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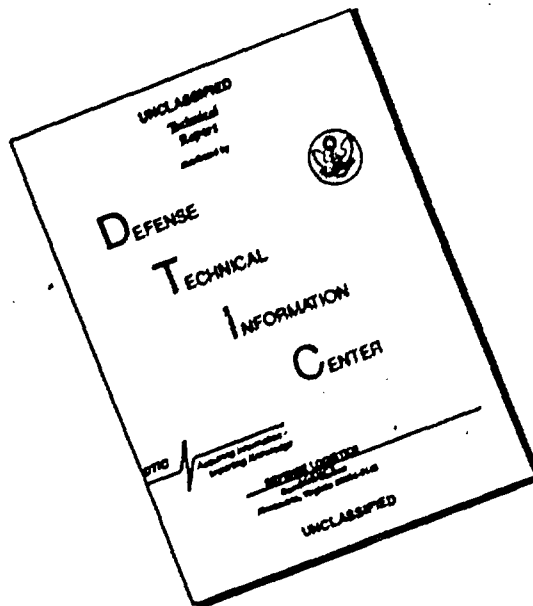
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TRAFFICABILITY OF SOILS

**TESTS ON COARSE-GRAINED SOILS
WITH SELF-PROPELLED AND TOWED
VEHICLES, 1956 AND 1957**



TECHNICAL MEMORANDUM NO. 3-240

FIFTEENTH SUPPLEMENT

June 1959

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

PREFACE

The tests reported herein are part of the studies conducted by the U. S. Army Engineer Waterways Experiment Station under Corps of Engineers Subproject 8-70-05-400, "Trafficability of Soils as Related to the Mobility of Military Vehicles," and were also financed in part by the Bureau of Yards and Docks, Department of the Navy.

Acknowledgment is made to the consultants for trafficability studies and to the representatives of the Bureau of Yards and Docks, Department of Agriculture, Detroit Arsenal, and Office, Chief of Engineers, who participated in a conference at the Waterways Experiment Station on 12 May 1955 and offered suggestions for conducting the tests reported herein. Special acknowledgment is made to Dr. A. A. Warlam, consultant, for his participation in the Pacific islands test program.

These tests were performed by personnel of the Army Mobility Research Center, Soils Division, Waterways Experiment Station, under the supervision of Messrs. W. J. Turnbull, C. R. Foster, and S. J. Knight. Engineers actively engaged in the study were Messrs. A. A. Rula and E. S. Rush. This report was prepared by Mr. Rush.

Directors of the Waterways Experiment Station during the conduct of this study and preparation of this report were Col. A. P. Rollins, Jr., CE, and Col. Edmund H. Lang, CE. Mr. J. B. Tiffany was Technical Director.

CONTENTS

	<u>Page</u>
PREFACE	iii
SUMMARY	vii
PART I: INTRODUCTION	1
Purpose and Scope of Test Program	1
Previous Investigations	1
Pilot Study of Coarse-grained Soils	2
Definitions	3
PART II: TEST PROGRAMS	7
Pacific Island Test Areas	7
Yuma, Arizona, Test Areas	24
Camp Lejeune, N. C., Test Area	25
Instruments Used to Obtain Test Data	26
Vehicles Tested	29
Tests Conducted	36
Vehicle-test Procedures and Data Obtained	39
Sand Data Obtained	41
PART III: ANALYSIS OF DATA	48
Basis of Analysis	48
Single Self-propelled Tests	50
Towing Tests	58
Towed-vehicle Tests	64
Notes and Observations	65
PART IV: CONCLUSIONS AND RECOMMENDATIONS	70
Conclusions	70
Recommendations	71
TABLES 1-9	
PLATES 1-16	

SUMMARY

Three types of vehicle tests (self-propelled, towing, and towed) were conducted with several military vehicles over a range of vehicle weights, tire pressures, and sand strengths and conditions for the following purposes:

- a. To determine whether the trafficability characteristics of coral and volcanic sands differ from those of quartz sands previously tested.
- b. To establish more definitive relations between sand condition and vehicle mobility by testing vehicles on softer sands than previously tested.
- c. To determine towing abilities of self-propelled vehicles over a range of sand conditions.
- d. To determine towing-force requirements of various vehicles over a range of sand conditions.

Single self-propelled wheeled vehicles were tested on undisturbed coral and volcanic sands on Pacific islands, and on quartz sand (desert and beach) in the United States. Towing tests with self-propelled vehicles were conducted on harrowed desert quartz sands near Yuma, Arizona. Towed wheeled trailers were tested on disturbed and undisturbed quartz sand at Camp Lejeune, North Carolina. Principal conclusions were that: (a) performance of single self-propelled wheeled vehicles can be expressed in cone index-slope climbing ability terms; (b) wet sands are more trafficable than dry-to-moist sands; (c) performance, as defined by the cone index-slope climbing curves, is the same regardless of sand source (quartz, volcanic, or coral) or location (beach or desert); (d) towing ability of self-propelled vehicles (wheeled and tracked) on harrowed sand slopes can be computed with reasonable accuracy from performance measurements obtained in tests of the respective vehicles on level harrowed sand; and (e) towing-force requirements of wheeled trailers can be correlated with cone index and tire pressure.

TRAFFICABILITY OF SOILS
TESTS ON COARSE-GRAINED SOILS
WITH SELF-PROPELLED AND TOWED VEHICLES
1956 AND 1957

PART I: INTRODUCTION

Purpose and Scope of Test Program

1. The tests reported herein are part of a study to establish relations between coarse-grained soils and the ability of military vehicles to negotiate them. These tests had the following specific objectives:
 - a. To determine whether the trafficability characteristics of coral and volcanic sands differ from those of quartz sands previously tested.
 - b. To establish more definitive relations between sand condition and vehicle mobility by testing vehicles on softer sands than previously tested.
 - c. To determine towing abilities of self-propelled vehicles over a range of sand conditions.
 - d. To determine towing-force requirements of various vehicles over a range of sand conditions.
2. Objectives a and b were accomplished by tests on the beaches of certain islands in the Pacific Ocean. Objective c was partially accomplished by tests on desert sands near Yuma, Arizona, and objective d was partially accomplished by tests at Camp Lejeune, North Carolina. Testing of additional vehicles on a wider range of sand conditions will be necessary to complete these latter two objectives.

Previous Investigations

3. Since 1945 the Waterways Experiment Station has conducted a large number of traffic tests with military vehicles on a variety of soil conditions. Results of this work have been published in a series of reports with the general title "Trafficability of Soils," Technical Memorandum No. 3-240, which are listed on the inside of the front cover of this volume. Most of the tests were conducted on fine-grained soils, as these

were believed to cause the greatest trafficability problems. The development of instruments and techniques for measuring the trafficability of these soils is considered to be essentially completed. Work to develop methods of measuring trafficability of coarse-grained soils is continuing.

Pilot Study of Coarse-grained Soils

4. In October 1953, a joint Army-Navy ad hoc committee assigned the responsibility for studying means of determining the trafficability of beaches (particularly those with coarse-grained soils) to the Waterways Experiment Station. The first phase of this project was a pilot study to provide background information concerning mobility problems on coarse-grained soils, and to determine whether instruments and techniques that have been successful in defining trafficability of fine-grained soils would also be successful in coarse-grained soils. This study was accomplished in 1954 and is reported in Technical Memorandum 3-240, 13th Supplement. All the vehicle tests reported in the 13th Supplement were conducted on quartz-type sands found on inland areas and beaches of the United States. The important findings of this pilot study are summarized as follows:

- a. Sand categories. Two distinct sand categories, each requiring a different technique for the determination of its trafficability, were recognized: (1) clean sands that reacted in a frictional manner to traffic, and (2) sand with fines, poorly drained, that reacted in a more plastic manner.
- b. Instruments. The cone penetrometer was found to be as accurate an instrument for measuring sand trafficability as any tested, and was recommended for future use in sands, mainly on the basis of its ability to determine profile conditions but also because it had been previously accepted for use in fine-grained soils.
- c. Remolding effects. No necessity was found for predicting strength changes under vehicle traffic for most sands (see subparagraph d). For sands with fines, poorly drained, strength changes had to be estimated and a technique for doing this was developed.
- d. Repetition of traffic. In general, the first pass was found to be the most difficult for a wheeled vehicle in a sand area. Succeeding passes were made with increasingly less difficulty and smaller and smaller increases in rut depth. An exception to this occurred in some crusted sand. The surface crust supported the vehicle for one pass (or a few)

but suddenly broke on a subsequent pass, causing the vehicle to become immobilized or making operation more difficult in the much softer sand and deeper ruts. Because only a few tests were conducted on crusted sands, no attempt was made to devise a means of predicting break-through.

- e. Tire pressure. Among individual vehicle characteristics, tire pressure was the most influential single factor in the performance of wheeled vehicles in sand.
- f. Critical layer. For all vehicles tested, the critical layer of the various sands appeared to be the top 6 in.

Definitions

5. Certain soil, beach, test-media, and vehicle terms used in this report are defined for the convenience of the reader.

Soil terms

Fine-grained soil (fines). A soil of which more than 50% of the grains, by weight, will pass a No. 200 U. S. standard sieve (smaller than 0.074 mm in diameter).

Coarse-grained soil. A soil of which more than 50% of the grains, by weight, will be retained on a No. 200 sieve (larger than 0.074 mm in diameter).

Sand. A coarse-grained soil with the greater percentage of the coarse fraction (larger than 0.074 mm) passing the No. 4 sieve (4.76 mm).

Sand with fines, poorly drained. A sand that contains some fine-grained soil and is slow-draining. When wet, such sands behave similarly to very wet fine-grained soils under vehicular traffic.

