MISCELLANEOUS PAPER NO. 4-766

TESTS WITH THE CH-47A CHINOOK HELICOPTER IN SOFT CLAY SOILS

by

E. S. Rush

January 1966

Sponsored by

U. S. Army Materiel Command

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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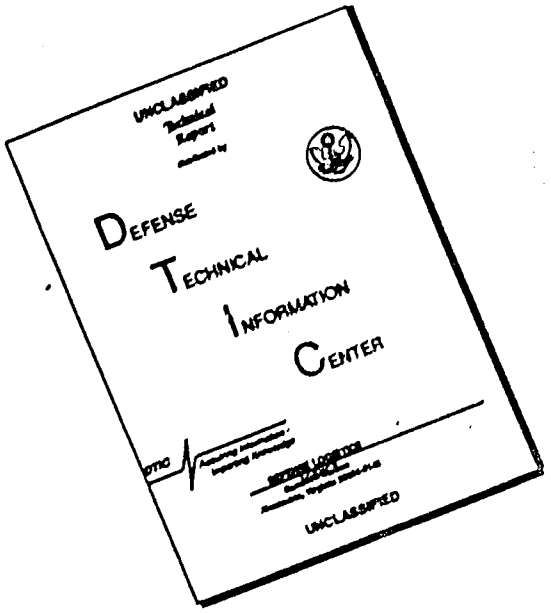

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U. S. Army Materiel Command
Project No. 1-V-0-21701-A-046
Task 02

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FOREWORD

The tests reported herein were requested by the U. S. Army Materiel Command in a telephone conversation on 20 May 1965. Funds were provided by Department of the Army Research and Development Project No. 1-V-0-21701-A-046, "Trafficability and Mobility Research," Task No. 1-V-0-21701-A-046-02, "Surface Mobility." The tests were conducted at three sites approximately 8 miles north of Vicksburg, Miss., on 27 and 28 May 1965 by a combination of U. S. Army Engineer Waterways Experiment Station (WES) and U. S. Army Aviation Test Board (USAAVNTB) personnel under the general direction of Mr. W. G. Shockley, Chief, Mobility and Environmental Division, WES, and Lt. Col. David H. Money, USAAVNTB. Field testing was directed by Dr. D. R. Freitag, Acting Chief, Army Mobility Research Branch (AMRB), Mobility and Environmental Division, WES, and Maj. William H. Scanlan, Project Officer, USAAVNTB. This report was prepared by Mr. E. S. Rush, Chief, Trafficability Section, AMRB.

Col. John R. Oswalt, Jr., CE, was the Director of WES during conduct of these tests. Mr. J. B. Tiffany was the Technical Director.

CONTENTS

SUMMARY

The primary purpose of the test program reported herein was to determine quantitatively the performance of the CH-47A Chinook helicopter in soft soils. Tests were conducted at three different locations on a range of soil strengths and at three different payloads. A total of 15 landings were made on 27 and 28 May 1965 near Vicksburg, Miss. Subsequent tests were conducted at Aberdeen Proving Ground, Md., from 21 to 24 June 1965. The Aberdeen Proving Ground tests are discussed briefly in Appendix A.

It was concluded that (a) the Chinook has adequate power for lift-off from most soft soil conditions, (b) a relation exists between sinkage of landing gear assembly into a soil and the ratio of bearing pressure to cone index, and (c) the presently designed cargo ramp will allow a cargo space entrance height of 72 in. only when the helicopter landing gear sinkage is about 12 in. or less.

TESTS WITH THE CH-47A CHINOOK HELICOPTER IN SOFT CLAY SOILS

PART I: INTRODUCTION

Purpose

1. The primary purpose of the test program reported herein was to determine quantitatively the performance of the CH-47A Chinook helicopter in soft soils. Of particular importance was the determination of the Chinook's ability to lift itself out of soft soils. Other measures of performance investigated were total torque output of the engines during lift-off, sinkage of the landing gear and/or hull into the soil, and maximum height of the ramp opening during a 3-min period (the maximum time requirement for unloading in an assault operation) in which the helicopter remained on the ground.

Scope

2. Tests were conducted with the Chinook at three different payloads in three different locations embracing a range of soil strengths. A total of 15 landings (tests) were made in the three areas on 27 and 28 May 1965. All three test areas were in the vicinity of Goose Lake, approximately 8 miles north of Vicksburg, Miss. (see plate 1).

3. The scope of the program was limited by the soil conditions that prevailed at the time of testing. The program therefore should not be considered an exhaustive testing of the Chinook's capabilities. Subsequent tests at Aberdeen Proving Ground, Md., with two Chinooks are discussed in Appendix A.

PART II: TEST PROGRAM

Helicopter Data

4. The CH-47A Chinook is shown in photograph 1. The following CH-47A data are those most pertinent to the program reported herein:

a. Power plant (two Lycoming shaft-turbine T-55-L-7 engines)

Maximum torque available (two engines): 1720 ft-lb

Maximum rotor rpm: 230

Maximum allowable (transmission limited) horsepower: 2480 per engine

Fuel:

Type: JP-4

Consumption rate: 2000 lb/hr (approximate) at high speeds and gross weights

b. Dimensions

Cargo volume: 78 in. high by 90 in. wide by 366 in. long

Ramp angle (lowered on firm surface): 8°

Distance between center lines of dual front wheels: 126 in.

Distance between center lines of single rear wheels: 134 in.

Wheel base length between center lines of front and rear wheels: 270 in.

Tire size: 8.50-10 III

Ground clearance:

At front wheels: 30 in.

At rear wheels: 19-1/2 in.

Approximate area of hull resting on ground with landing gear buried in mud: 52,920 sq in.

c. Weight

Empty: 17,475 lb

Maximum: 33,000 lb

Location and Description of Test Sites

5. The test areas were located in the Yazoo floodplain area

approximately 8 miles north of Vicksburg, Miss. (see plate 1). Three areas--designated borrow, lake, and spoil areas herein--were employed in the test program.

Borrow area

6. This area was located south of a recently built backwater levee (see plate 1). The top few feet of soil had been removed during construction of the levee, leaving a vegetation-free, relatively flat surface. Tests were conducted at two sites within the area (see plate 2). One site, free of surface water but with a sticky soil surface, was the scene of two tests (tests 1 and 8); the other, where 3 to 6 in. of water was standing on the surface, was also used for two tests (tests 2 and 9). Typical scenes of tests in this area are shown in photograph 2.

Lake area

7. This area was located north of the backwater levee at the southern end of Goose Lake (plate 1). A few small trees were removed from the area before testing. It is believed that the presence of root structure did not affect test results. The dry soil surface was free of vegetation and gave the impression of being firm although the subsoil actually was soft. Six tests (tests 3, 4, 6, 10, 11, and 12) were made in this area (see plate 3). Typical scenes of tests in the lake area are shown in photograph 3.

Spoil area

8. This area was located about 3-1/2 miles northeast of the other two areas. The site for three of the tests in this area (tests 5, 7, and 13) was inside a spoil retainer levee where dredgings from the Sunflower Diversion Canal had been pumped (see plate 4). The soil at this site was extremely soft to a depth of 6 ft. Two tests (tests 14 and 15) were made just outside the retainer levee where overflow from the spoil pit has been allowed to stand. At this site the soil was soft to a depth of about 15 in. and firm below that depth. Typical scenes of tests in this area are shown in photograph 4.

Soils Tested

9. Soils of all the areas tested classified as heavy clay (CH) according to the Unified Soil Classification System.

Test Procedures

10. Each test consisted of landing the Chinook in the desired location and allowing it to remain for a minimum of 3 min. During this period the rotors remained at flight revolutions per minute, but according to the pilot, no lift was being imposed on the helicopter by the rotors. The ramp to the cargo space was lowered as far as possible during the period. After the desired period, power was applied and the helicopter lifted out of the soil.

Data Collected

11. Helicopter and soil data collected are summarized in tables 1 and 2, respectively.

Helicopter data

12. Weight. Because of the rapid fuel consumption, close and frequent checks were made on gross vehicle weight. Consequently, table 1 shows a different vehicle weight for each test.

