITY LBS./CU.FT.	WATER CONTENT	CBR 0.1" PEN.	
.05 mm	0.10 mm	0.297 mm	2.0 mm	4.7 mm	19.1 mm	L.L.	P.L.	>#4	<#4				
											5.1		Large stones protruded from all sides of pit and closed in at 4.5'.
											16.1-24.1		Possibly a crevice in ledge. Refusal due to ledge.
										135.5	5.7		
										131	12.9		Large stones encountered from 2.5' to 6' depth.
										131	8.2		
										125	9.6		
										134.5	1.1		
										109	16.5		
										123	14.5		No water in pit during excavation but worked in from sides at 4.5' depth. Approx. rate of flow was ½ gallon per hour.
										103	12.9		
										97	12.9		
										123.5	13.3		
										115.5	11.5		
										120	13.8		Large boulders encountered at 5' depth. Refusal due to boulders.
										119	15.3		
										121	10.5		Slight bleeding of water at 2.6' depth.
										126	12.3		
										113	18.5		

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



FROST INVESTIGATION

GEOGRAPHICAL LOCATION MAP
BOSTON DISTRICT

FROST EFFECTS LABORATORY BOSTON MASS

PLATE I

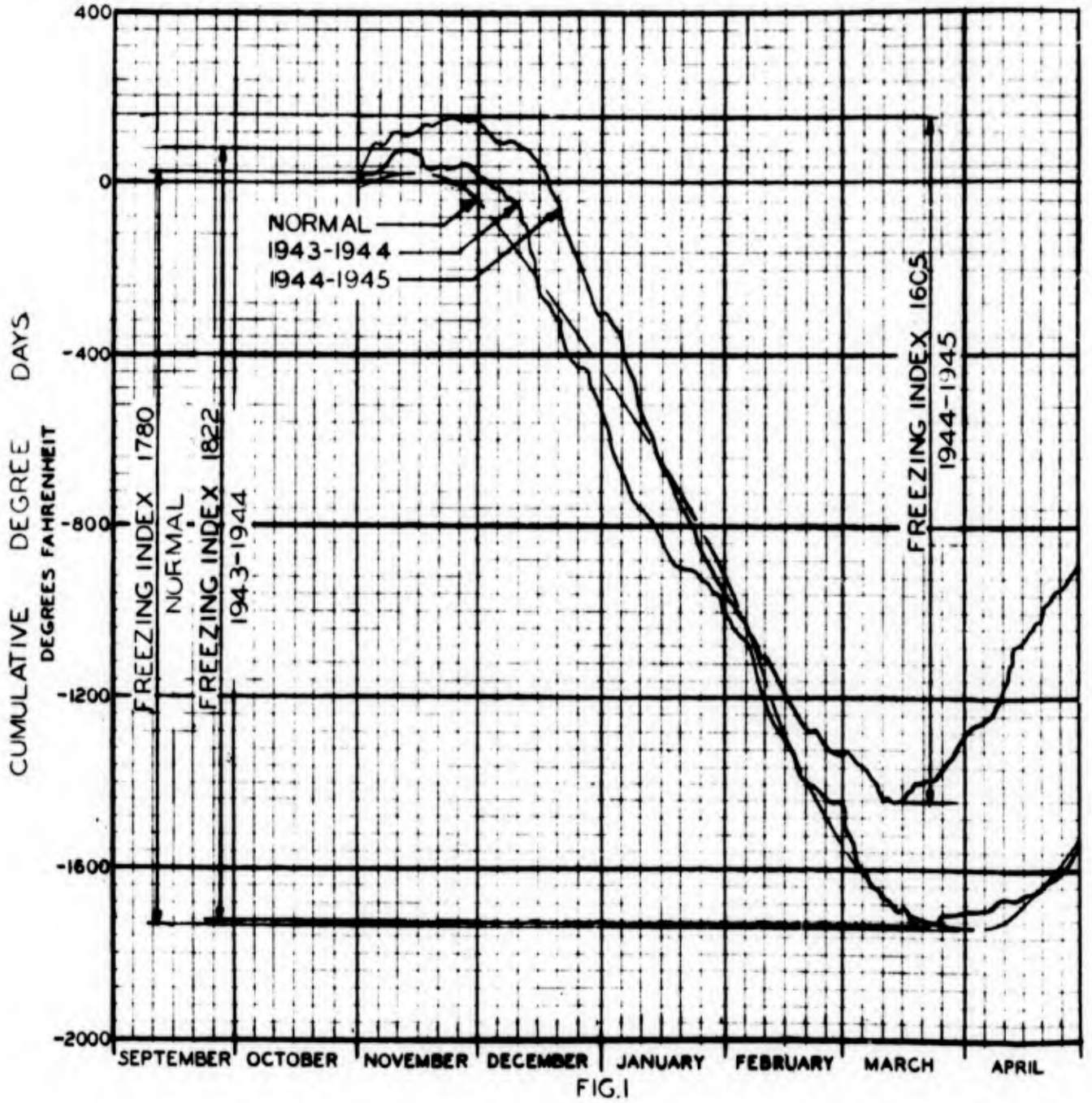

CUMULATIVE DEGREE DAYS
DEGREES FAHRENHEIT
400
0
-400
-800
-1200
-1600
-2000
NORMAL
1943-1944
1944-1945
FREEZING INDEX 1780
NORMAL
FREEZING INDEX 1822
1943-1944
FREEZING INDEX 1605
1944-1945
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL

FIG.1

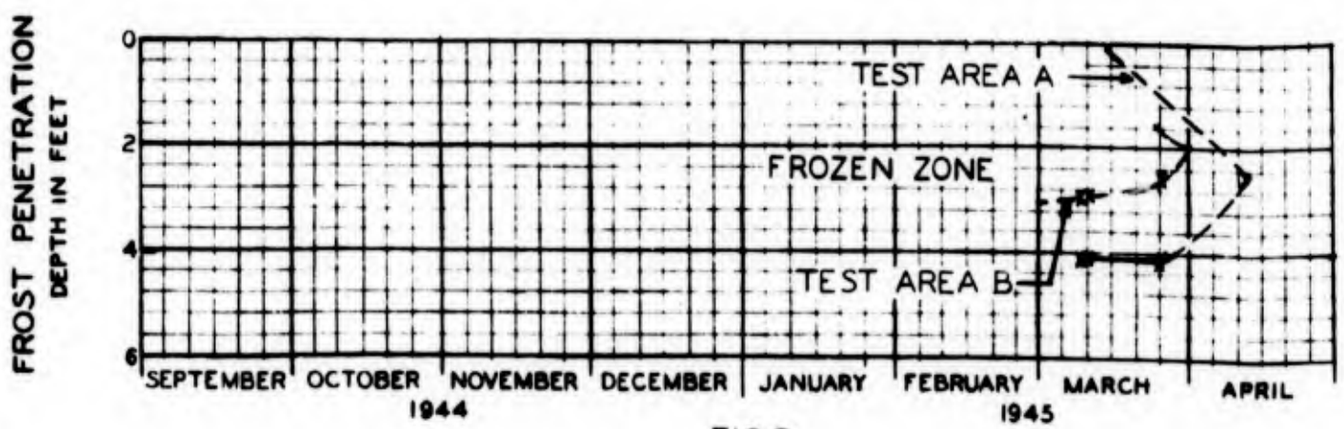

FROST PENETRATION
DEPTH IN FEET
0
2
4
6
TEST AREA A
FROZEN ZONE
TEST AREA B
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
1944
1945