D_n . Particle diameter, in millimeters, that is larger than the grain diameter of n per cent by weight of the sample (e.g., $D_{60} = 0.30$ means that 60% of the sample, by weight, has a grain diameter less than 0.30 mm).

Effective size. The effective size of a soil is that particle diameter, in millimeters, that is larger than the grain diameter of 10% by weight of the sample (D_{10}).

Uniformity coefficient (C_u) = $\frac{D_{60}}{D_{10}}$. An index reflecting the shape

of the grain-size curve. A material composed entirely of grains of the same diameter would have a uniformity coefficient of 1.0.

Median diameter. The median diameter is that particle diameter that is larger (or smaller) than the grain diameter of 50% by weight of the sample (D_{50}).

Density. The unit weight of the soil in pounds per cubic foot. Unless otherwise stated, the density is the dry unit weight.

Moisture content or water content. The ratio, expressed as a percentage, of the weight of water in the soil to the dry weight of the solid particles.

Cone index. An index of the shearing resistance of soil obtained with the cone penetrometer. The value is a dimensionless number representing the resistance of the soil to penetration of a 30-deg cone of 0.5-sq-in. base or projected area. The number, although considered dimensionless, actually denotes pounds of force on the handle divided by the area of the cone base in square inches.

Trafficability. The capacity of a soil to support the traffic of military vehicles.

Bearing capacity. The ability of a soil to support a vehicle without undue settlement.

Traction capacity. The ability of a soil to provide sufficient resistance to the push of the track or wheel of the vehicle to furnish the necessary thrust to move it.

Critical layer. The layer of soil regarded as being most pertinent to establishing the relation between soil strength and vehicle performance. (For coarse-grained soils, this appears to be the 0- to 6-in. layer.)

Liquefaction. The puddling and drastic reduction in strength of saturated (although initially firm) soil under the action of repetitive loading.

Erosion. The washing away of soil particles by water moving under and around that portion of a wheel or track in contact with the soil.

Beach terms

Foreshore (FS).* That part of the beach ordinarily traversed by the uprush and downrush of waves as the tide rises and falls.

* The beach terms noted with an asterisk were extracted from Appendix A, Beach Erosion Board Bulletin, Special Issue No. 2, March 1953. Other terms pertain to specific areas in which vehicular tests were conducted but which are not defined in the above-mentioned reference.

Backshore (BS).* That part of the beach between the foreshore and the forward dune apron (if present) or the coast line.

Berm crest (BC) or beach berm.* The seaward limit of the backshore; usually a relatively flat area paralleling the foreshore and occasionally wetted by waves at high tide.

Berm backslope (BBS). A backshore area between the berm crest and the forward dune apron, usually sloping gently downward and landward.

Forward dune apron (FDA). The concave seaward slope of a line of dunes.

Dune area (DA), coastal. An area of wind-deposited sand between the forward dune apron and the coast line. Coastal dunes may be active or partially stabilized by vegetation.

Dune area, desert. An area of active sand dunes with little or no vegetation present. Desert dunes are much higher and much larger in area than coastal dunes.

Cusp.* One of a series of naturally formed low mounds of sand separated by crescent-shaped troughs spaced at more or less regular intervals along the foreshore.

Scarp, beach.* A line of steep slopes facing seaward, caused by wave erosion of the beach.

Test-media terms

Harrowed sand. Sand that has been harrowed to at least a 12-in. depth and the surface smoothed with a light drag.

Disturbed sand. Sand disturbed by traffic.

Undisturbed sand. A sand that apparently has not been recently disturbed.

Vehicle terms

Pass. One trip of the vehicle over the test course.

Immobilization. In this report, failure of a self-propelled vehicle to travel forward over sand, although it could possibly back up in its ruts. In this report, immobilizations of wheeled vehicles also were considered to have occurred whenever the drive wheels began to jerk violently and the vehicle began to make very labored, slow progress.

* See footnote on preceding page.

Maximum drawbar pull. The maximum amount of sustained towing effort a self-propelled vehicle can produce at its drawbar under given test conditions.

Towing-force requirements. The amount of force required to tow a given vehicle under given test conditions.

Tractive coefficient. The ratio of the maximum drawbar pull to the gross weight of a vehicle.

Slip. The percentage of track or tire movement ineffective in thrusting the vehicle forward.

Ply rating (PR).* A term used to identify a given tire with its maximum recommended load when used in a specific type of service. It is an index of tire strength and does not necessarily represent the number of cord plies in the tire.

* American Tire and Rim Association. et , 1955.

PART II: TEST PROGRAMS

6. As stated earlier, tests were conducted on a number of Pacific islands, at Yuma, Arizona, and at Camp Lejeune, North Carolina. The test program on the Pacific islands consisted in operating single self-propelled, rubber-tired vehicles across level and sloping sand beaches. At Yuma, both rubber-tired and tracked vehicles were tested as single self-propelled and towing vehicles on level and sloping natural sand and harrowed sand lanes. At Camp Lejeune, single self-propelled or towing, and trailer or towed-type wheeled vehicles were tested on disturbed and undisturbed sand, and asphalt. Measurements and/or observations of vehicle performance and pertinent sand data were made for each test. Details of the program are described in the following paragraphs. Locations of test sites on the various Pacific islands are shown in plates 1 and 2. Plate 3 shows the locations of the Yuma and Camp Lejeune sites used in tests reported herein, as well as the sites used in the pilot study reported in TM 3-240, 13th Supplement.

Pacific Island Test Areas

7. Brief descriptions of the islands visited and beaches tested are contained in the following paragraphs. All the beaches tested are of coral and shell origin except the following four: Kalapana Beach on Hawaii, Talofofo Beach on Guam, and the famed Red and Yellow Beaches on Iwo Jima, all of which are of volcanic origin. Representative grain-size curves for the sands at the various test sites are shown in plate 4; supplementary physical property data are presented in table 1. Average beach profiles and cone index isopleths are shown in the figures accompanying the text descriptions. Isopleths show the general strength profile of each beach to assist in a more complete beach description; however, they are not considered in the actual analysis.

Oahu, T. H.

8. Oahu, the third largest island in the Hawaiian Islands chain, is of volcanic origin, but there is no volcano activity there at the present time. The ocean beaches on Oahu are of three types: sand, rocky or

cliffed, and silty clay with vegetation growing down to the water's edge. Only the sand beaches were tested. They consist mainly of coral sands deposited by wind and wave action, but they also include seashell fragments and sand eroded from rock formations which can be seen just below the waterline at low tide on some of the beaches. Vehicle tests were run on five beaches, and cone index profiles and sand samples were obtained on four others. The locations of the beaches are shown in plate 1; they are described in the following paragraphs.

9. Mokuleia Beach. This beach, located on the northwestern shore of

Oahu approximately one and one-half miles west of Mokuleia Station, is about 1000 ft long and 250 ft wide (fig. 1). A profile of the beach is shown in fig. 2. The foreshore averages 15 ft in width, has a 30% slope, and is entirely covered with water at high tide and partly covered at low tide.



Fig. 1. Oahu, T. H., Mokuleia Beach

Above the foreshore is a flat berm crest (which comprises all of the backshore) averaging 12 ft in width, frequently wetted by wave action. Beyond the berm crest is a

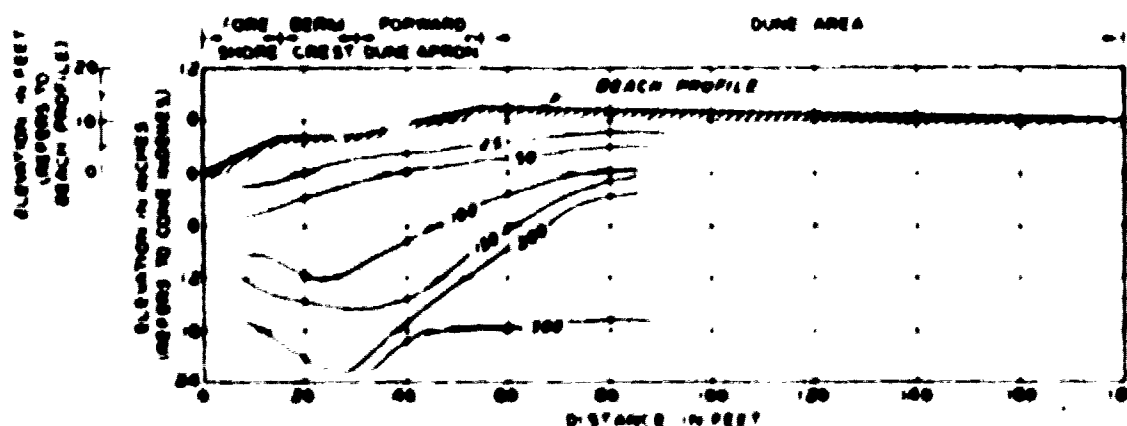


Fig. 2. Beach profile and cone index isopleths,* Mokuleia Beach

* This and all subsequent beach profiles include cone index isopleths, which are lines of equal cone index and denoted by —25—. Elevations are referred to mean low tide. Cone indexes were measured at the surface and at 3-in. vertical increments to a maximum depth of 24 in.

forward dune apron averaging 25 ft in width, with a 2 $\frac{1}{4}$ % slope, on which 1-1/2 in. of dry, loose sand overlies deep, moist sand. The dune area, some 200 ft in width, is relatively flat with 4 in. of dry, loose sand overlying deep, moist sand. On the landward side of the dune area, where the beach sand has mixed with alluvium, there is some vegetation.