13. Torque output. Engine torque for each lift-off was read from the indicator dials on the helicopter's instrument panel.

14. Sinkage. Average sinkage of the landing gear and/or hull in the soft soil was measured for each test. In those tests where ruts were created and soil did not flow into the ruts after lift-off, sinkage was determined by measuring the depth of each rut. Where tests were conducted in semifluid or fluid soil, sinkage was determined from a predetermined datum plane on the helicopter's hull.

15. Maximum ramp opening height. At the end of the rest period after each landing, measurements were made from the top of the cargo area opening, vertically to the aft edge of the ramp, to determine the maximum opening height. In photograph 5 it can be seen that the underside of the ramp is lower than the bottom of the hull and that the aft edge of the ramp actually rests on the soil surface. The ramp opening height was measured vertically from the inside aft edge of the ramp to a hull support member inside the helicopter above the ramp. This support member is in approximately the same plane as the top of the cargo space. The location

at which the ramp opening height was measured is shown in photograph 5.

Soil data

16. Soil strength. Cone index (CI) was measured at five points around each rut after each landing, except for tests 5, 7, and 13, in which CI was measured before the landings because of the semifluid state of the soil. At each point, measurements were made at the surface and at 3-in. vertical increments to a depth of 24 in., and then at 6-in. vertical increments to at least 30 in. Remolding index (RI) was determined for 6-in. layers to a depth of 18 in. where possible. CI's were averaged for 6-in. layers, and the average value per layer was multiplied by the RI of that layer to obtain the rating cone index (RCI) values shown in table 2.

17. Moisture content and density. Samples were obtained during each test for moisture content and density determinations. Samples were obtained to a depth of 18 in. at the lake area, but to a depth of only 12 in. at the borrow and spoil areas because of the firmness of the soil and the fluid condition of the soil at these two areas, respectively. Results are shown in table 2.

18. Soil classification. Bulk samples were obtained at each area for laboratory analysis and classification. Results are shown in table 2.

PART III: ANALYSIS OF DATA

19. Analysis of data consists mainly of comparing measures of helicopter performance (torque output, sinkage, and ramp opening height) with measures of soil properties (soil strength, moisture, and density). Also included are observations made during conduct of the tests. As will be pointed out in the analysis, data in certain areas are lacking and some data collected should have been rechecked had time permitted.

20. It was anticipated that the helicopter might have difficulty extricating itself after sinking in soft soil areas and that some critical soil condition might occur where excessive sinkage into the soil and strong adhesion qualities of the soil could prevent the takeoff of the helicopter. Consequently, tests were conducted first with the helicopter empty in the firmest soil, then in increasingly softer soils, and then in the same areas with increasingly heavier loads.

Comparison of Torque Requirements with Cone Index

21. The average CI of the soil profile to a depth of 30 in. was compared with the torque on lift-off as read from the dial indicator. Results of these comparisons were inconclusive, except for a slight trend of increasing torque with a decrease in CI when the helicopter was empty. The maximum torque noted (except for questionable readings for test 8 and hard-surface lift-off when the helicopter was loaded) was 1180 ft-lb. Immobilization of the helicopter was never imminent, however, because the maximum torque available was 1720 ft-lb.

22. It should be noted that the soil in the lake area, although soft enough to allow the helicopter to sink to its hull, was relatively dry on the surface and did not adhere to the hull. The soil in the spoil area also was soft enough to allow the helicopter to sink to its hull, but the soil surface was extremely wet and fluid; therefore, adherence to the hull was relatively small. A soil condition (not tested during this program) probably exists that would cause greater power requirements for takeoff than observed in these tests. A heavy clay soil with a RCI of 15 to 25 through the 30-in. depth and with a wet, sticky surface would

probably present such a condition. While it is believed that even this soft, sticky condition would not prevent takeoffs of the Chinook, the case should be explored.

Comparison of Sinkage with Bearing Pressure and Cone Index

23. Sinkage of wheels and landing gear into the soil (see photograph 6) was found to be related to soil strength and an expression of bearing pressure based on Chinook weight, nominal tire size, and number of tires. The formula used to express bearing pressure (N) was as follows:

$$N = \frac{W}{bdn}$$

where

W = vehicle weight, lb

b = nominal tire width, in.

d = tire diameter (2b + rim diameter), in.

n = number of tires

24. To account for the effects of changes in both load and CI on sinkage, N was divided by the average CI in the 0- to 30-in. layer, and the resulting value was plotted against sinkage as shown in plate 5. It can be seen that a straight-line relation exists up to about 22-in. sinkage. At this sinkage a significant portion of the load probably is transmitted to the soil by the hull. Thus, after the helicopter sinks deep enough the hull contacts the soil, and further sinkage is restrained by the large supporting surface.

25. The relation of the sinkage of the vehicle to the wheel loads and soil strength can be shown to be principally that of bearing capacity of a simple footing. It can be seen in plate 5 that at the maximum sinkage possible before the hull carries much of the load (about 22 in.), the ratio N/CI is about 0.70. From theoretical considerations the ultimate bearing capacity (q) of a deeply buried footing in a purely cohesive clay is

$$q = 8.3\ C$$

where C is the soil cohesion. Data presented in Waterways Experiment Station Technical Report No. 3-639, Strength-Moisture-Density Relations

of Fine-Grained Soils in Vehicle Mobility Research, show that the CI of a cohesive soil is related to cohesion as follows:

$$CI = 12.5\ C$$

Therefore, letting the contact pressure, N , on the vehicle's tires be the ultimate bearing capacity, the ratio

$$\frac{N}{CI} = \frac{8.3\ C}{12.5\ C} = 0.66$$

This compares favorably with the measured ratio. Similarly, for a footing on the surface of a cohesive soil, the theoretical bearing capacity is

$$q = 5.7\ C$$

Then, letting the contact pressure, N , reach the ultimate surface bearing capacity,

$$\frac{N}{CI} = \frac{5.7\ C}{12.5\ C} = 0.46$$

In plate 5 the N/CI ratio at a sinkage of 13.5 in., the depth at which the full tire diameter can be assumed to be in contact with the surface, is approximately 0.43. Thus, again the agreement is quite good.

Effect of Sinkage on Ramp Opening Height

26. At the beginning of the test program it became obvious that sinkage of the wheels and landing gear into the soil restricted the lowering of the rear ramp. The ramp was so designed that when it was lowered, the outside surface of its hinged end dropped below the bottom of the hull (see photograph 5); however, when sinkage was deep as demonstrated in photograph 7, the ramp would not open to the full extent. The effects of sinkage on ramp opening height are shown graphically in plate 6. The ramp opening height was measured vertically between the top of the cargo cabin and the aft edge of the ramp. Maximum height of the cargo cabin was 78 in.; however, when sinkage was less than about 7 in., the aft edge of the

ramp would lower below the bottom of cabin floor, giving a measurement greater than the maximum height of the cabin. It can be seen in plate 6 that when the helicopter was resting on its hull, the ramp opening was only about 45 in., thus making discharge of cargo, especially vehicles, difficult to impossible.

Determination of Experimental Vehicle Cone Index* for the Chinook

27. One of the most important objectives of this test program was to determine the minimum soil strength required to support landings and takeoffs of the Chinook helicopter. Inasmuch as extremely soft soil conditions (as low as RCI = 4 in top 12 in.) provided no difficulty for the Chinook, it must be concluded, at least tentatively (paragraph 22), that soil strength per se will not limit landings and takeoffs of the Chinook.

28. Tactical use of the Chinook envisions it being used to transport ground vehicles used or being considered for use by the U. S. Army that require soil strengths on the order of 10 to 15 RCI for one pass or about 25 RCI for 50 passes. Thus, the practical employment of the Chinook appears to be limited to soil strengths that are adequate to support the ground vehicles transported by the helicopter.