FIG.2

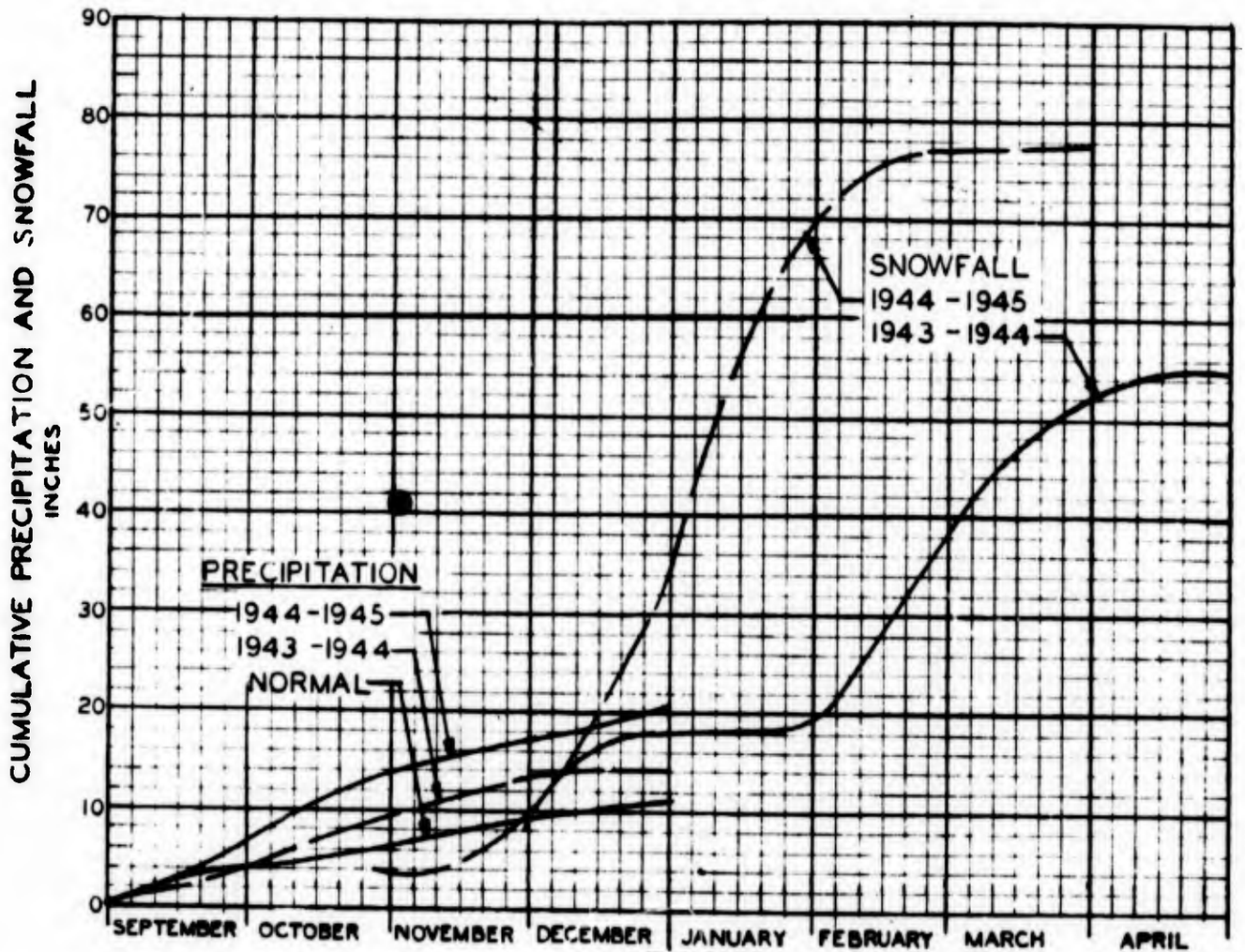


FIG.3

NOTES

Normal data based on 41 years of record by U.S. Weather Bureau.

Exploration for frost penetration in Test Area B stopped by boulders and may not indicate full depth of frost.

Test Area A - bituminous concrete pavement on soil cement base.

Test Area B - bituminous concrete pavement.

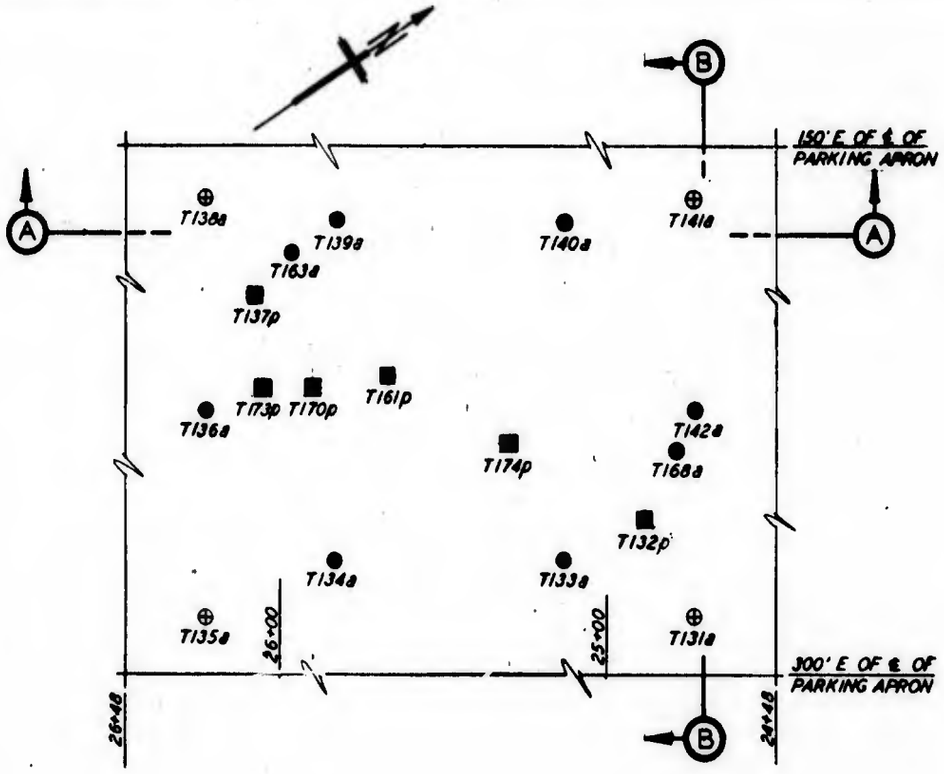
Dash lines in Fig. 2 are estimated portion of curves

FROST INVESTIGATION
HOULTON AIRFIELD HOULTON ME.

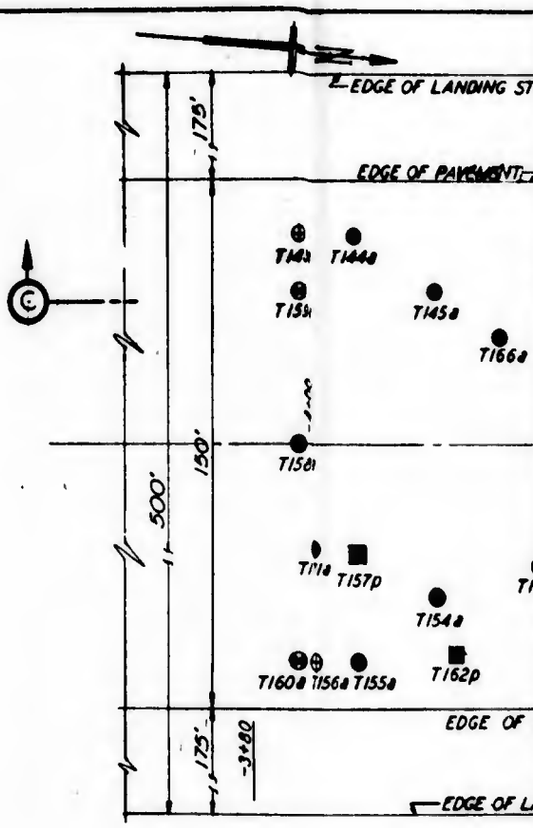
WEATHER AND FROST PENETRATION DATA

JUNE 1945
FROST EFFECTS LABORATORY BOSTON, MASS.