10. Vehicle tests were run on the berm-crest and dune-area portions of Mokuleia Beach. The foreshore was too short and the forward-dune-apron slopes too irregular to be suitable test areas. Vehicle tests were run parallel to the shore line on the berm crest, and both parallel and perpendicular to the shore line in the dune area. A representative sample revealed the soil to be a poorly graded (SP) medium sand (plate 4, fig. 1). The cone index for the 0- to 6-in. depth ranged from 14 to 51. Characteristics of the sand are listed in table 1.

11. Drone Beach. Drone Beach is on the same coast as Mokuleia Beach and approximately 3/4 mile farther west (plate 1). This beach is approximately 800 ft long and averages 200 ft in width. A profile of the beach is shown in fig. 3. The foreshore averages 20 ft in width, has a 30% slope, and is entirely

covered with water at high tide and partly covered at low tide. Rock outcrops can be seen underneath the water at the foot of the foreshore. Above

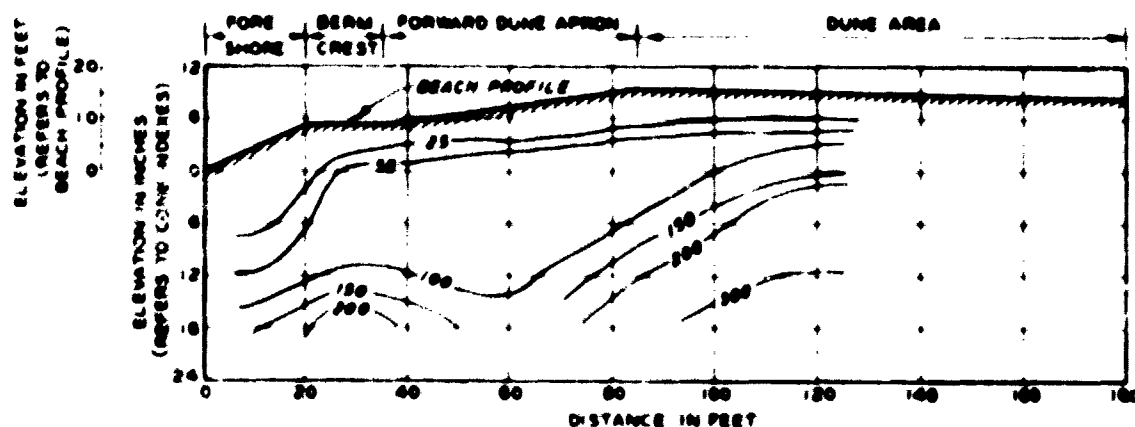


Fig. 3. Beach profile, Drone Beach

the foreshore is a berm crest (which comprises all of the backshore) approximately 15 ft wide and fairly flat, which is frequently wetted by waves at high tide. Beyond the berm crest is a forward dune apron that averages 50 ft in width, has a 15% slope, and is covered with loose, fairly dry sand. The dune area is relatively flat near the forward dune apron but slopes downward as it extends inland.

12. Vehicle tests were run parallel to the shore on the berm crest and perpendicular to the shore on the forward dune apron. No tests were run on the foreshore because of its narrow width, or in the dune area

because of vegetation and irregularity of the surface. The sand was uniform in gradation over the entire beach; a representative sample revealed poorly graded sand (SP), medium-textured (plate 4, fig. 1). The cone index for the 0- to 6-in. depth ranged from 21 to 48. Characteristics of the sand are listed in table 1.

13. Makua Beach. This beach is located on the western shore of Oahu, 3 miles south along the coast from Kaena Point (see plate 1), and is



Fig. 4. Oahu, T. H., Makua Beach

approximately $3/4$ mile long and averages 200 ft in width (fig. 4). A profile of the beach is shown in fig. 5. The foreshore is approximately 30 ft wide and has an average slope of 25%. At high tide the foreshore is almost covered with water.

Most of the foreshore is underlain by rock, which

can be seen as outcrops some distance out from the water's edge. Occasionally, the shore line is broken by crescent-shaped troughs which extend to the forward dune

apron. The berm crest averages 15 ft in width, is relatively flat, and is occasionally wetted by wave action. Landward of the berm crest is the berm backslope, which averages 50 ft in

width; its slope averages 6% downward as it continues inland. The berm backslope is seldom wetted by surf except when the waves are unusually high. Beyond the berm slope is the forward dune apron, which averages

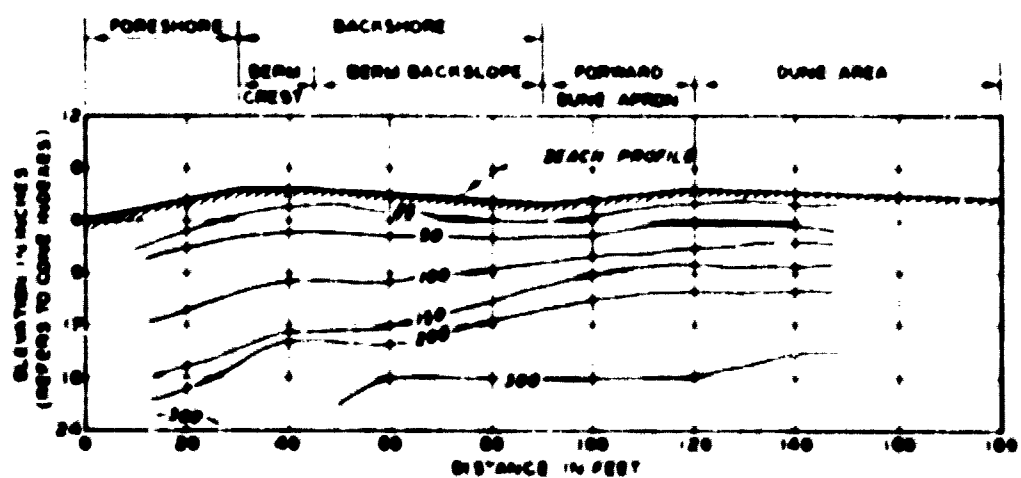


Fig. 5. Beach profile, Makua Beach

25 ft in width and has an uneven surface that is partly due to an old railroad bed over which beach sand has been deposited by wind. Some portions of the dune area were suitable for testing.

14. Vehicle tests were run on all areas of Makua Beach. The tests on the berm crest were run parallel to the shore line, and most of the tests on the forward dune apron were run perpendicular to the shore line. Only a small portion of the foreshore was suitable for vehicle tests. The sand was poorly graded (SP) and fine to medium in texture (plate 4, fig. 1, and table 1); in the dune area the sand was darker in appearance than that of the other areas and had little or no fines. The cone index for the 0- to 6-in. depth ranged from 22 to 136.

15. Crescent Beach. Crescent Beach (fig. 6), located approximately 1 mile southeast of Makua Beach, is not as uniform throughout its length as the beaches described previously and thus is represented by two different profiles, one through a crescent-shaped trough area between cusps, designated area one (fig. 7), and the other through an



Fig. 6. Oahu, T. H., Crescent Beach

area with no cusps, designated area two (fig. 8).

16. An average profile through area one shows a foreshore that is long and relatively flat for foreshores in this area. It averages

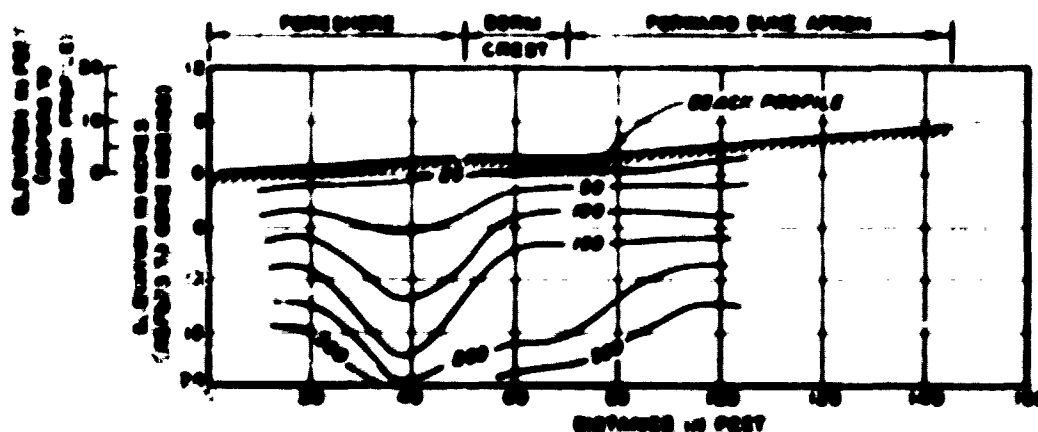


Fig. 7. Beach profile, Crescent Beach, area one

50 ft in width, has a 6% slope, and is entirely covered by surf during periods of high tides and occasionally wetted during low tides. Rocks are exposed at the toe of the foreshore

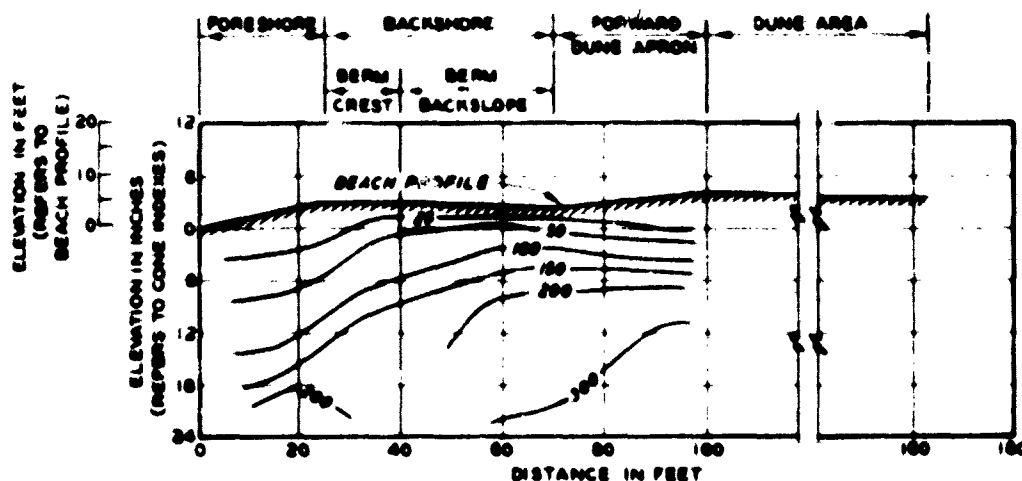


Fig. 8. Beach profile, Crescent Beach, area two

during low tide. Landward of the foreshore is the berm crest, which averages 20 ft in width. No berm backslope is evident, and the forward dune apron rises directly from the berm crest. It averages 75 ft in width and has an

8% slope. The dune area on this beach is a mixture of sand and silt and supports vegetation to such an extent that it was impractical to run vehicle tests on it.