29. However, the problem is more complex than this, because, as pointed out in paragraph 26, sinkage of the helicopter into soft soils will restrict the height of the ramp opening through which the ground vehicles must pass. Thus it is necessary to consider not only the VCI's of the ground vehicles to be transported but also their dimensions before the minimum soil strength that will ensure successful tactical employment can be determined.

30. In order to "assign a number" to a minimum soil condition for tactical operation of the Chinook, i.e. a VCI, it was arbitrarily decided to use the value of the soil condition that permitted a sinkage that resulted in a ramp opening height of 72 in. This height will permit

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* Vehicle cone index (VCI) is a term specifying the minimum RCI required for the operation of a ground vehicle. Reference Waterways Experiment Station Technical Memorandum No. 3-240, Trafficability of Soils; A Summary of Trafficability Studies Through 1955, Supplement 14 (Vicksburg, Miss., December 1956).

fairly easy entrance and exit of most of the ground vehicles the Chinook would be expected to transport. The sinkage that results in this 72-in. ramp opening height is 12 in. (from plate 6). VCI's for most ground vehicles are expressed in terms of the minimum RCI of the 6- to 12-in. layer that will support their traffic. For the sake of consistency, the RCI of the 6- to 12-in. layer was used also for the Chinook VCI.

31. A plot was made (plate 7) of the test weight of the vehicle versus RCI of the 6- to 12-in. layer, and ramp opening heights were marked by each point. A curve was then drawn which separated ramp opening heights equal to or less than 72 in. from those greater than 72 in. This curve defines the Chinook VCI in terms of gross weight and soil condition for a 72-in. ramp opening height. Obviously, VCI's for the Chinook corresponding to other ramp opening heights could be determined in a similar manner.

32. The following example illustrates the above discussion. If it is assumed that the Chinook's gross weight is 30,000 lb when carrying a load that includes a vehicle that requires a minimum ramp opening height of 72 in., it must be concluded that the Chinook should not land in a soil condition in which RCI of the 6- to 12-in. layer is less than 56 (see plate 7). Despite the fact that such a soil would afford easy landing and takeoff of the Chinook and be more than adequate for the traffic of the ground vehicle(s) expected to be transported in the Chinook, the height of the maximum possible ramp opening would prohibit the discharge of the vehicle(s) on soil with a RCI of less than 56.

Observations of Performance of Chinook in Soft Soils

33. Based on results and observations of the Chinook's performance in the short test program reported herein and the tests described in Appendix A, the following comments are offered.

34. The Chinook appears to have adequate power for lift-off from most soil conditions that may be encountered. It was observed that on lift-off of a Chinook resting on the hull, the helicopter breaks contact with the ground first at the front end and last at the rear end of the hull. In this operation, surface contact is broken in increments rather

than all at once, as would be the case if the helicopter lifted evenly; this, therefore, eliminates to a great extent "suction" beneath the hull. Photograph 1 demonstrates the position of the helicopter on lift-off.

35. It also was observed that the wheel and landing gear assemblies probably are unnecessary when the helicopter is operating in soft soil. On first touchdown, the wheels penetrate the soil, preventing any rolling action, and on lift-off, they create additional drag on the engines.

36. As pointed out previously, the main problem from an operational standpoint appears to be maintenance of adequate ramp opening height for discharge of cargo. With the helicopter resting on its hull, the ramp opening height was only 45 in. First thoughts were to force the ramp down into the soil with the existing hydraulic system used to raise and lower the ramp, but this proved impracticable, since on the first attempt a hydraulic line was ruptured. Removal of the ramp was one alternative, since this does not affect operation of the helicopter, but it leaves approximately a 1-ft drop-off from the floor of the cargo cabin to the ground surface, which creates some problems (see Appendix A). Another alternative was to mount skis of sufficient size to prevent sinkage of the landing gear into the soil (see Appendix A). It was observed also that redesign of the ramp to allow it to open fully when the helicopter is resting on the hull probably could be accomplished.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

37. As a result of the tests reported herein and observations of the tests discussed briefly in Appendix A, the following conclusions are drawn:

a. The Chinook apparently has adequate power for lift-off from most soft soil conditions.

b. Practical employment of the Chinook as a transport for ground vehicles is not limited by soft soil conditions per se, but rather by the fact that sinkage of the Chinook into soft soil reduces the ramp opening height and thus restricts movement of ground vehicles into and out of the helicopter.

c. A relation exists between sinkage of landing gear assembly into the soil and the ratio of bearing pressure to CI.

d. With critical height of the ramp opening assumed to be 72 in. (approximately 6 in. less than maximum height of the cargo space), a relation was developed between RCI of the 6- to 12-in. layer and helicopter weight. This relation defines a VCI for the Chinook.

e. With the presently designed ramp, skis help to maintain adequate height of ramp opening except in extremely soft soils.

Recommendations

38. It is recommended that:

a. Additional tests be conducted in a clay soil with a RCI of 15 to 25 and a wet, sticky surface.

b. Consideration be given to redesigning the Chinook's ramp to permit it to open to a maximum height when the helicopter is resting on its hull.

Table 1

Helicopter Data

Test No.	Weight, lb: Approx Payload	Weight, lb: Fuel	Weight, lb: Gross*	Torque Output on Lift-off ft-lb	Average Sinkage in.	Maximum Ramp Opening Height in.
			Borrow Area			
1	0	2500	20,475	725	6-1/4	84
2	0	2480	20,455	825	5-1/2	83
8	12,330	3300	33,605	1220 (?)	11-3/4	72-1/2
9	12,330	3250	33,555	1180	10-1/2	69
			Lake Area			
3	0	2300	20,275	785	11-1/4	75
4	0	2200	20,175	825	13-3/4	72
6	5000	3300	26,275	965	21	62
10	12,330	2900	33,205	1100	21-3/4	54
11	12,330	2800	33,105	1100	--	48
12	12,330	2700	33,005	1140	18-1/2	48
			Spoil Area			
5	0	1300	19,275	865	28	51
7	5000	2800	25,775	910	30 (est)	47
13	12,330	2250	32,555	1020	31	44
14	12,330	1900	32,205	980	15 (est)	60
15	12,330	1800	32,105	980	15 (est)	60 (est)

Note: Maximum torque available = 1720 ft-lb.
Hard-surface lift-off torques: No payload = 725 ft-lb.
5000-lb payload = 920 ft-lb.
12,330-lb payload = 1220 ft-lb (?).
Hard-surface clearance beneath hull: Front landing gear = 30 in.
Rear landing gear = 19-1/2 in.
Maximum rotor rpm = 230.
(?) Question mark denotes questionable reading.
* Gross weight = Empty weight (17,475 lb) + crew (500 lb) + fuel + payload.

Photograph 1. CH-47A Chinook helicopter during lift-off

Table 2

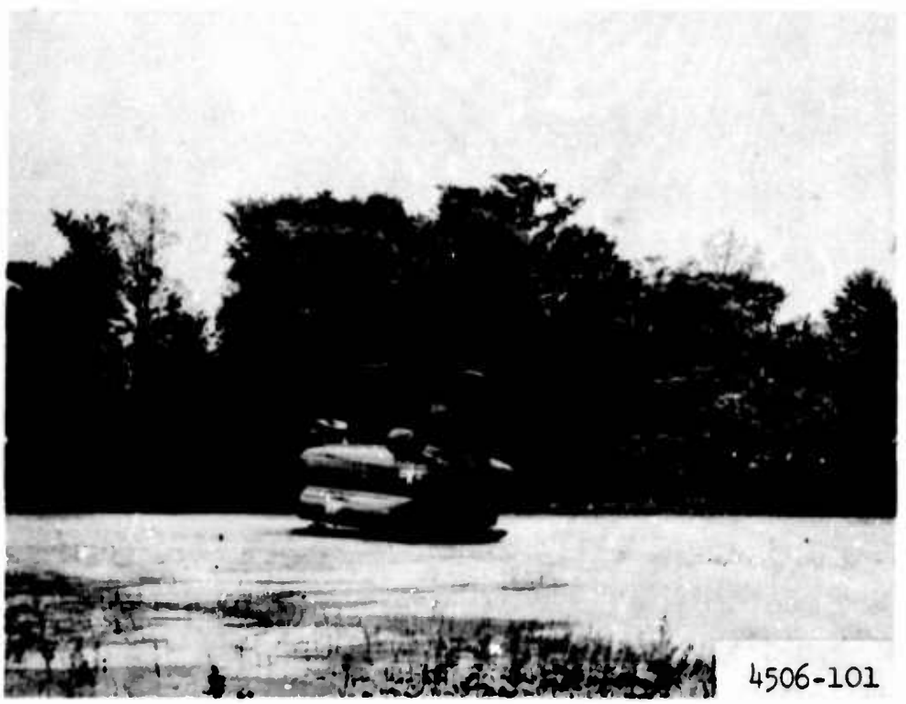
Soil Strength, Moisture, Density, and Classification Data