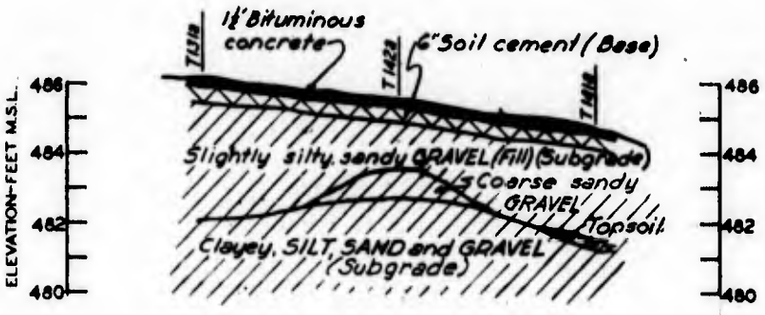
PLATE 2



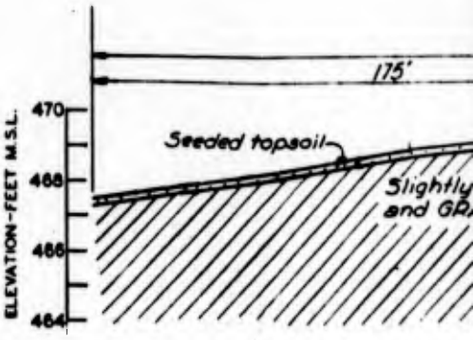
PLAN

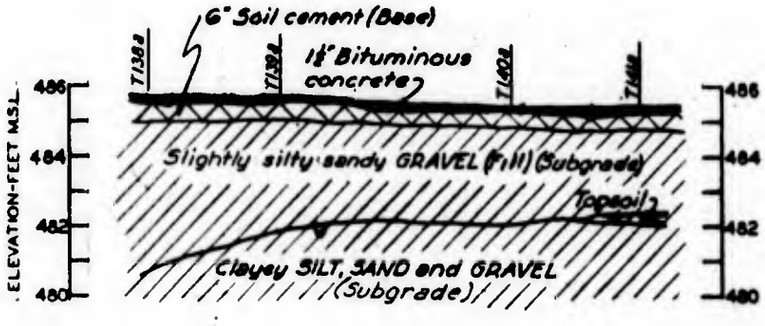


PLAN



SECTION B-B



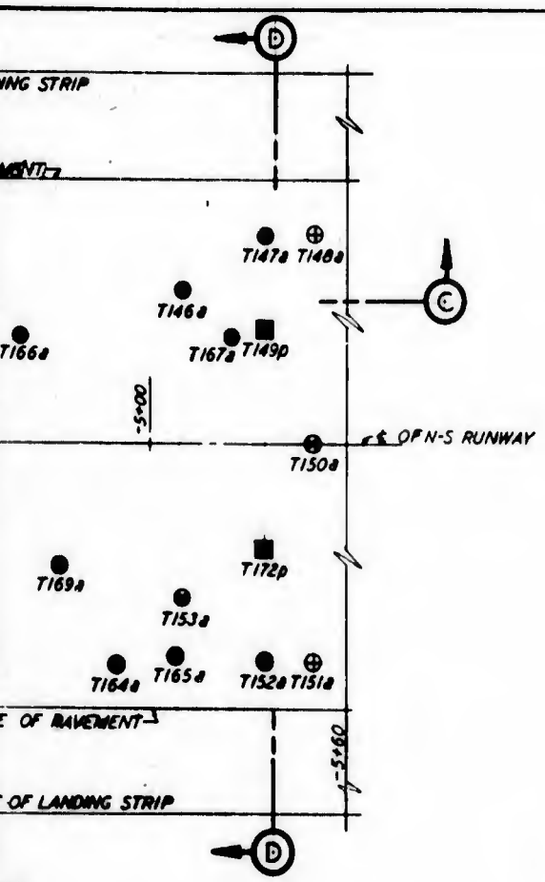


SECTION A-A

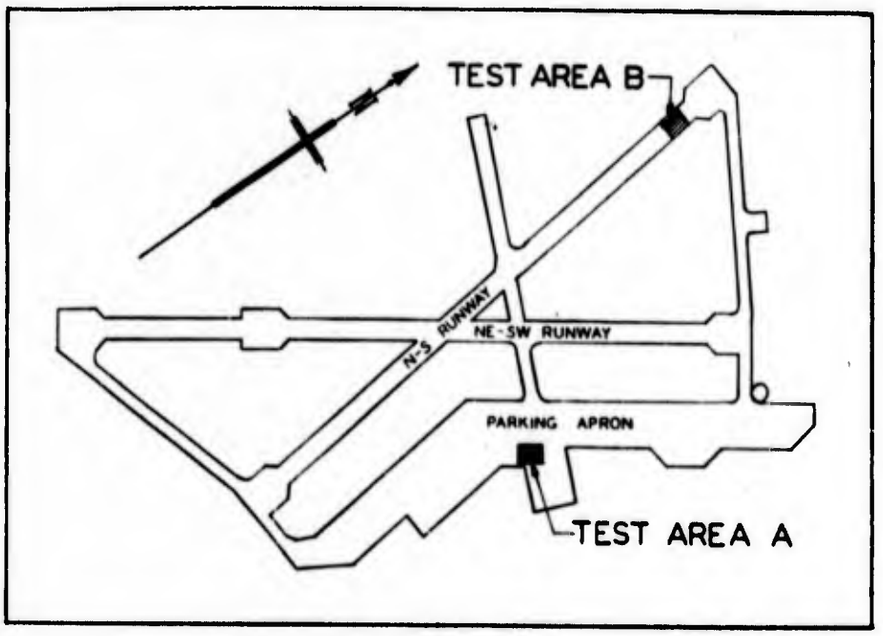
TEST AREA A

SECTION C-

TEST AREA

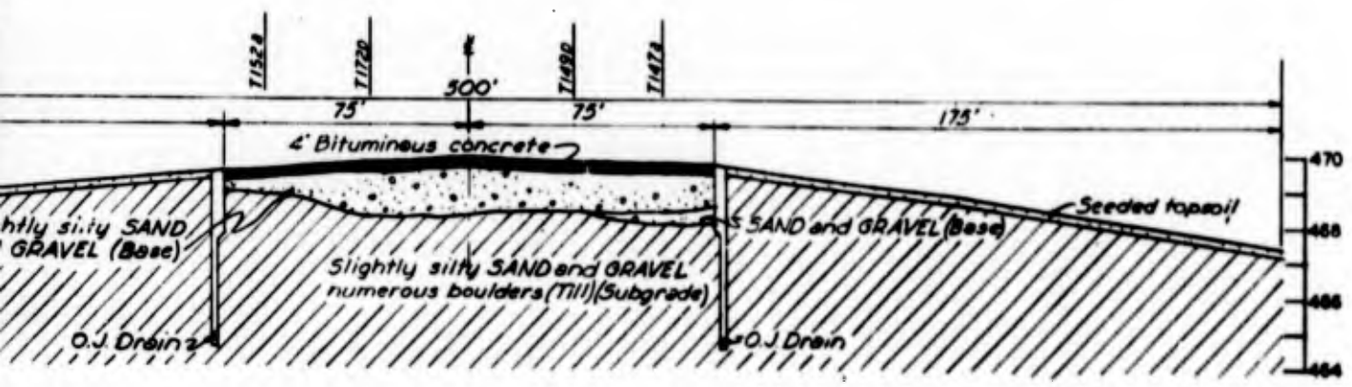


AN



SITE PLAN

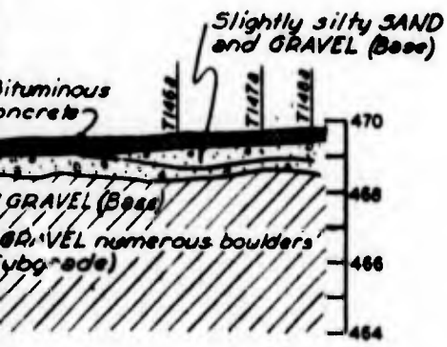
SCALE IN FEET



SECTION D-D

LEGEND

- Auger hole
- Test pit
- Observation well-bench mark
- Observation well in gravel base