17. An average profile of beach area two is similar to the profile of Makua Beach. The foreshore averages 25 ft in width, has a 25% slope, and leads up to a berm crest approximately 15 ft in width. Landward of the berm crest is the berm backslope, which averages 30 ft in width and slopes downward toward the forward dune apron on an average slope of 4%. The forward dune apron averages 30 ft in width, has a 10% slope, and leads up to a dune area on which are found vegetation such as trees and underbrush.

18. Vehicle tests were run on all portions of Crescent Beach except the dune area. Foreshore tests in the vicinity of the crescent-shaped troughs were run both parallel and perpendicular to the shore line. Tests on the berm crest were run parallel to the shore line, and tests on the berm backslope were run perpendicular to the shore line. A representative sample of sand from Crescent Beach shows a poorly graded (SP), fine-textured material (plate 4, fig. 1, and table 1). The cone index for the 0- to 6-in. depth ranged from 18 to 66.

19. Bunker Beach. This beach (fig. 9), adjacent to the southeast end of Crescent Beach, is approximately 2000 ft long and has two distinct profiles, one of which is similar to the profile of Makua Beach.

20. Area one profile (fig. 10) shows a foreshore averaging 30 ft in width, with an average slope of 25%. The berm crest is about 20 ft wide and is wetted occasionally by high waves. Beyond the berm crest is the berm backslope, averaging 50 ft in width; it has an average slope of 5%

downward as it extends inland. The forward dune apron is about 25 ft wide, and has a 15% slope leading up to a dune area on which some vegetation is growing.

21. Area two profile (fig 11) represents an area in which the berm backslope slopes downward, leaving a low area behind the beach in which water no doubt stands for some time after



Fig. 9. Oahu, T. H., Bunker Beach

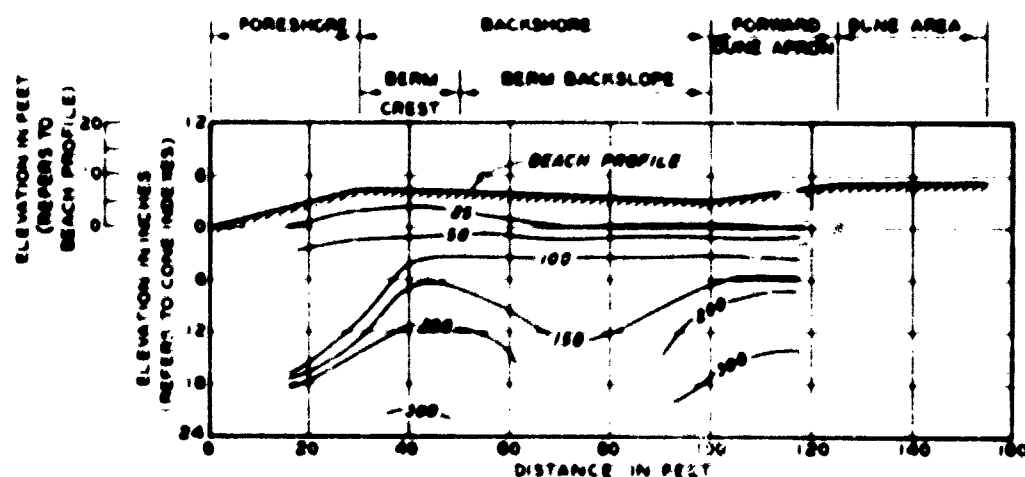


Fig. 10. Beach profile, Bunker Beach, area one

heavy rains. The foreshore of this profile resembles other beaches mentioned in that it averages 30 ft in width and has a 25% slope. The berm crest averages 20 ft in width and is relatively flat. Landward, the berm backslope

22. Vehicle tests were run on the berm crest (parallel to the shore line), the berm backslope (perpendicular to the shore line), and on the forward dune apron (perpendicular to the shore line). The foreshore slope was too steep for vehicle tests, and the dune area contained too much vegetation. The sand

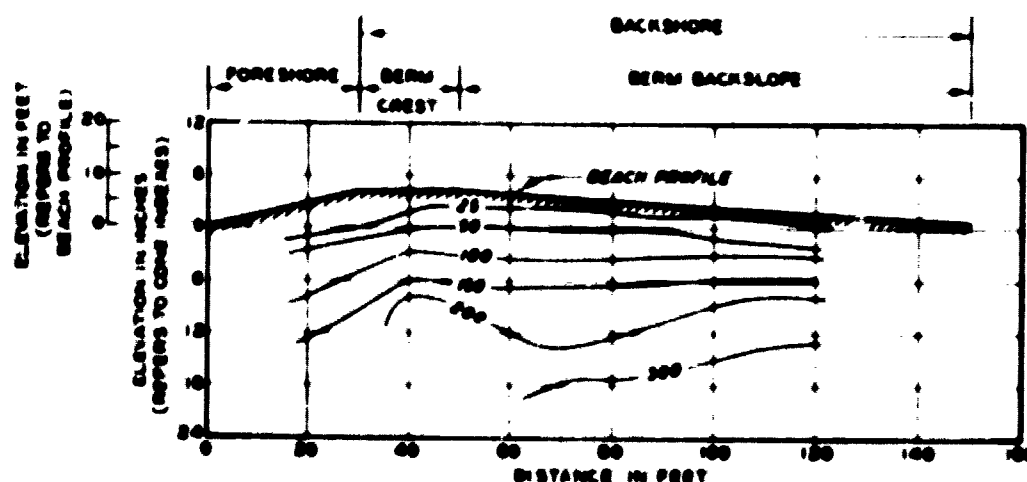
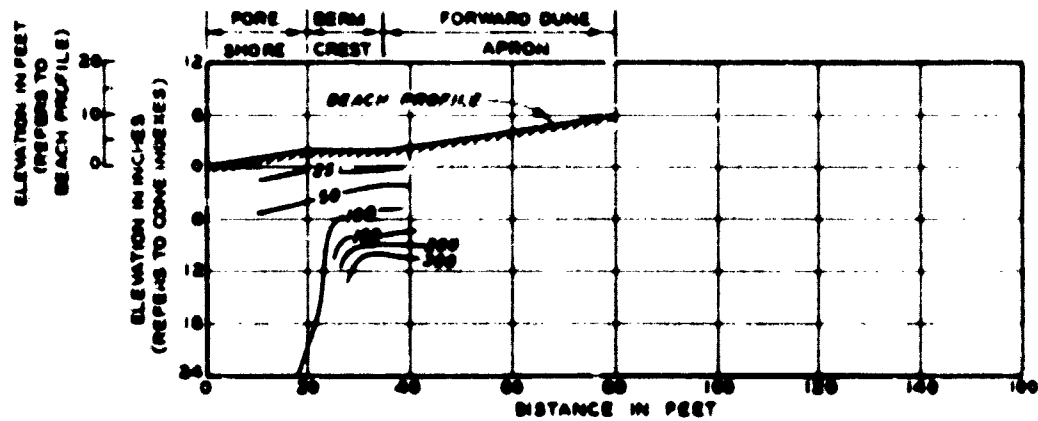
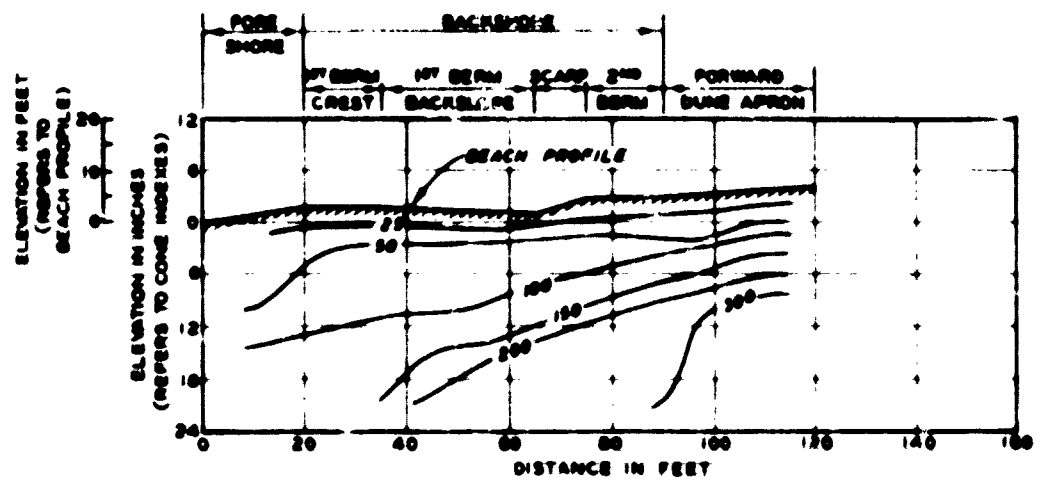