Test No.	Soil Strength: Cone Index (At Indicated Depths, Inches) 0	3	6	9	12	15	18	21	24	30	36	42	48	Remolding Index: 0- to 6-in. Layer	6- to 12-in. Layer	12- to 18-in. Layer	Rating Cone Index: 0- to 6-in. Layer	6- to 12-in. Layer	12- to 18-in. Layer	Moisture Content % of Dry Weight: 0- to 6-in. Layer	6- to 12-in. Layer	12- to 18-in. Layer	Dry Density lb per cu ft: 0- to 6-in. Layer	6- to 12-in. Layer	12- to 18-in. Layer
Borrow Area																									
1	17	60	84	95	89	92	110	116	124	135	144	--	--	0.86	0.73	--	46	65	--	39.3	32.3	--	77.1	83.8	--
2*	27	72	84	92	102	126	129	133	132	131	--	--	--	0.86	0.82	--	52	76	--	38.2	37.2	--	89.8	85.4	--
8	20	58	80	80	92	98	113	105	119	128	130	--	--	0.88	0.94	0.78	47	79	70	31.8	33.5	--	86.2	88.5	--
9*	12	44	62	82	92	93	95	102	115	124	--	--	--	0.88	0.82	--	34	65	--	47.0	--	--	73.8	--	--
* 3 to 6 in. of water on surface.																									
Lake Area																									
3	22	35	38	36	37	33	33	32	28	29	31	--	--	0.73	0.74	--	23	27	--	56.7	77.0	--	60.6	52.8	--
4	22	22	25	28	31	34	34	32	32	32	32	--	--	0.79	0.75	--	18	21	--	67.2	78.1	--	59.3	53.6	--
6	21	22	22	23	26	27	32	30	27	28	--	--	--	← Use Test 4 Data →					--	← Use Test 4 Data →					--
10	24	33	29	30	29	35	38	40	43	42	40	29	32	0.91	0.85	0.81	26	25	28	42.5	66.7	--	73.6	57.4	58.5
11	← Use Test 12 Data →																								
12	22	29	28	32	37	44	48	53	58	48	43	30	35	0.87	0.71	0.71	23	23	31	48.6	61.0	67.5	71.8	57.1	54.6
Spoil Area																									
5	2	2	2	4	5	7	13	11	16	18	16	20	26	← 1.00 (Assumed) →			2	4	8	97.7	72.3	75.8	44.2	56.4	--
7	← Use Test 5 Data →																								--
13	← Use Test 5 Data →																								--
14	2	2	2	6	34	64	81	86	92	102	--	--	--	**	**	**	--	--	--	159.5	49.2	--	--	72.6	--
15	2	2	4	29	57	70	72	73	80	92	--	--	--	**	**	**	--	--	--	← Use Test 14 Data →					--
** Unable to obtain remolding sample.																									

Soil Classification

Area	Layer in.	Percent Fines	Atterberg Limits LL	PL	PI	Unified Soil Classification System Symbol
Borrow	0-6	100	53	23	30	CH
	6-12	100	54	25	29	CH
Lake	0-6	100	78	30	48	CH
	6-12	100	80	30	50	CH
Spoil (Tests 5, 7, and 13)	0-12	100	85	33	52	CH
Spoil (Tests 14 and 15)	0-15	100	95	32	63	CH

a. Test 8, no surface water, 12,330-lb payload



b. Test 9, 3 to 6 in. of water, 12,330-lb payload

Photograph 2. Typical scenes of landings in borrow area

a. Test 3, no payload

b. Test 10, 12,330-lb payload

Photograph 3. Typical scenes of landings in lake area

a. Test 13, no payload

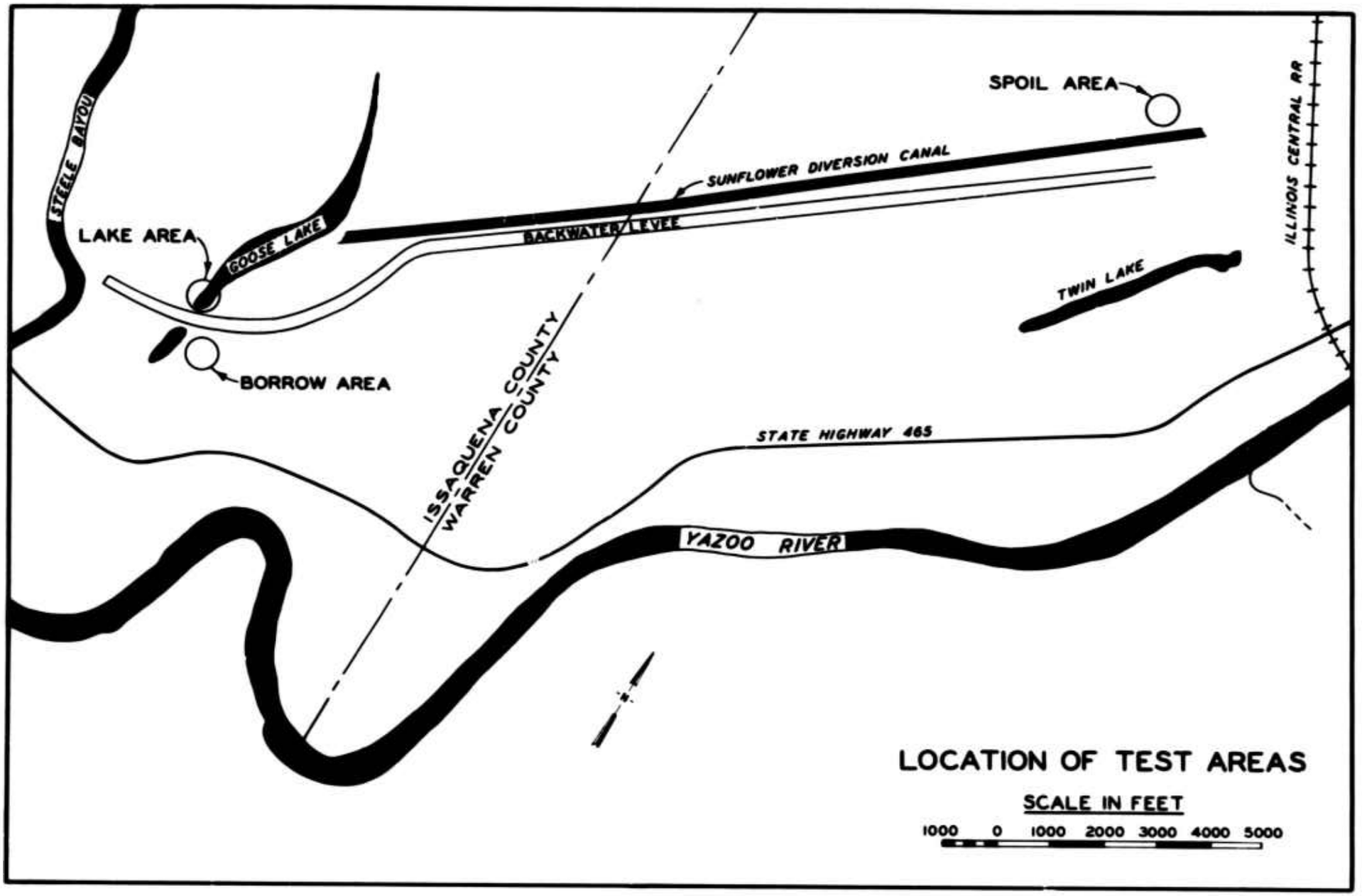
b. Test 15, 12,330-lb payload

Photograph 4. Typical scenes of landings in spoil area

Photograph 5. Illustration of ramp opening height with Chinook resting on firm soil