C-C

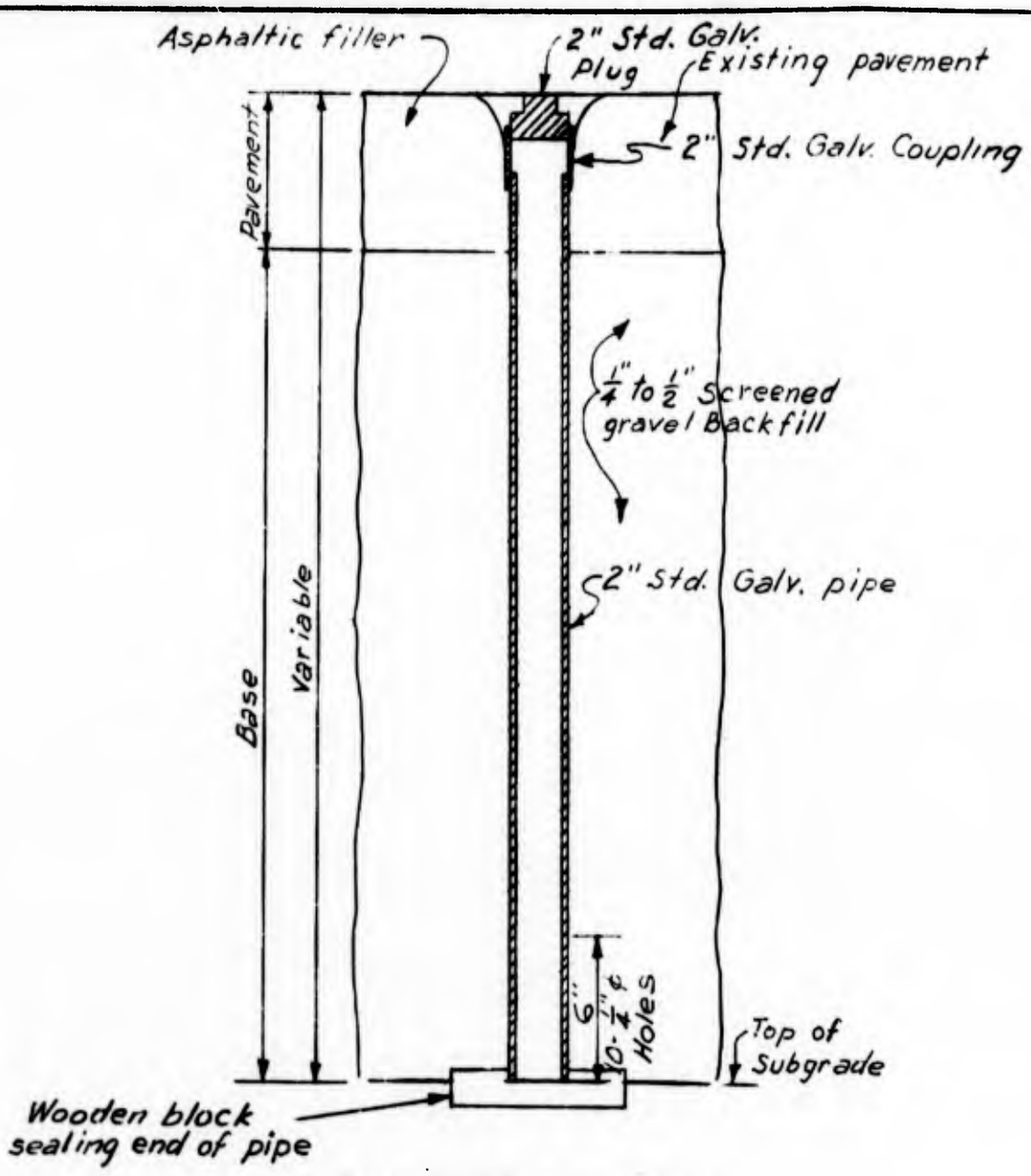
REA B

FROST INVESTIGATION
HOULTON AIRFIELD, HOULTON, ME

PLAN AND PROFILES
TEST AREAS A & B

SCALE IN FEET

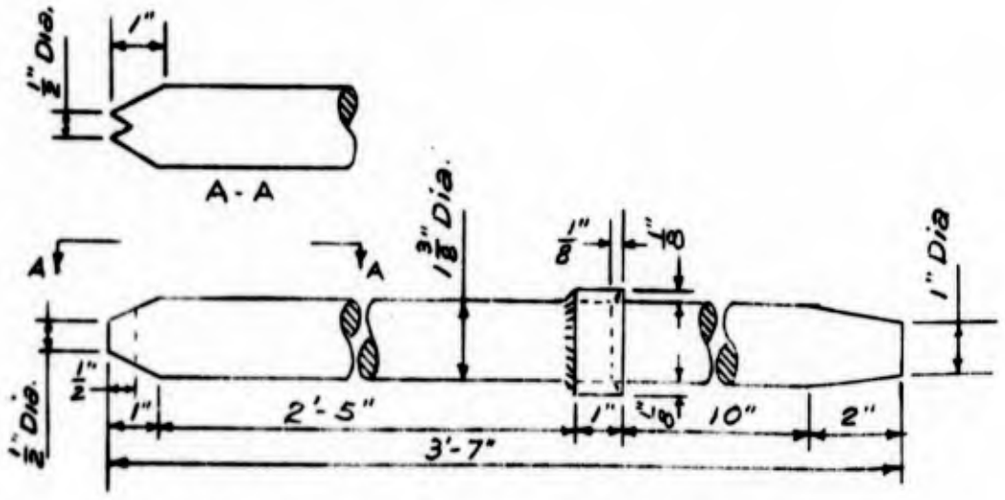
FROST EFFECTS LABORATORY, BOSTON, MASS JUNE 1945



OBSERVATION WELL

FIG.1

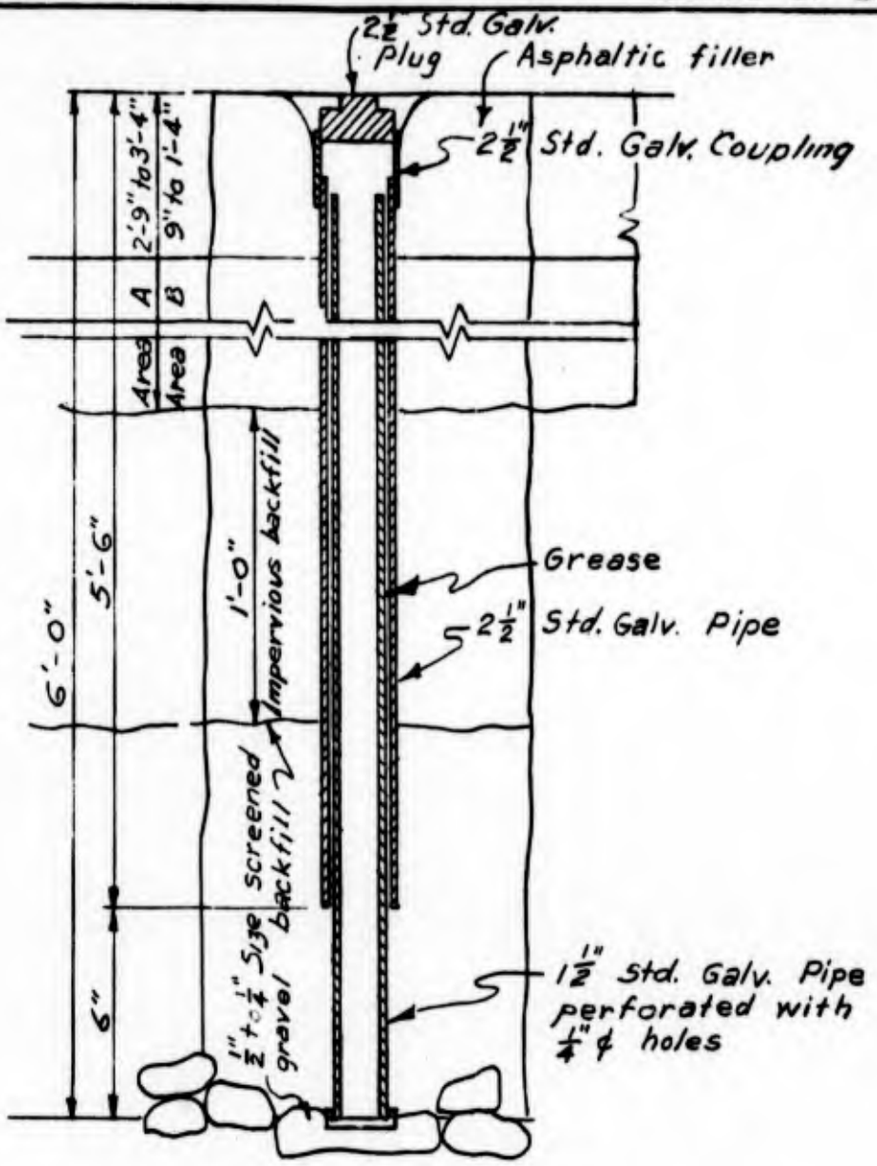
Scale : 1½" = 1-0'



BENCH MARK EXTENSION ROD

FIG.3

Scale : Quarter Size



BENCH MARK-OBSERVATION WELL

FIG. 2

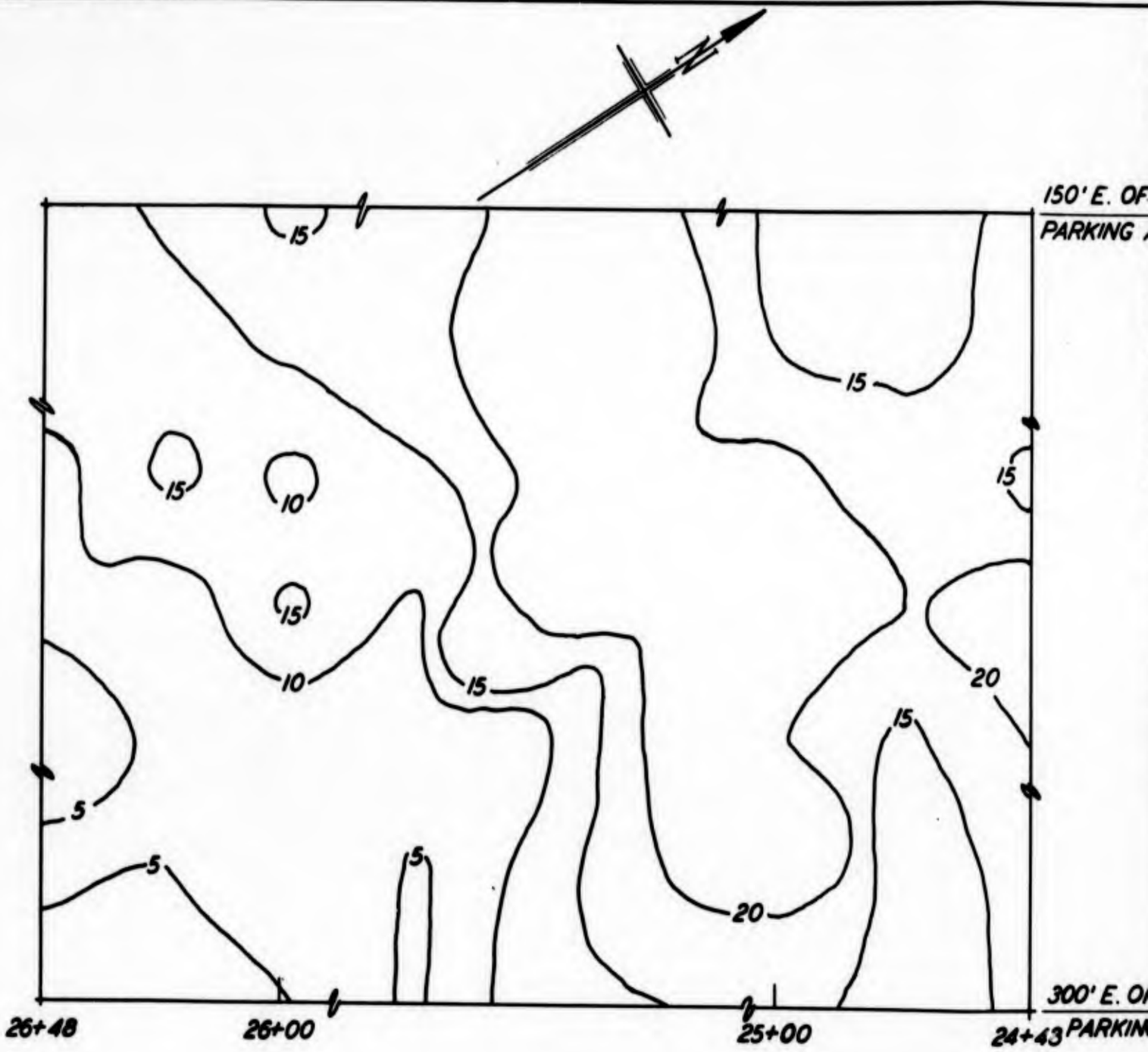
Scale: 1½" = 1-0'

FROST INVESTIGATION
HOULTON AIRFIELD, HOULTON, ME.