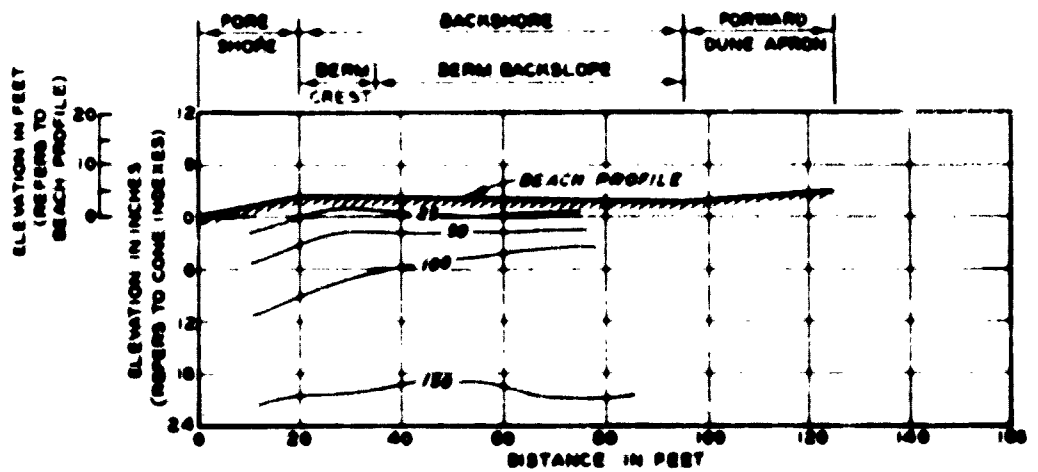
Fig. 11. Beach profile, Bunker Beach, area two



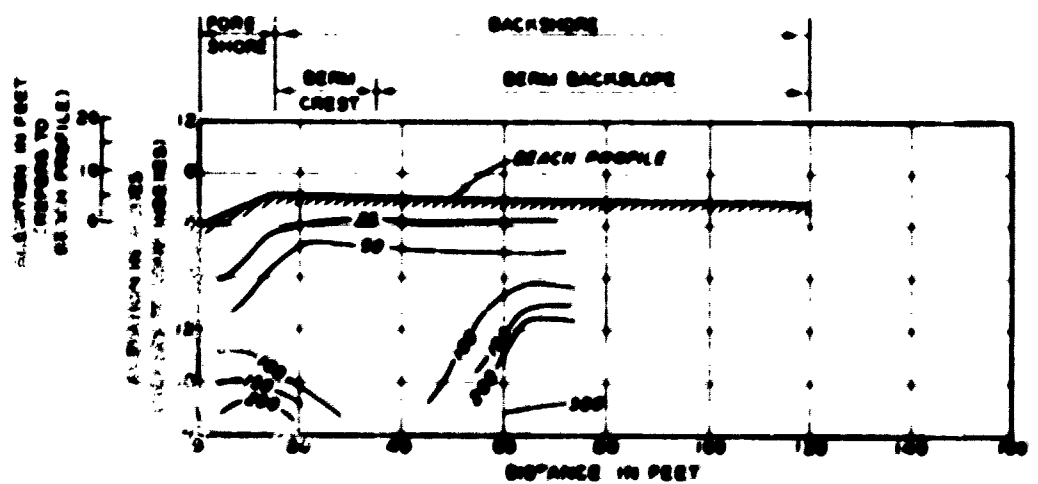
Pokai Bay 1



Pokai Bay 2



Naval
Ammunition
Depot (NAD)



Lact Beach

Fig. 12. Beach profiles and cone index isopleths, Oahu

was poorly graded (SP), with almost equal amounts of medium and fine sizes (plate 4, fig. 2, and table 1). The cone index for the 0- to 6-in. depth ranged from 39 to 85.

23. Other beaches. Only cone index and sand data were obtained on the beaches at Pokai Bay 1, Pokai Bay 2, Naval Ammunition Depot (NAD), and Last Beaches. Profiles of these beaches are shown in fig. 12. The sands from these beaches were all poorly graded (SP) and ranged in texture from medium for Last and Pokai Bay 1 Beaches, to fine-to-medium for NAD and Pokai Bay 2 Beaches (see table 1). The cone index for the 0- to 6-in. depth ranged from 28 to 31 for Pokai Bay 1 Beach, 22 to 52 for Pokai Bay 2 Beach, 26 to 51 for NAD Beach, and 11 to 27 for Last Beach.

Hawaii, T. H.

24. Hawaii is the largest island of the Hawaiian Islands chain and, like Oahu, is of volcanic origin. It is the only island of this chain that has an active volcano at the present time. For the most part the shores of Hawaii are rocky and cliffed, but there are a few sand beaches.

25. The beach tested on Hawaii is covered with black sand derived from lava rock



Fig. 13. Hawaii, T. H., Kalapana Beach

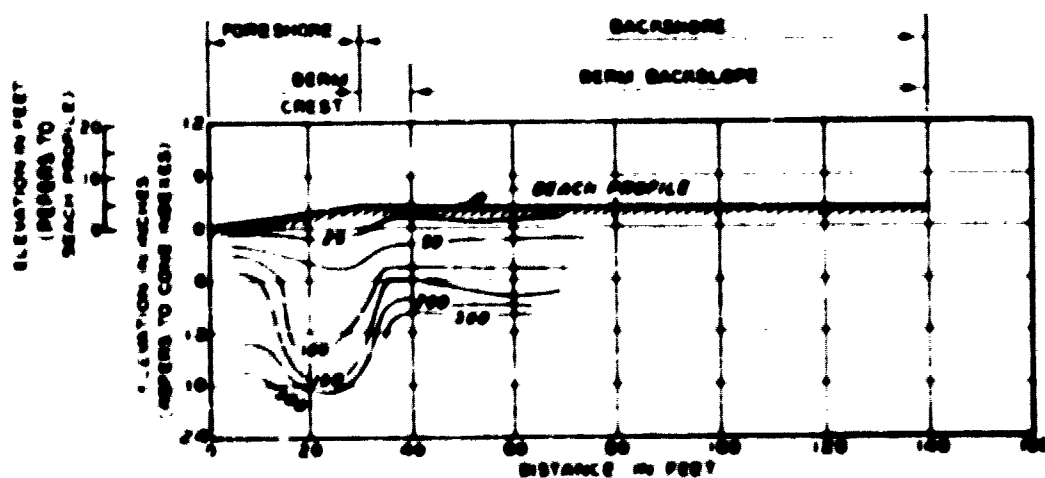


Fig. 14. Beach profile, Hawaii, Kalapana Beach

(fig. 13). A beach profile is shown in fig. 14. Because the beach itself is almost inaccessible by vehicle, no trafficability tests were performed; however, cone index profiles and sand samples were obtained. Kalapana

Beach is approximately $1/4$ mile long and about 150 ft wide. The foreshore is approximately 30 ft wide and has a 12% slope. Bedrock can be seen at the toe of the slope and is partially exposed at low tide. The entire foreshore is wetted during high tide. A berm crest at the top of the foreshore averages 10 ft in width, and the backshore slopes gently downward as it continues inland, with palm trees growing near the berm crest. The sand was poorly graded (SP), fine- to medium-textured (plate 4, fig. 3, and table 1). The cone index for the 0- to 6-in. depth ranged from 25 to 68.

Kwajalein Atoll

26. Kwajalein Atoll (plate 1), one of the largest atolls in existence, is approximately 75 miles long from the western to the southern tip. It consists of coral reefs and small sand bars surrounding a lagoon. Kwajalein, its largest island, is located on the southern tip of the atoll and is approximately 3 miles long and $1/2$ mile wide; most of this area is



Fig. 15. Kwajalein Atoll, ocean side

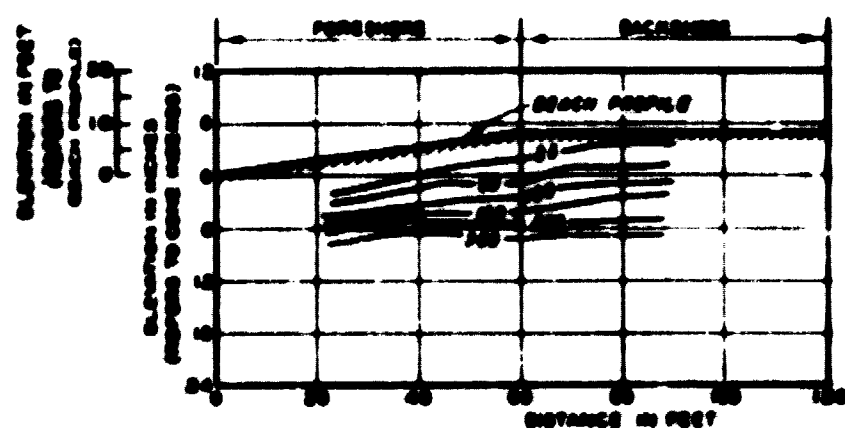


Fig. 16. Kwajalein Atoll, lagoon side

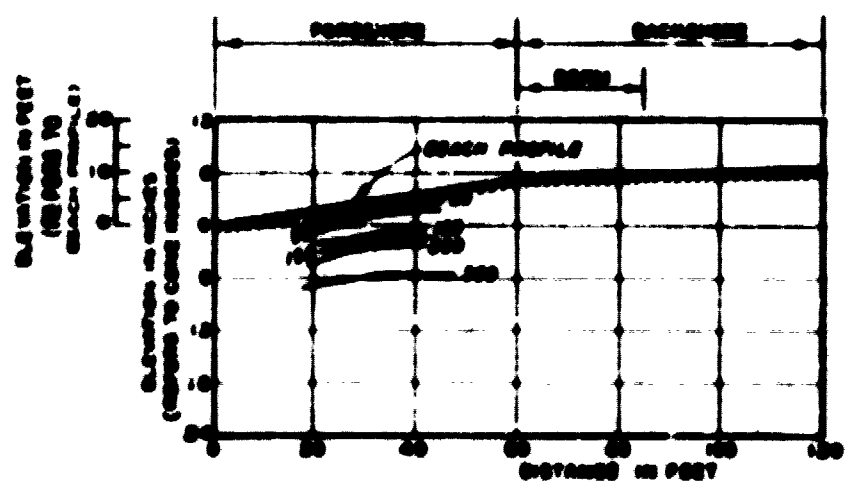
used for an airfield. A profile across the island shows the beaches on the ocean side to be primarily gravel (fig. 15) and somewhat steeper than the coral sand beaches on the lagoon side (fig. 16). The sand on the ocean-side beaches is only a few inches deep and overlies bedrock.