Photograph 7. Hinged end of ramp resting on soil when sinkage is deep

Photograph 6. Chinook resting on hull after sinkage of wheels and landing gear into soil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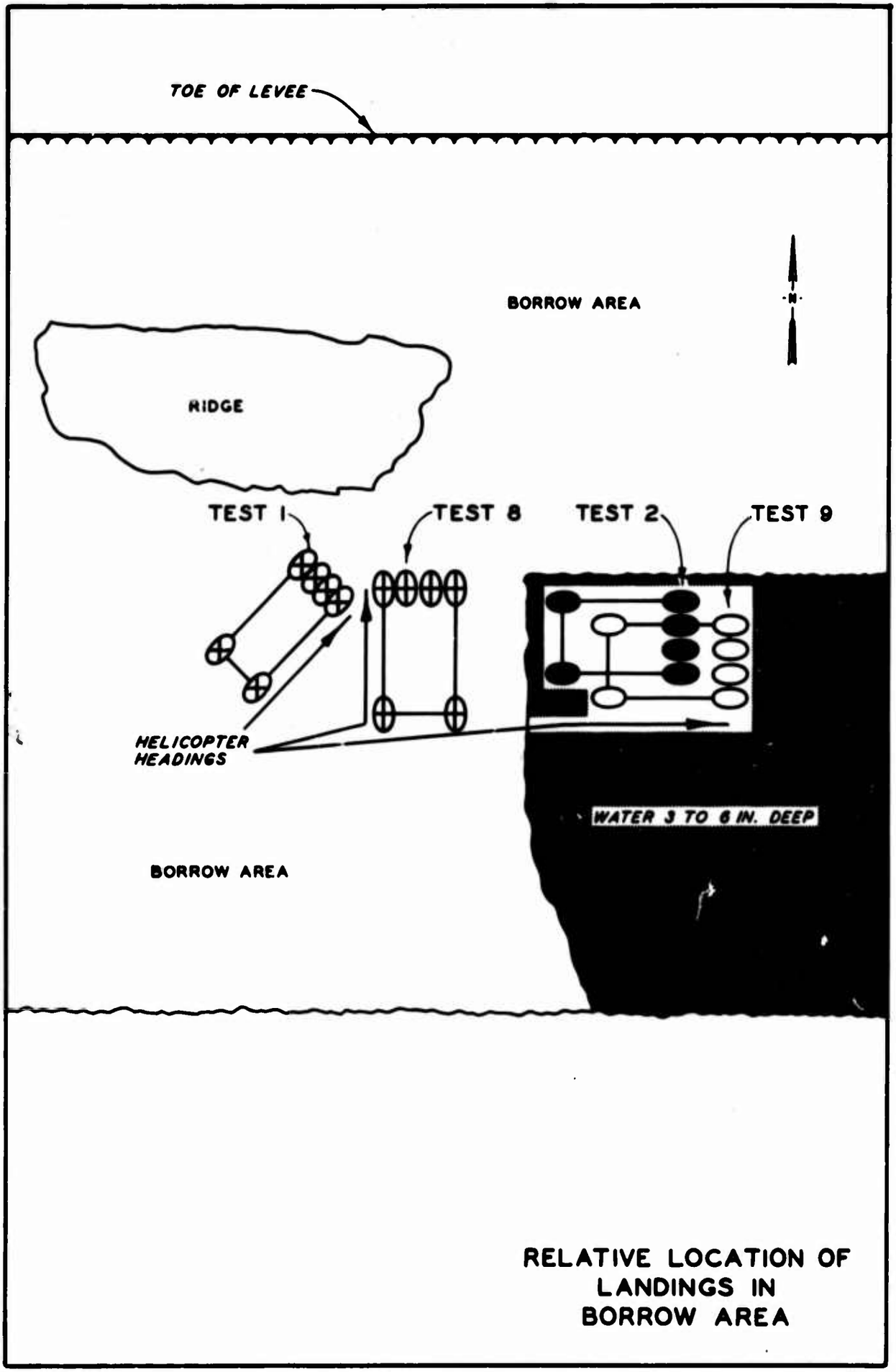
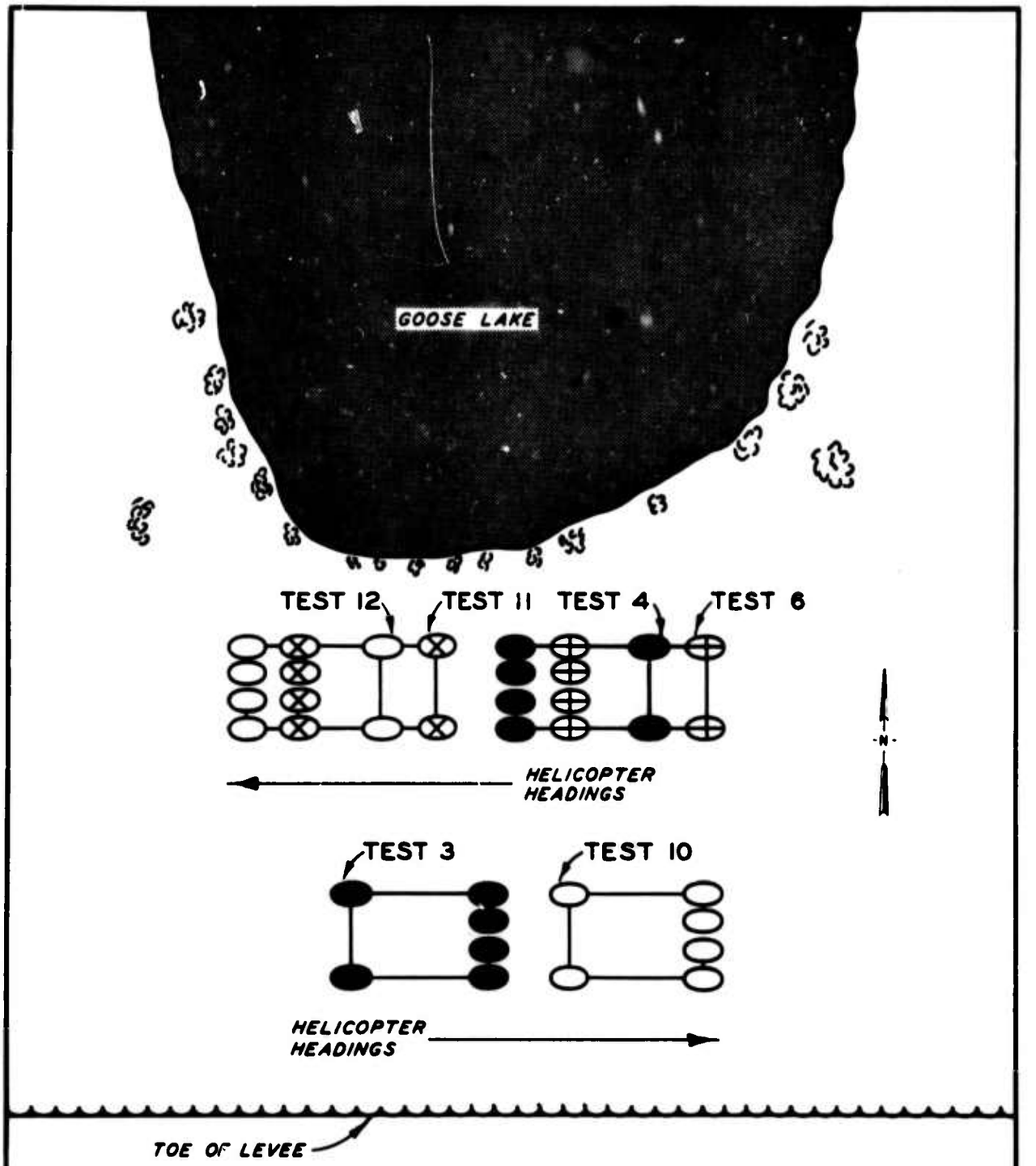
GOOSE LAKE
LAKE AREA
BORROW AREA
SPOIL AREA
SUNFLOWER DIVERSION CANAL
BACKWATER LEVEE
ILLINOIS CENTRAL RR
TWIN LAKE
ISSAQUENA COUNTY
WARREN COUNTY
STATE HIGHWAY 465
YAZOO RIVER
LOCATION OF TEST AREAS
SCALE IN FEET
1000 0 1000 2000 3000 4000 5000