OBSERVATION WELLS AND
BENCH MARK-OBSERVATION WELLS

JUNE, 1945
FROST EFFECTS LABORATORY BOSTON, MASS

PLATE 4



TEST AREA A

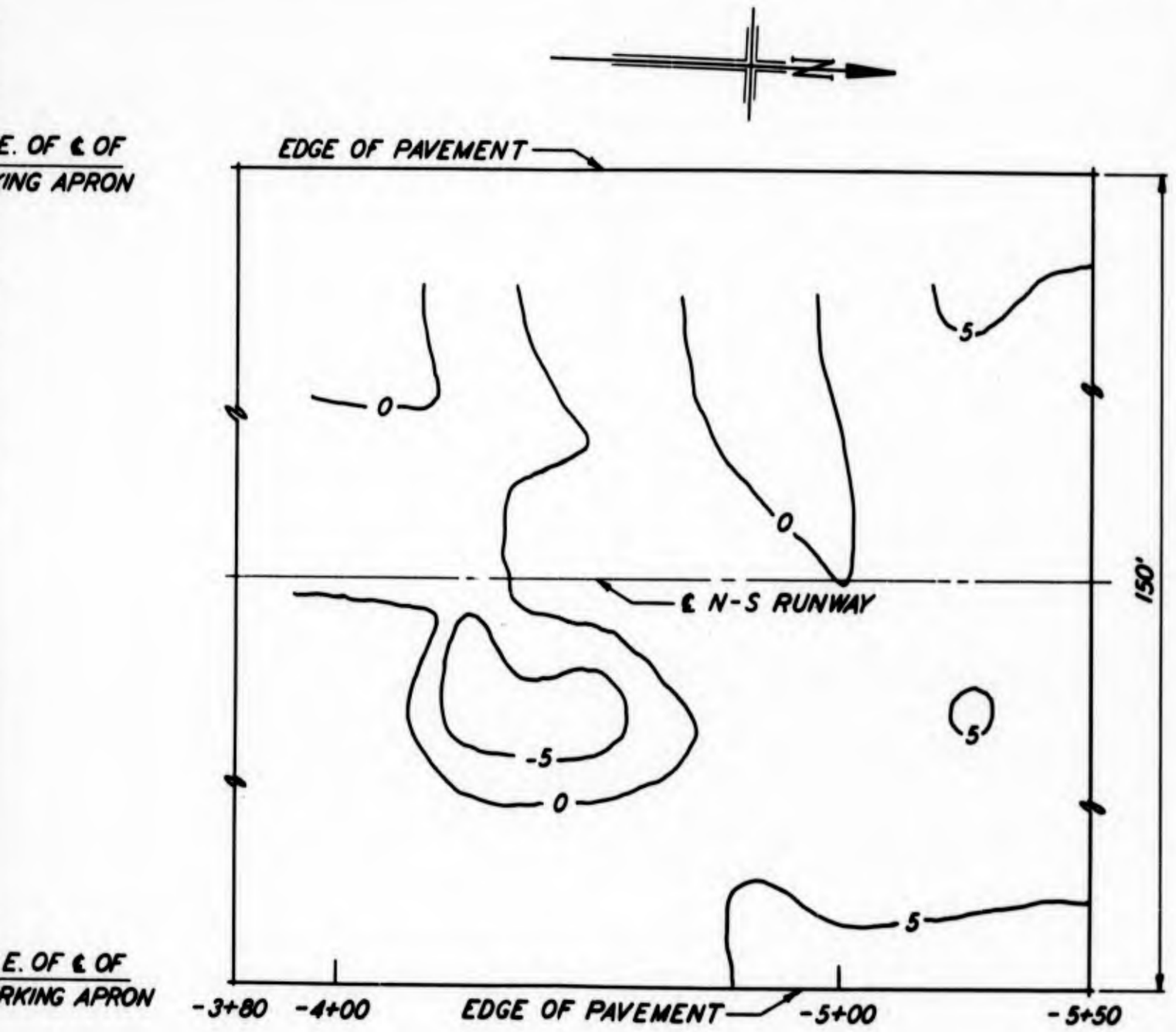
FIG. 1

NOTES

SURVEYS 14 DECEMBER, 1944 - 26 FEBRUARY, 1945

CONTOURS IN HUNDREDTHS OF FEET

CONTOUR INTERVAL = 0.05'



TEST AREA B

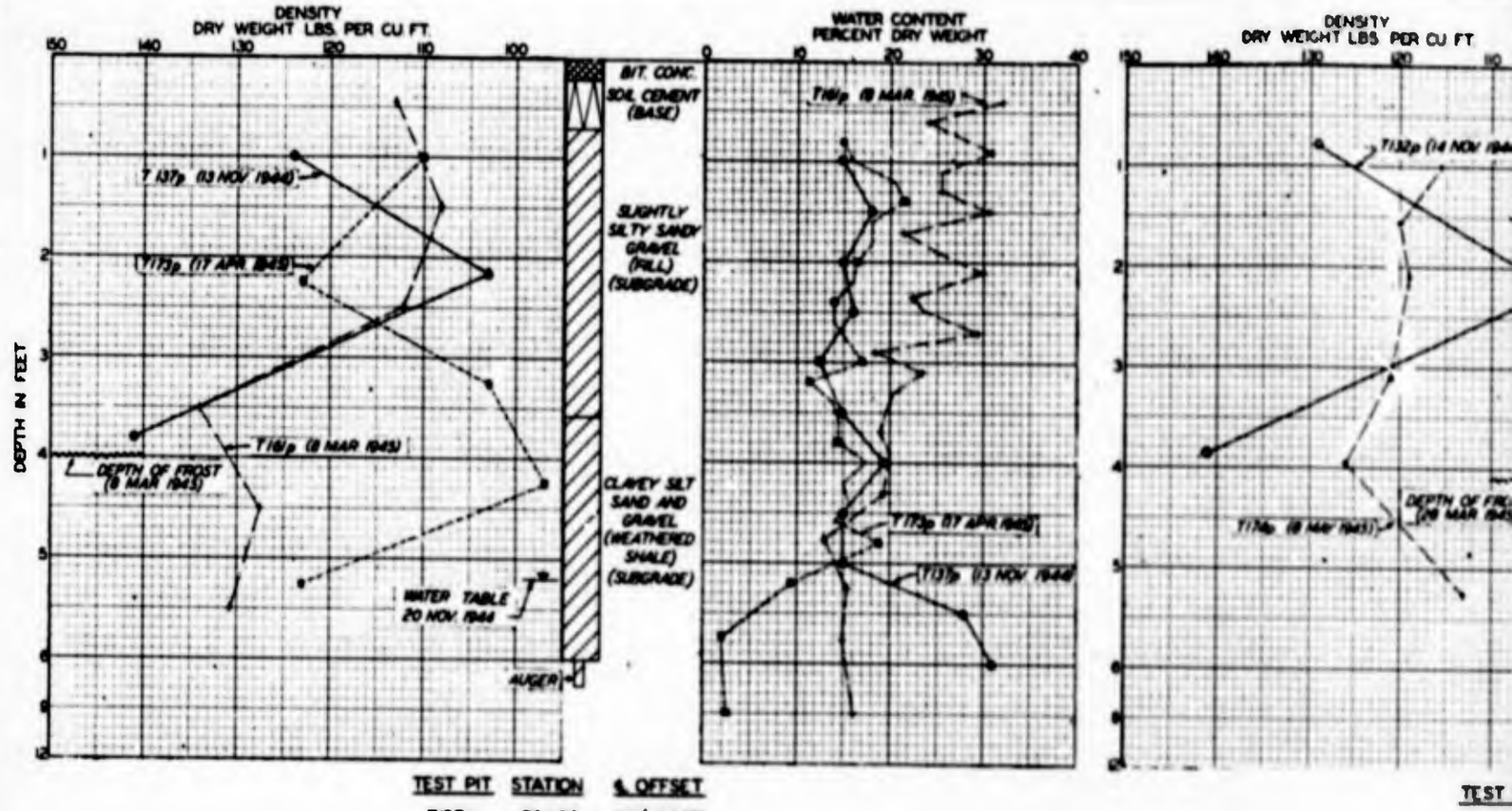
FIG. 2

FROST INVESTIGATION
HOULTON AIRFIELD, HOULTON, ME.