Also, it should be noted that the ending foreshore and beginning of backshore on the lagoon beaches of Kwajalein are not as well defined as on Oahu, where berm crests were present on nearly every beach. Nine vehicle tests were run on three beaches (designated numbers 5, 6, and 7) on the lagoon side of the island where American landings were made in 1944; in addition, cone index and sand data were obtained on another lagoon beach (designated number 1). These four beaches are described in the following paragraphs, and profiles of each are shown in fig. 17. Gradation and characteristics of the sand found on them are given in plate 4 (figs. 3 and 4) and table 1, respectively.

27. Beach No. 1. This beach is located approximately midway along the lagoon coast line of the island. As shown in fig. 17a, the foreshore is 60 ft wide and has a slope of 14%; it is underlain by coral rock at a depth of about 7 in. The backshore extends 60 ft inland and is fairly flat.



a. Beach No. 1



b. Beach No. 5

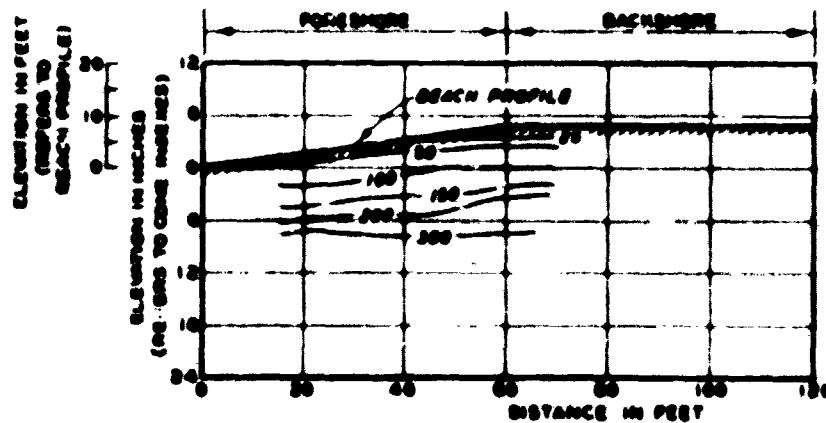
Fig. 17a and b. Beach profiles and cone index isopleths, Kwajalein

The sand from this beach was poorly graded (SP) and fine-textured. Range of cone index for the 0- to 6-in. depth was 47-52.

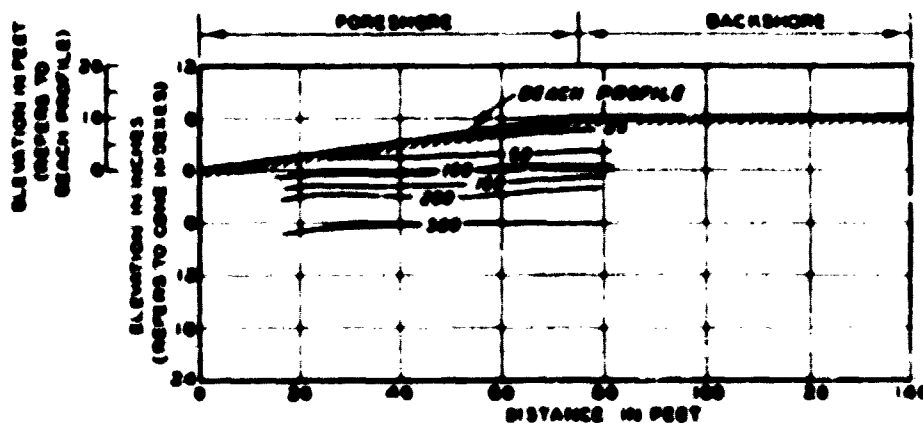
28. Beach No. 5. This beach is located about 1000 ft west of Beach No. 1. Its foreshore averages 60 ft in width and has a 13% slope (fig. 17b). The backshore extends 60 ft inland, rising slightly. The sand was poorly graded (SP), fine- to medium-textured. Cone index for the 0- to 6-in. depth ranged from 107 to 128.

29. Beach No. 6. Located about 2000 ft west of the northernmost tip of the island, this beach has been modified by a hydraulic fill which was pumped in from the lagoon. As shown in fig. 17c, the

foreshore averages 60 ft in width and has a 13% slope. The backshore extends 60 ft inland and is fairly flat. A representative sample from this



c. Beach No. 6



d. Beach No. 7

Fig. 17c and d. Beach profiles and cone index isopleths, Kwajalein

miles long, 4 to 8 miles wide, and about 275 square miles in area. It consists essentially of volcanic rock and coral limestone, with a fringing reef of coral around most of the island. All beaches tested were coral except Talofofo, which was made up of volcanic materials. In the beach descriptions, the backshore areas are not separated into berm crest and berm backslope since these beach areas on Guam were not as pronounced as on Oahu. Seven vehicle tests were run on four beaches, and sand and cone index data were obtained on two additional beaches. The beaches are described in the following paragraphs, and gradation and characteristics of the beach materials are shown in plate 4 and table 1, respectively.

32. Nimitz Beach is located on the west coast of Guam approximately 1 mile south of New Agat. A beach profile is shown in fig. 18. The foreshore in the vicinity of the test area slopes 8% and is approximately 25 ft

beach revealed the sand to be poorly graded (SP), medium- to fine-textured, with some silt. Cone index for the 0- to 6-in. depth ranged from 50 to 153.

30. Beach No. 7. Located on the northern tip of the island, this beach has a foreshore that averages 75 ft in width and has

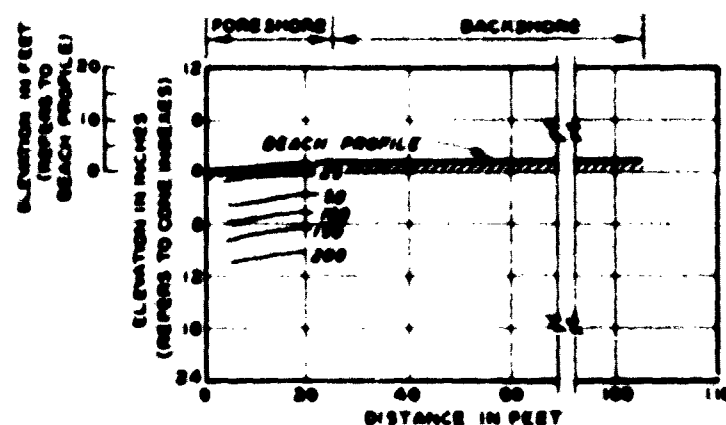
an average slope of 13% (fig. 17d). The backshore extends 65 ft inland and is fairly flat. The sand was poorly graded (SP), medium- to fine-textured. Cone index for the 0- to 6-in. depth ranged from 62 to 136.

Guam

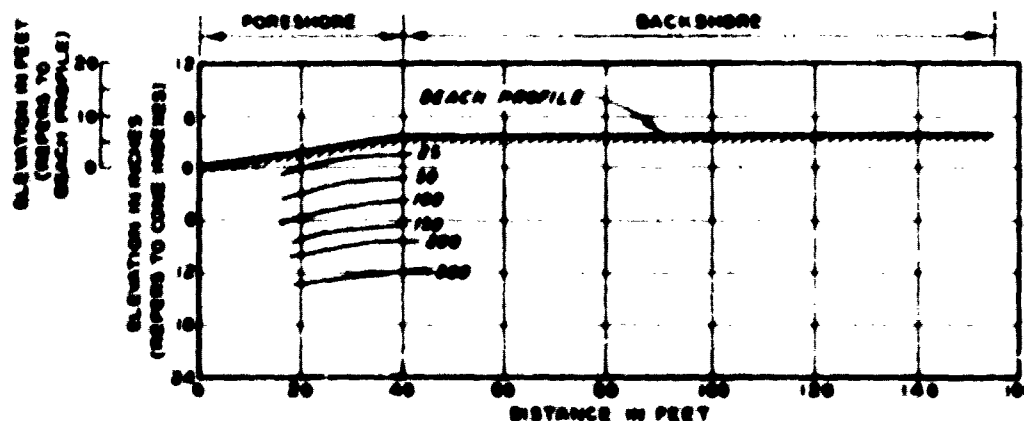
31. The island of Guam (plate 2) is approximately 30

wide. The backshore is relatively flat and extends 80 ft inland (fig. 18a). The sand on this beach was poorly graded (SP) and fine-textured. The cone index for the 0- to 6-in. depth ranged from 52 to 68.