PLATE I



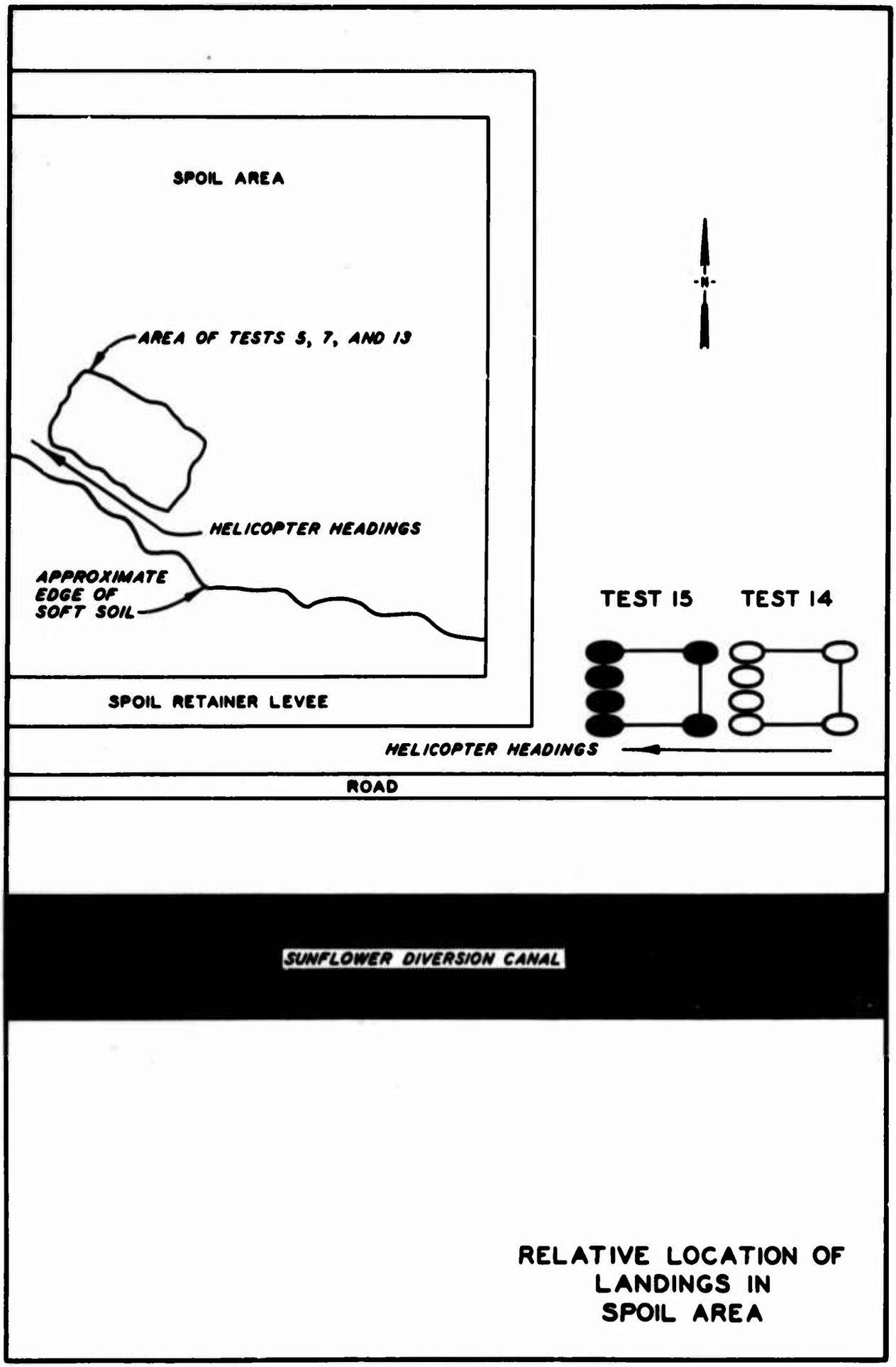
RELATIVE LOCATION OF LANDINGS IN BORROW AREA

PLATE 2



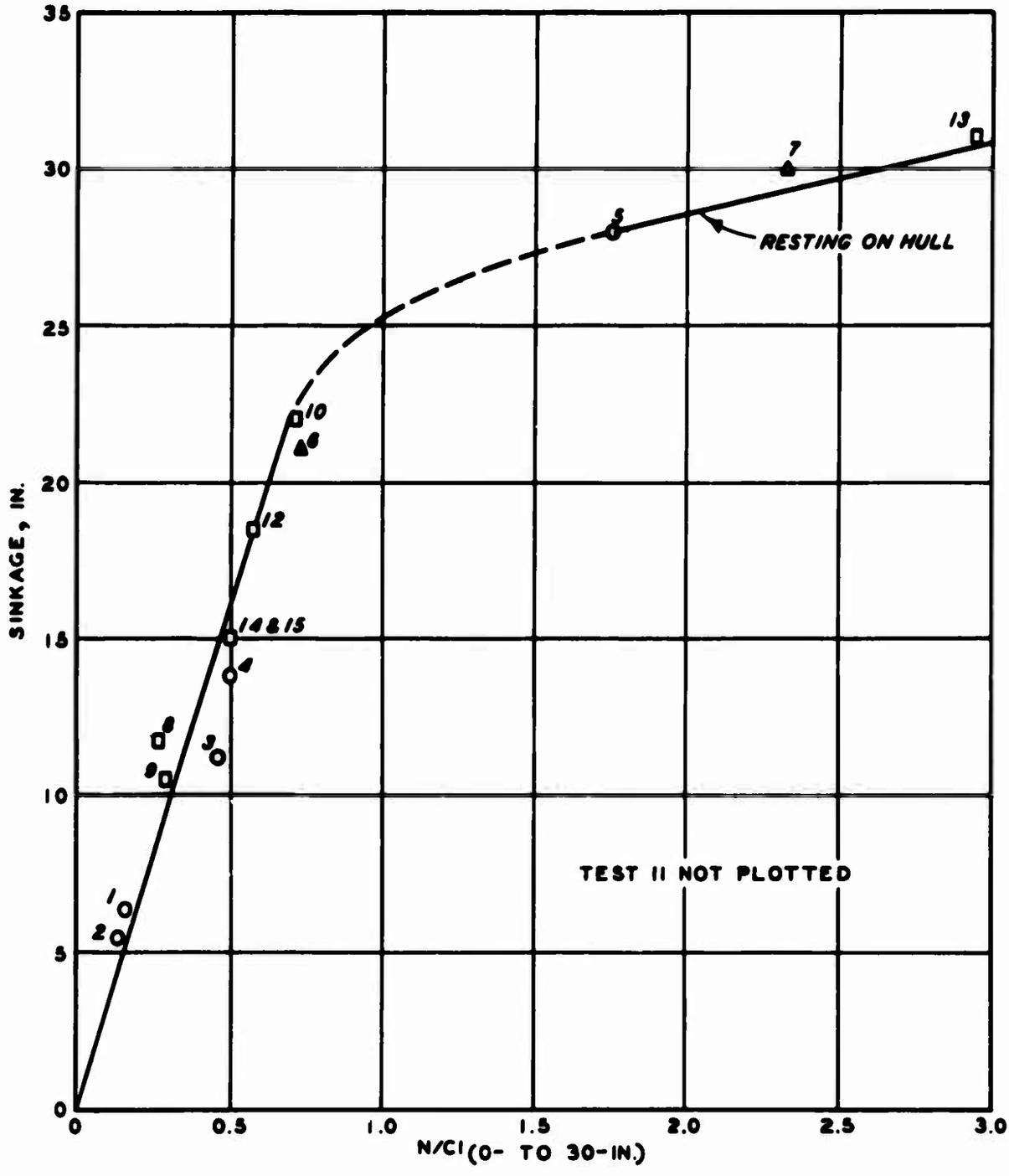
RELATIVE LOCATION OF LANDINGS IN LAKE AREA