FROST HEAVE CONTOURS

JUNE, 1945 SCALE 1"=30'
FROST EFFECTS LABORATORY, BOSTON, MASS.

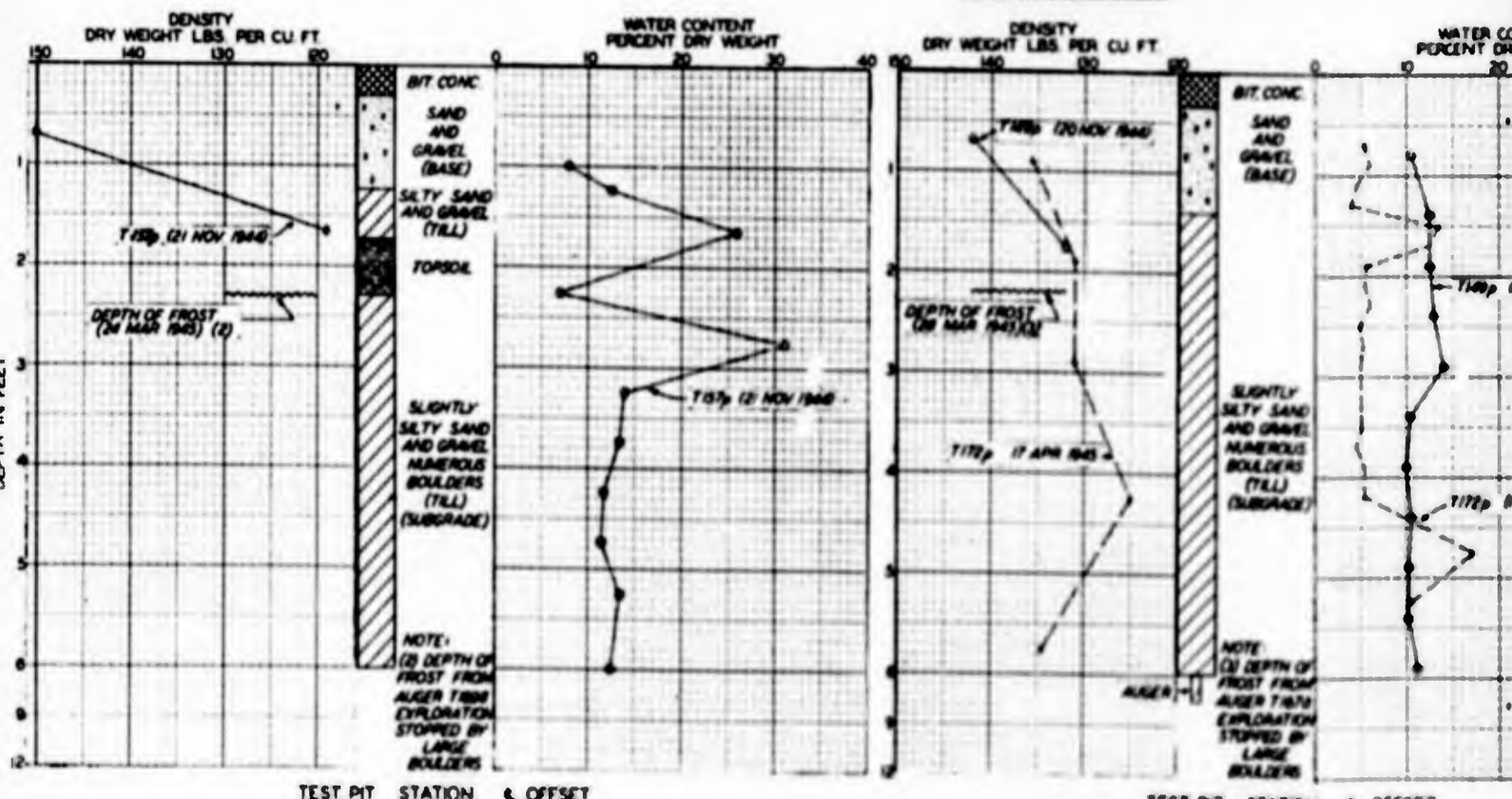
PLATE 5



TEST PIT	STATION	& OFFSET
T137p	26+08	183' EAST
T161p	25+68	215' EAST
T173p	26+05	219' EAST

FIG. 1

WATER CONTENT-DENSITY-SOIL PROFILE
TEST AREA A



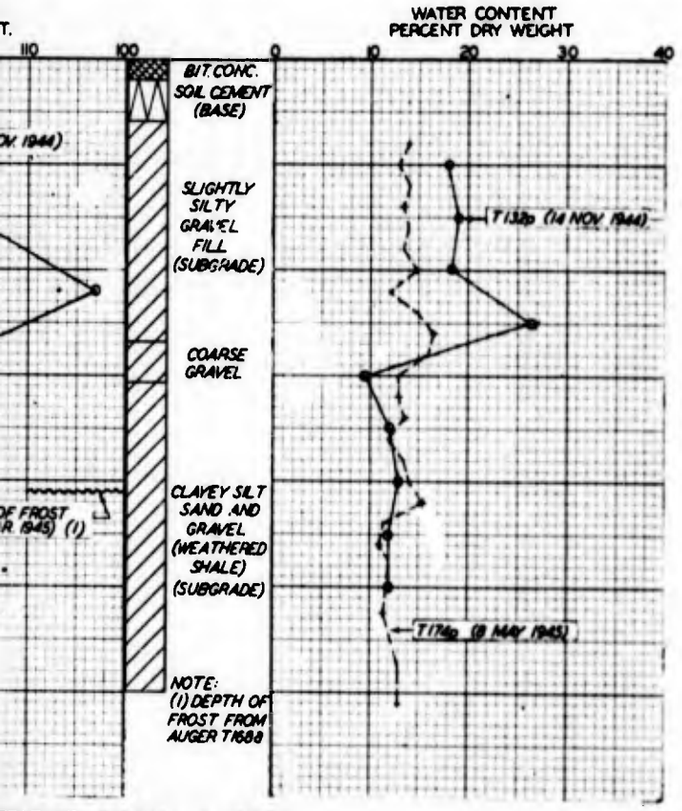
TEST PIT	STATION	& OFFSET
T 157p	-4+15	32' SOUTH

FIG. 5

TEST PIT	STATION	& OFFSET
T 149p	-5+35	32' WEST
T 172p	-5+35	30' EAST

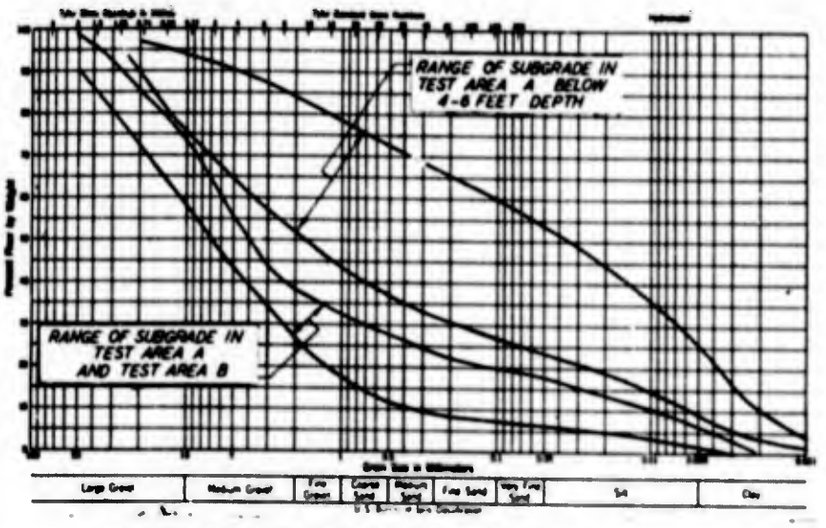
FIG. 6

WATER CONTENT-DENSITY-SOIL PROFILE
TEST AREA B



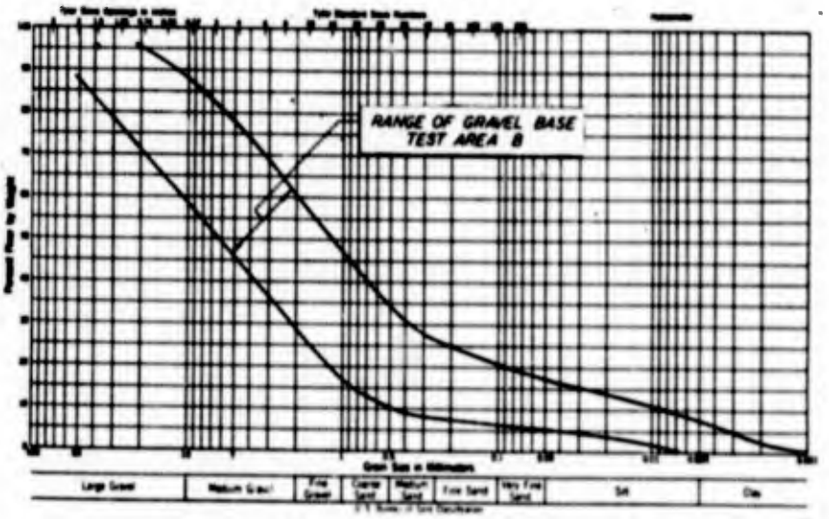
TEST PIT	STATION	℄ OFFSET
T132 p	24+88	232' EAST
T174 p	25+30	235' EAST