33. Jones Beach, located on the east coast of Guam approximately 1-1/2 miles north of Talofofo Bay, has a foreshore approximately 40 ft in width, with a 14% slope. As shown by the profile in fig. 18b, the backshore is 110 ft wide and fairly flat. Sparse vegetation grows on the backshore. The sand was poorly graded (SP) and medium-textured. The cone index for the 0- to 6-in. depth ranged from 31 to 52.



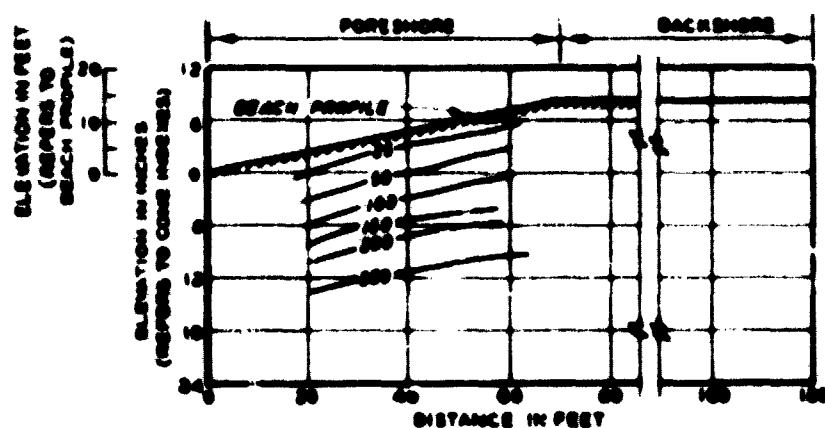
a. Nimitz Beach



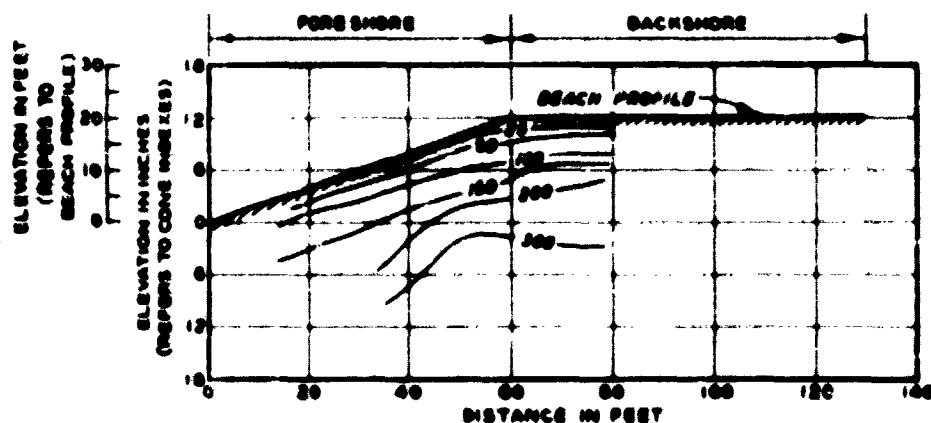
b. Jones Beach

Fig. 18a and b. Beach profiles and cone index isopleths, Guam

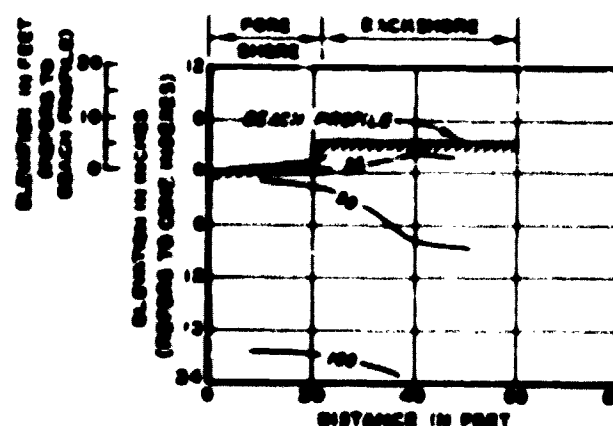
34. Tarague Beach, located on the northern coast, midway between Ritidian Point and Pati Point, is about 180 ft wide. The foreshore averages 70 ft in width and has a 20% slope; the backshore is flat (fig. 18c). The sand was poorly graded (SP), medium- to fine-textured. Cone index for the 0- to 6-in. depth was 40 to 41. Fig. 19 is a view of this beach.



c. Tarague Beach



d. NCS Beach



e. Talofoto Bay Beach

Fig. 18c, d, and e. Beach profiles and cone index isopleths, Guam

35. NCS Beach is located on the western shore about 1 mile south of Haguto Point. The foreshore is about 60 ft wide with a 20% slope. The backshore is flat and 70 ft in width (fig. 18d). The sand was poorly graded (SP), fine- to medium-textured. Cone index for the 0- to 6-in. depth ranged from 79 to 86.



Fig. 19. Guam, Tarague Beach

36. Talofoto Beach is located on the eastern shore near the neck of Talofoto Bay. The foreshore is about 20 ft wide with a 10% slope. Beyond it is a 4-ft-high scarp (fig. 18e), exposed to erosion by waves during high tide. Above the scarp is a fairly level backshore, 40 ft wide. This beach is inaccessible to wheeled vehicles. A representative sample of soil

showed it to be a poorly graded (SP), medium- to fine-textured sand containing some silt. Range of cone index for the 0- to 6-in. depth was 32-61.

37. Tumon Beach is located on the western shore of Guam, near the southern end of Tumon Bay. As shown in fig. 20, the foreshore averages 60 ft in width and has a 20% slope. The backshore also averages 60 ft in width and slopes downward from the foreshore. Some vegetation is growing on the backshore. The sand is poorly graded (SP), medium- to fine-textured. The cone index for the 0- to 6-in. depth ranged from 102 to 144.

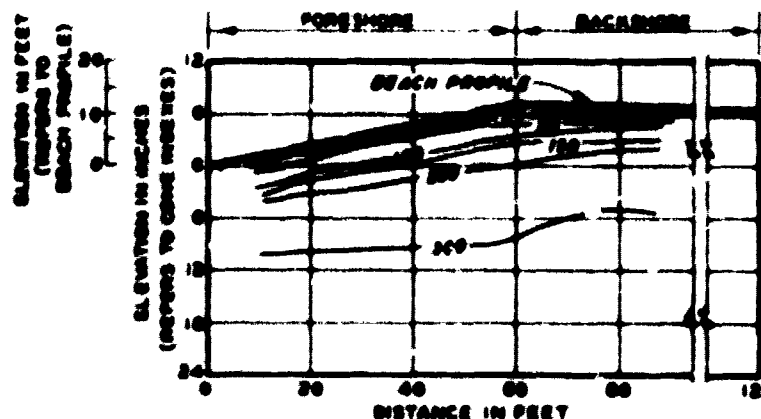


Fig. 20. Beach profile, Tumon Beach

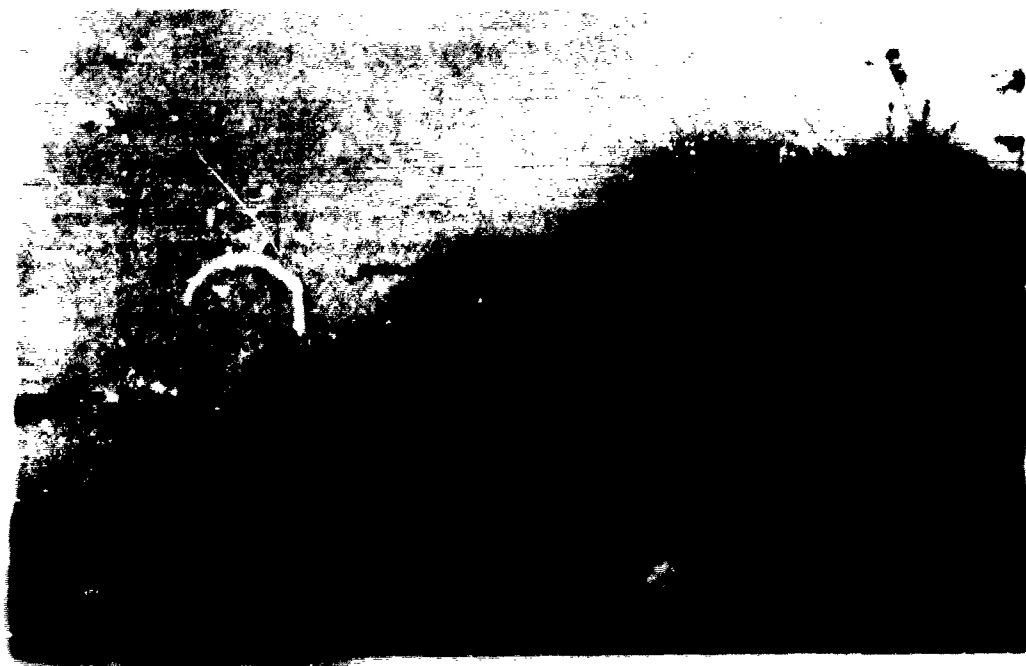


Fig. 21. Luzon, P. I., Lido Beach

Luzon, P. I.

38. Luzon, the largest island of the Philippine Islands group, measures some 40,420 square miles in area. Beaches are numerous but because of the great distance between most beaches and any military reservation, only one beach, Lido, was tested. Lido (fig. 21) is located

approximately 20 miles south of Manila on Manila Bay. The foreshore area tested averages 60 ft in width and has a slope of 18%. The backshore extends 100 ft inland and slopes gently downward (see fig. 22). The Lido Beach grain-size curve showed a poorly graded (SP), fine to medium sand (plate 4, fig. 6, and table 1). Cone index for the 0- to 6-in. depth ranged from 97 to 131.