PLATE 3



RELATIVE LOCATION OF LANDINGS IN SPOIL AREA

PLATE 4



NOTE: $N = \frac{W}{bdh} = \frac{\text{VEHICLE WEIGHT}}{\text{NOMINAL TIRE WIDTH} \times \text{TIRE DIAMETER} \times \text{NUMBER OF TIRES}}$

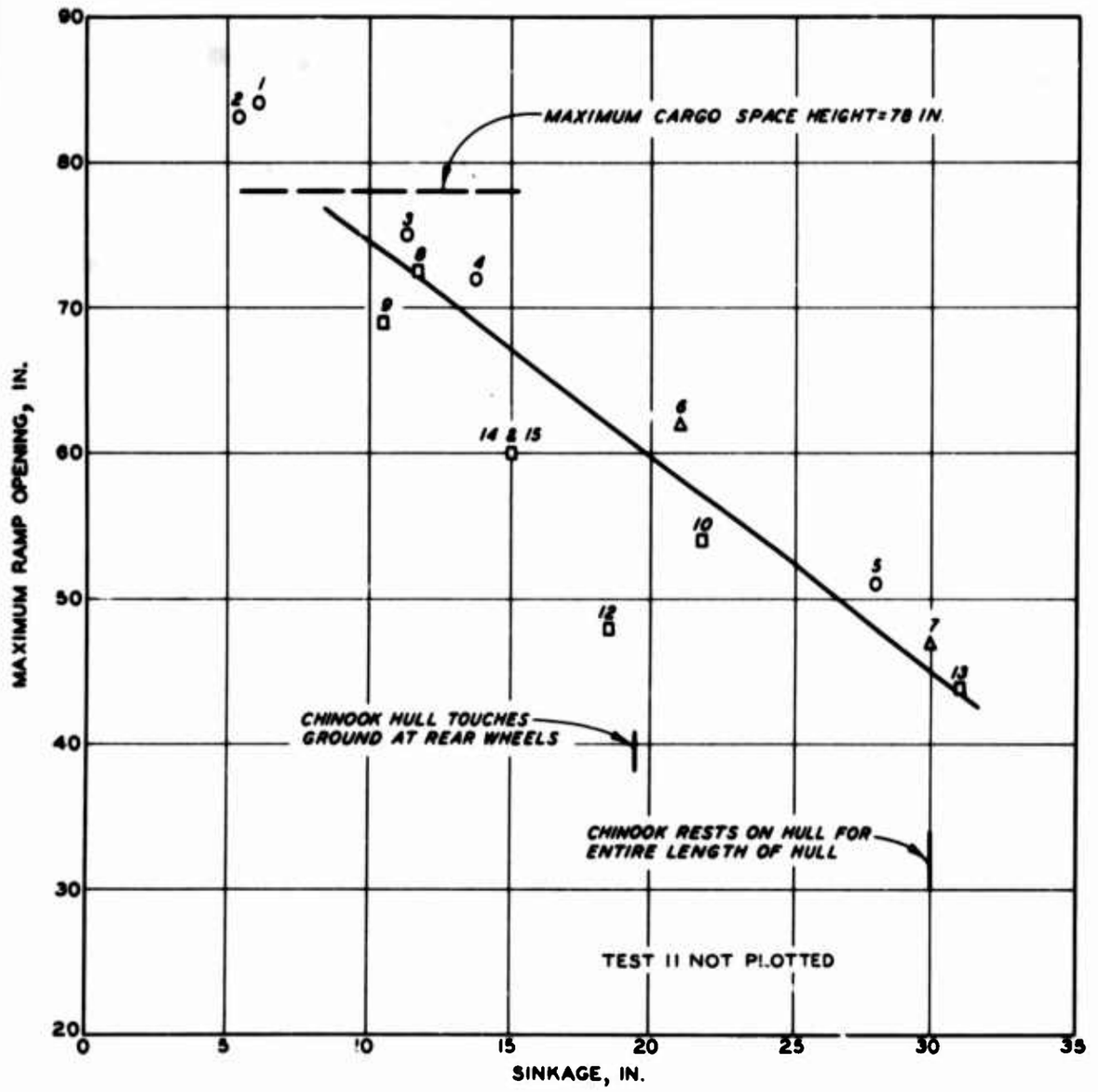
LEGEND

- ○ EMPTY WEIGHT
- △ 5000-LB PAYLOAD
- □ 12,330-LB PAYLOAD

NUMBERS BY POINTS ARE TEST NUMBERS.

SINKAGE VS BEARING PRESSURE-CONE INDEX RATIO

PLATE 5



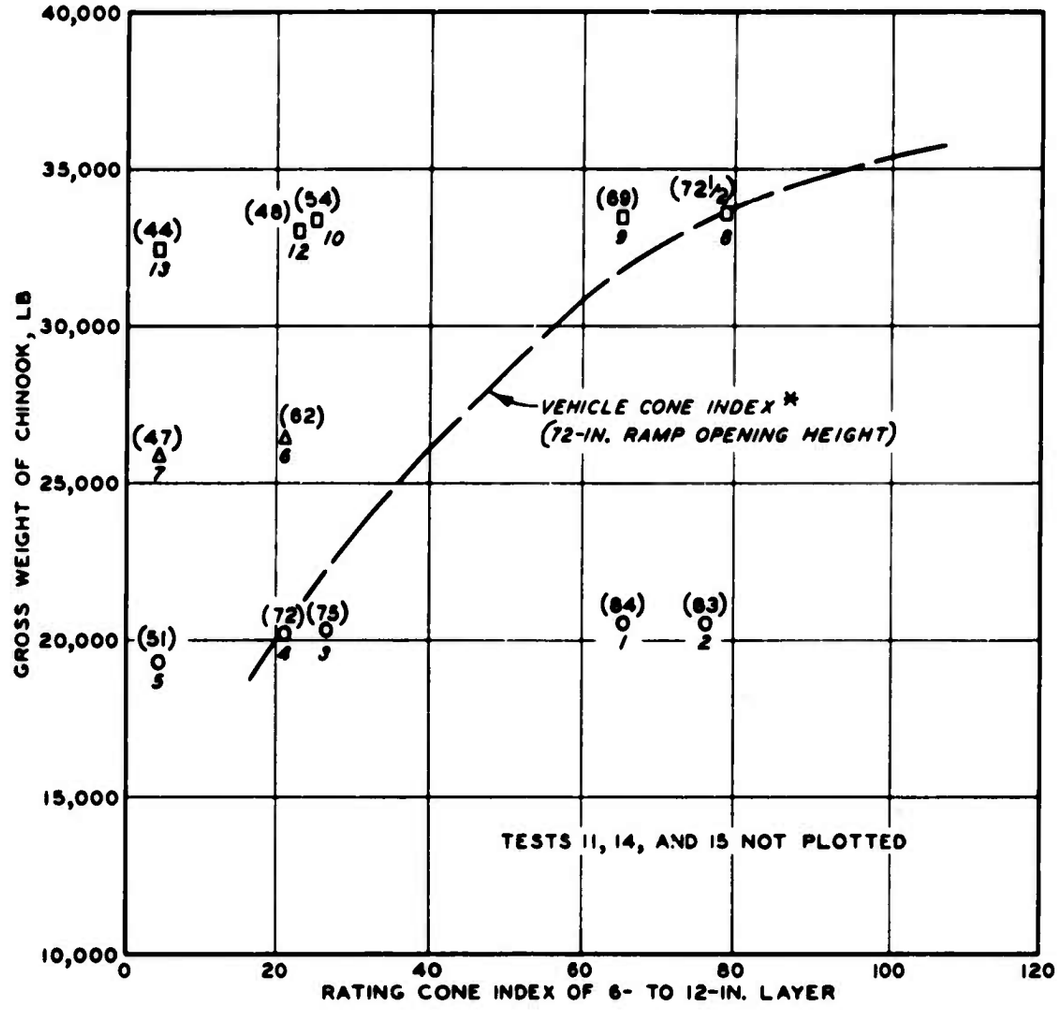
LEGEND

- O EMPTY WEIGHT
- Δ 5000-LB PAYLOAD
- □ 12,330-LB PAYLOAD

NUMBERS BY POINTS ARE TEST NUMBERS.