FIG. 2



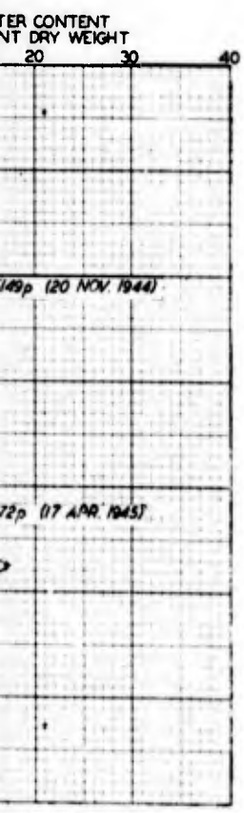
GRADATION OF SUBGRADE MATERIAL

FIG. 3



GRADATION OF BASE MATERIAL

FIG. 4



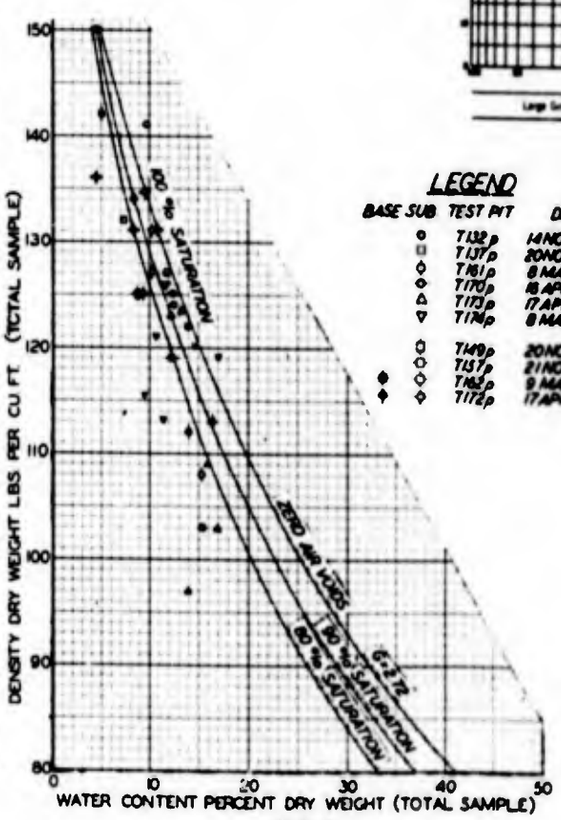


FIG. 7

WATER CONTENT-DENSITY
TEST AREAS A & B

LEGEND

BASE SUB	TEST PIT	DATE	
○	T132p	14 NOV 1944	TEST AREA A
□	T137p	20 NOV 1944	
◇	T161p	8 MAR 1945	
◆	T170p	16 APR 1945	
△	T173p	17 APR 1945	
▽	T174p	8 MAY 1945	
⬡	T149p	20 NOV 1944	TEST AREA B
⬡	T157p	21 NOV 1944	
◆	T162p	9 MAR 1945	
◆	T172p	17 APR 1945	

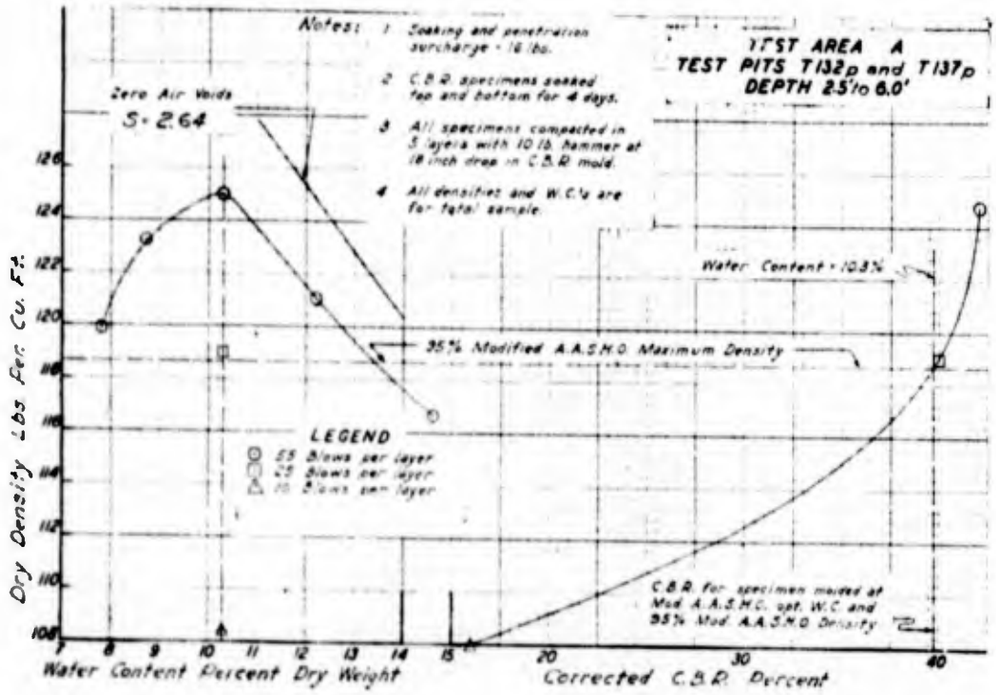
TEST AREA	TYPE	CLASSIFICATION		ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	SPECIFIC GRAVITY: >¼"	SPECIFIC GRAVITY: <¼"
A	SUB-GRADE (0-4'-0")	SLIGHTLY SILTY SANDY GRAVEL (GF)	AVG	–	–	–	2.65	2.73
			RANGE	30-33	NONE-25	NONE-8	2.54-2.71	2.71-2.78
	SUB-GRADE (4'-0"-8'-0")	CLAYEY SILT, SAND AND GRAVEL (GC)	AVG	28	16	12	2.68	2.76
			RANGE	26-30	16-17	10-13	2.60-2.72	–
B	BASE	WELL GRADED SAND AND GRAVEL (GW)	AVG	NON-PLASTIC			2.69	2.74
			RANGE				2.65-2.72	–
	SUB-GRADE	SLIGHTLY SILTY SAND AND GRAVEL (GF)	AVG	22	18	4	2.61	2.69
			RANGE	–	–	–	–	–

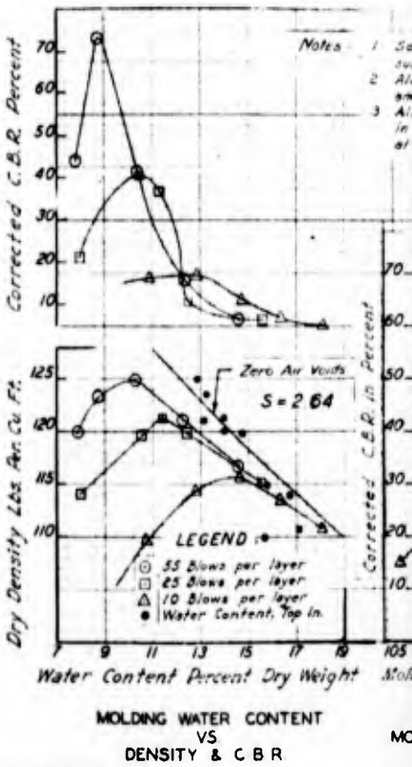
FROST INVESTIGATION
HOULTON AIRFIELD, HOULTON, MAINE

SOIL DATA SUMMARY
TEST AREAS A & B

FROST EFFECTS LABORATORY, BOSTON, MASS JUNE, 1945

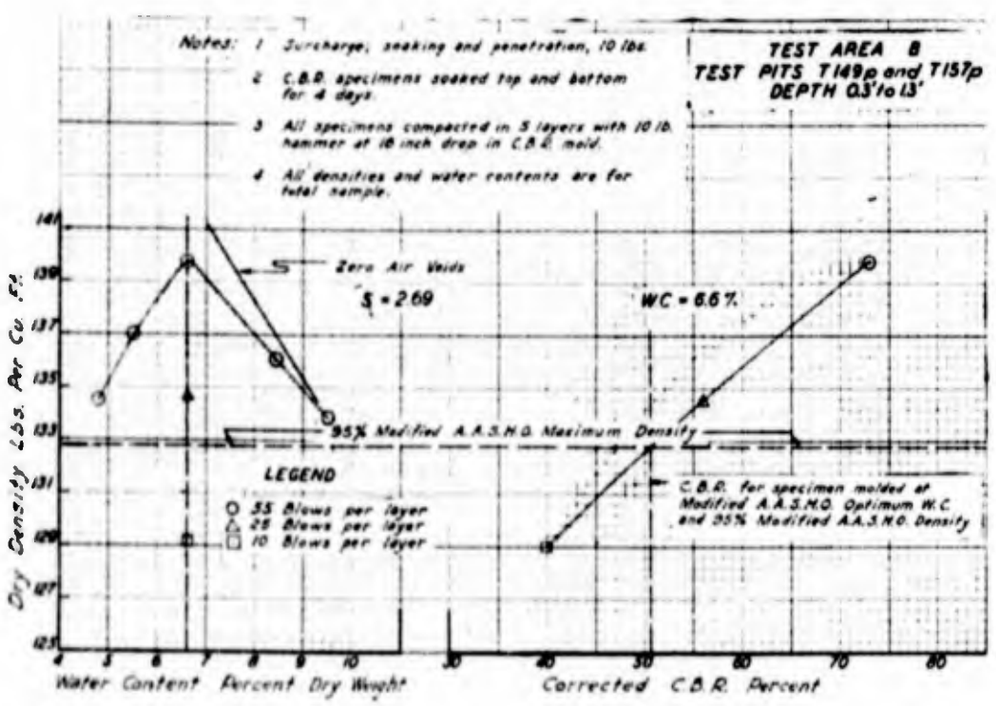
PLATE 6

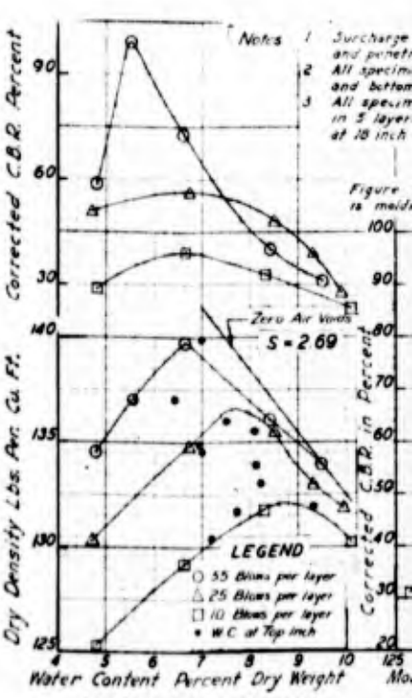




MOLDING WATER CONTENT
VS
DENSITY & C B R

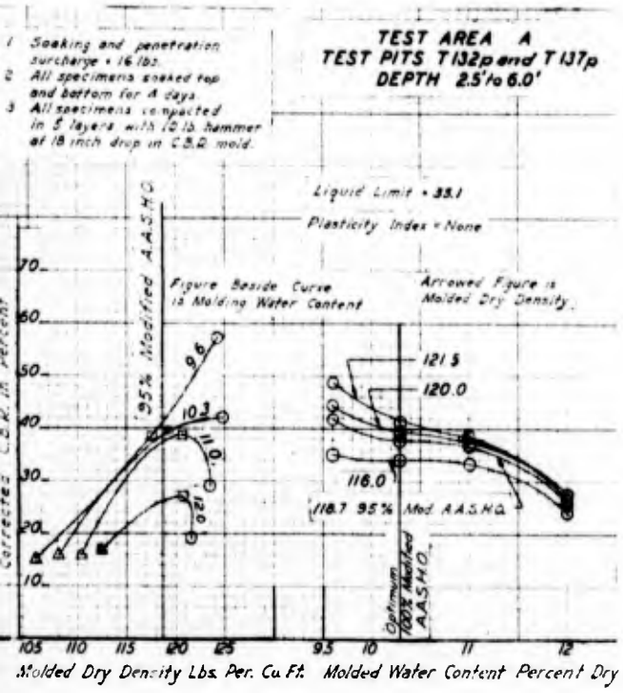
SUBGRADE MATERIAL
TEST AREA A AND B
FIG. 1



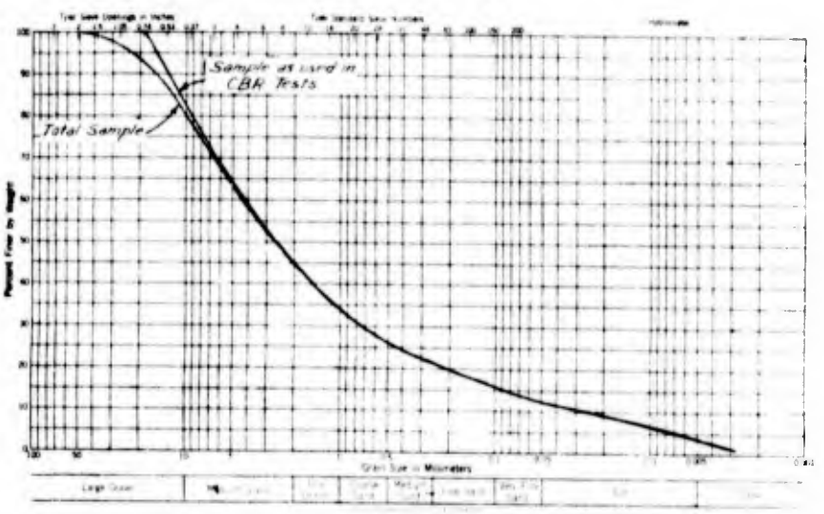


MOLDING WATER CONTENT
VS
DENSITY & C.B.R

BASE MATERIAL
TEST AREA B
FIG. 3

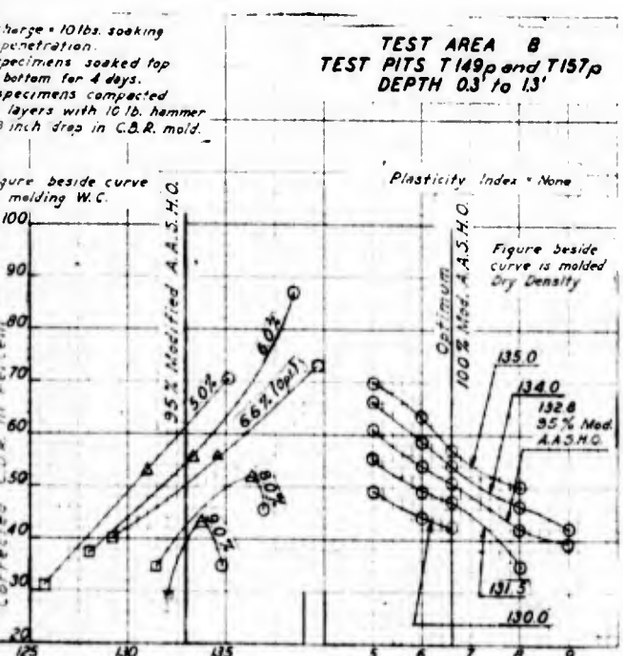


MOLDED DENSITY VS. C.B.R. MOLDED W.C VS C.B.R.

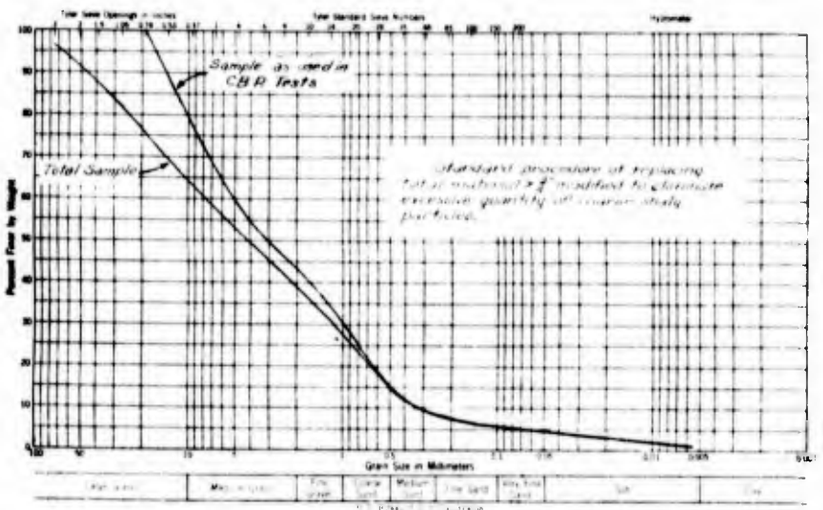


GRADATION OF SUBGRADE MATERIAL

FIG. 2



MOLDED DENSITY VS C.B.R MOLDING WATER CONTENT VS C.B.R



GRADATION OF BASE MATERIAL

FIG. 4

Note
Density is defined as unit dry weight in lbs. per cu ft

FROST INVESTIGATION
HOULTON AIRFIELD, HOULTON, MAINE.

SUBGRADE AND BASE MATERIALS REMOLDED C.B.R. DATA

FROST EFFECTS LABORATORY, BOSTON, MASS. JUNE 1945

PLATE 7