SINKAGE VS MAXIMUM RAMP OPENING

PLATE 6



LEGEND

- ○ EMPTY WEIGHT
- △ 5000-LB PAYLOAD
- □ 12,330-LB PAYLOAD

NOTE: NUMBERS IN PARENTHESES OVER PLOTTED POINTS INDICATE RAMP OPENING HEIGHT IN INCHES. OTHER NUMBERS ARE TEST NUMBERS.

*SEE PARAGRAPH 30 OF TEXT.

EFFECTS OF VEHICLE WEIGHT AND RATING CONE INDEX ON HEIGHT OF RAMP OPENING

APPENDIX A: CHINOOK TESTS ON SOFT SOIL AT ABERDEEN PROVING GROUND, MD.

WESFR 28 June 1965

MEMORANDUM FOR RECORD

SUBJECT: Chinook Tests on Soft Soil at Aberdeen Proving Ground (APG), Md.

1. From 21 to 24 June 1965 soft-soil testing with the Chinook was continued at APG, since the Vicksburg tests pointed out that the loading ramp opening height would not be large enough to permit discharge of vehicles when sinkage of the landing gear was greater than about 12 in. At APG, vehicle ingress and egress tests were performed in a swampy area consisting predominantly of dense vegetation (cattails) on a heavy mat of dead vegetation and roots overlying decomposed organic material to a depth of at least 3 ft. Ground vehicles used were an M116, a Spryte, and an XM571.

2. Two Chinook helicopters were used. One had standard landing gear but the rear ramp was removed; the other had snow skis mounted on it and had the standard ramp in place. Each landing is discussed below; cone indexes for the landings and a reconnaissance performed later are given in Incl 1.

a. First landing - Chinook with wheels and no ramp. The Chinook sank to the hull, but no vehicle tests were conducted.

b. Second landing - Chinook with wheels and no ramp. The Chinook sank to the hull. A modified 3-ft-long ramp was built, with a 12-in. rise and a lip that fitted over the floor of the cargo space. The M116 and the Spryte could not enter the cargo space because the steep ramp slope caused the top of the vehicle to hit the top of the cabin. The XM571 entered and exited without difficulty.

c. Third landing - Chinook with skis and standard ramp. The sinkage was approximately 3 in. after the vehicle entrance-exit tests. The ramp opened at least 78 in. Approximate ski size was: front, 3-1/2 ft wide by 12 ft long; rear, 3 ft wide by 7 ft long. The only problem

encountered was vehicle-track slippage on the ramp after water and mud accumulation.

d. Fourth landing - Chinook with skis and standard ramp. Sinkage was 6 to 9 in., but the ramp opening was adequate for entrance and exit of vehicles.

3. To test the capabilities further, a reconnaissance was made on the afternoon of 23 June in the Chinook with skis and with an approximate 10,000-lb payload (M116). The landings made are listed below; measurements and observations were made without leaving the helicopter (except for cone index measurements).

a. Romney Creek, first landing. This was a small area free of vegetation and consisting of black, smelly, organic matter with some fibrous qualities. Ski sinkage was approximately 6 in. on the front and 12 in. on the rear. The ramp opening height was marginal for vehicle discharge; however, the ramp probably could have been forced into the soil without damage.

b. Romney Creek, second landing. This area consisted of a dense vegetal growth and firm mat. There was no ski sinkage.

c. Romney Creek, third landing. There was approximately 15 in. of water over a vegetation-free surface in this area. Water obscured sinkage, but the Chinook was still settling at lift-off approximately 3 min after landing. Almost the entire length of the hull of the helicopter was in the water. The ramp opening height was large enough to permit discharge of the vehicle.

d. Swaderick, first landing. Very little vegetation over black organic matter with little to no root mat comprised this area. Sinkage was approximately 10 in. with adequate ramp opening height to permit discharge of the vehicle. The organic material was underlain by sand at 36 in.

e. Swaderick, second landing. Water and seaweed to a depth of 18 in. were present here. Sinkage could not be measured, but the ramp opening height was adequate to permit discharge of the vehicle.

f. Munson. In the Munson area one landing was made along a drainageway at high tide. The water was 15 in. deep over a soft, black, loose, nonfibrous peat. Had the Chinook remained at rest longer than about 2 min, it probably would have settled to a depth at which the ramp opening height would have been less than that required to permit discharge of the vehicle.

4. It was my observation that the skis help to maintain an adequate ramp opening height, except possibly in the softest soil areas. Some modification may have to be made in the method of mounting the skis, since

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SUBJECT: Chinook Tests on Soft Soil at Aberdeen Proving Ground (APG), Md.

it was observed after the above-discussed recon landings that two ski alignment cables had been broken. Tests with skis also should be conducted on soft mineral soils. If ski operation proves impractical, it is believed possible that a modified ramp, operated mechanically rather than hydraulically, could be used on the standard Chinook to allow adequate ramp opening height for the vehicles to enter and exit.

1 Incl
as

E. S. RUSH
Engineer
Chief, Trafficability Section, AMRB

Area and Landing	Cone Index (at Indicated Depth, in.) Surface	3	6	9	12	18	24	30	36
Munson, 1st	5	14	28	17	21	24	49	49	67
Munson, 2d	6	17	31	28	22	23	24	28	31
Munson, 3d	8	31	36	24	21	23	19	33	58
Munson, 4th	7	17	21	21	19	21	19	23	19
				Reconnaissance					
Romney Creek, 1st	5	10	10	15	15	20	20	20	20
Romney Creek, 2d	10	30	40	55	40	30	25	25	25
Romney Creek, 3d	5	5	5	10	10	10	10	--	--
Swaderick, 1st	5	5	5	5	12	12	15	15	80
Swaderick, 2d	----water and seaweed----					10	15	20	--
Munson, 1st	0	0	5	5	5	10	--	--	--

Incl 1

Unclassified
Security Classification

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Vicksburg, Mississippi

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2b GROUP

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4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Final report

5 AUTHOR(S) *(Last name, first name, initial)*
Rush, E. S.

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11 SUPPLEMENTARY NOTES

12 SPONSORING MILITARY ACTIVITY
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Washington, D. C.

13 ABSTRACT

The primary purpose of the test program reported herein was to determine quantitatively the performance of the CH-47A Chinook helicopter in soft soils. Tests were conducted at three different locations on a range of soil strengths and at three different payloads. A total of 15 landings were made on 27 and 28 May 1965 near Vicksburg, Miss. Subsequent tests were conducted at Aberdeen Proving Ground, Md., from 21 to 24 June 1965. The Aberdeen Proving Ground tests are discussed briefly in Appendix A.

It was concluded that (a) the Chinook has adequate power for lift-off from most soft soil conditions, (b) a relation exists between sinkage of landing gear assembly into a soil and the ratio of bearing pressure to cone index, and (c) the presently designed cargo ramp will allow a cargo space entrance height of 72 in. only when the helicopter landing gear sinkage is about 12 in. or less.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Helicopters						
Soils -- Strength						

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