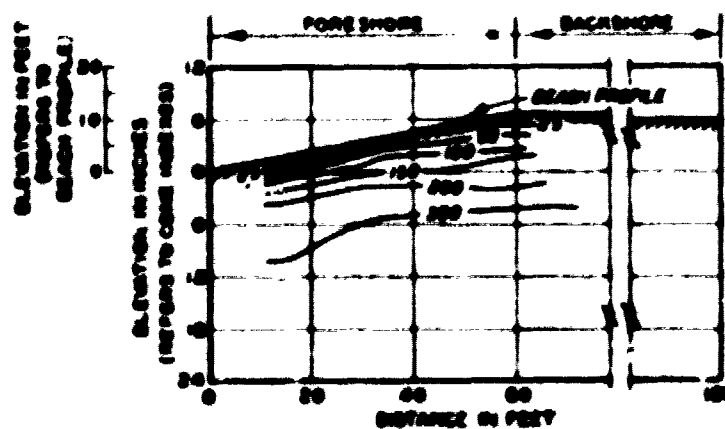


Fig. 22. Beach profile; Lido Beach

Midway Atoll

39. Midway Atoll is located 1300 miles west of Oahu, near the end of the Hawaiian chain. It is circular in shape, the diameter within the en-



Fig. 23. Midway Atoll, Officers' Club Beach

circling reef being about 6 miles. The atoll includes two islands, Sand and Eastern, which have a combined area of approximately 2 square miles. Tests were performed only on Officers' Club Beach (fig. 23), which is located on the northern shore of the lagoon side of Sand Island.

The foreshore averages 60 ft in width and has a slope of 12%. The backshore is fairly flat and is 75 ft wide (fig. 24). A representative sample showed a poorly graded (SP), fine- to medium-textured sand (plate 4, fig. 6, and table 1). The cone index for the 0- to 6-in. depth ranged from 34 to 72.

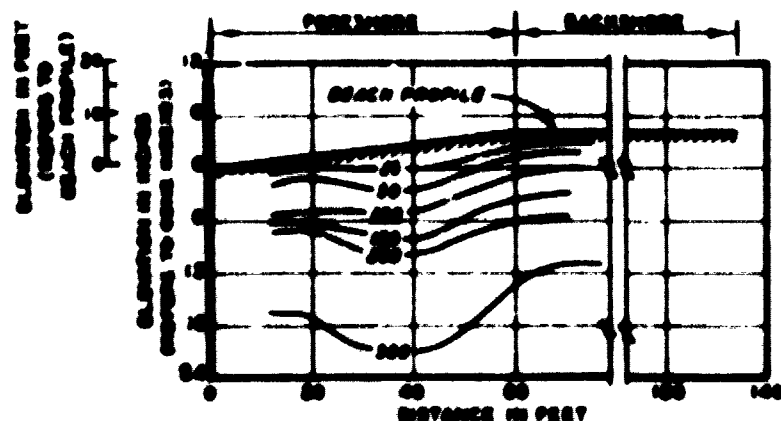


Fig. 24. Beach profile, Officers' Club Beach

Iwo Jima

40. Iwo Jima, the central one of three small islands that make up the Volcano Islands chain, is 5 miles long and 2-1/2 miles wide. The northern portion of the island is a ravine-cut dome, which descends southward through a rough plateau and is connected to Mount Suribachi by an isthmus. Vehicle tests were performed on the two beaches on Iwo Jima on which severe military losses were suffered in 1945, Red Beach and Yellow Beach. Both beaches consisted of weathered volcanic ash.

41. Red Beach. Red Beach (fig. 25) is located on the west shore of Iwo Jima, and extends approximately 2-1/2 miles northward from Mount

Fig. 25. Iwo Jima,
Red Beach

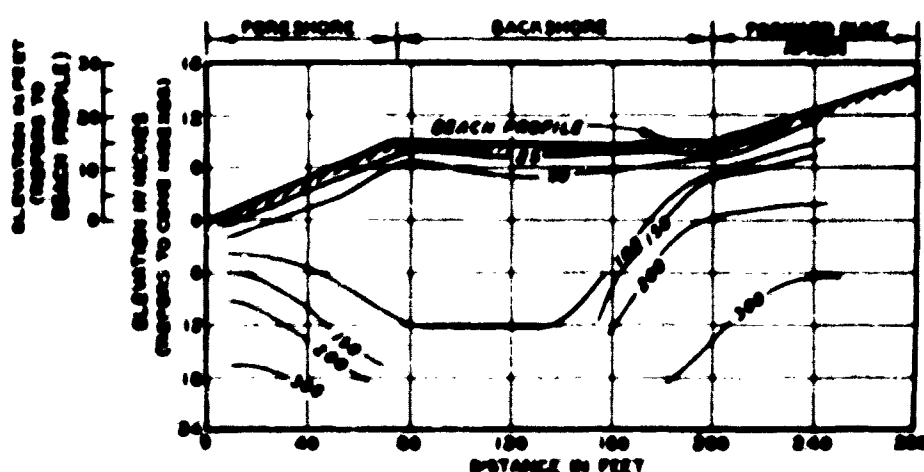


Fig. 26. Beach profile,
Red Beach

Suribachi. The foreshore averages 75 ft in width and has a 20% slope. The backshore extends 125 ft inland and has two berms (see fig. 26). Beyond the backshore the forward dune apron extends 800 ft, and its slope averages 15%. The dune area is partially stabilized by vegetation. The Red Beach grain-size curve showed a poorly graded (SP), fine to medium sand (plate 4, fig. 6, and table 1). The cone index for the 0- to 6-in. depth ranged from 24 to 141.

42. Yellow Beach.

This beach (fig. 27) is located on the east shore of Iwo Jima and



Fig. 27. Iwo Jima, Yellow Beach

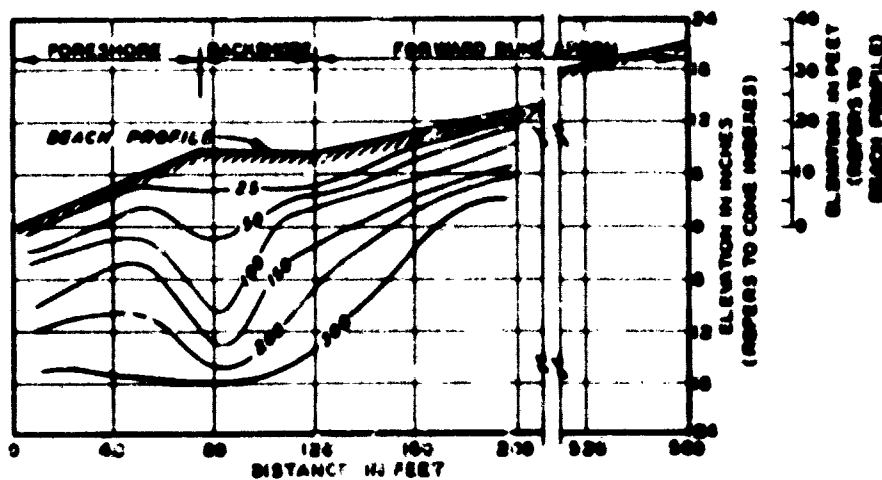


Fig. 28. Beach profile, Yellow Beach

extends approximately 1-1/2 miles northward from Mount Suribachi. The foreshore is 75 ft in width and has a 20% slope. Beyond the foreshore the backshore averages 45 ft in width and slopes slightly downward. The forward dune apron extends 450 ft inland, and its slope averages 12%

(fig. 28). The sand was poorly graded (SP), and medium-textured (plate 4, fig. 6, and table 1). The cone index for the 0- to 6-in. depth ranged from 18 to 88.

Yuma, Arizona, Test Areas

Test Station area

43. Testing at the Yuma Test Station (plate 3), located approximately 25 miles north of Yuma, Arizona, on the east bank of the Colorado River, was confined to prepared test lanes. The test lanes are shown in fig. 29. Towing tests were performed on the prepared lanes, but no single self-propelled vehicle tests.

44. The test lanes, approximately 300 ft long and 40 ft wide, were prepared by harrowing to a depth of 20 in. and smoothing the surface with an aluminum I-beam attached behind the harrow. The test sites included one level area and three slopes with grades of approximately 10, 15, and 20%, respectively. Analyses of samples revealed the



Fig. 29. Yuma Test Station area

sand to be medium- to fine-textured, with a small percentage of fines (see table 1). A representative grain-size curve is shown in fig. 7 of plate 4.

Dune area

45. Tests were also conducted in a sand dune area referred to herein as the Yuma dune area, although it is actually located in California, approximately 20 miles west

of Yuma, Arizona (see plate 3). Fig. 30 shows the general appearance of the test area, which consists of active sand dunes, some as high as 300 ft, although the majority are less than 100 ft high. Analyses of samples from the test area showed the sand to



Fig. 30. Yuma dune area

be medium- to fine-

grained. A representative grain-size curve is shown in plate 4, and supplementary sand data are presented in table 1. Cone index for the 0- to 6-in. depth ranged from 21 to 141. The moisture content of the 0- to 6-in. depth during the test period was approximately 2.0% by weight, unusually high for this area. This was attributed to the fact that the first general rain in about two years occurred at the beginning of testing.

Camp Lejeune, N. C., Test Area

46. Tests were conducted on Onslow Beach (fig. 31) which is located on the Atlantic Coast within the reservation boundaries of Camp Lejeune, N. C. (see plate 3 for location). It is approximately 5 miles long and consists of firm quartz sand. A beach profile is shown in fig. 32. The foreshore ranges in width from 15 to 20 ft at high tide to as much as 100 ft during low tide. The average foreshore slope is about 6%. Cone index for the 0- to 6-in. depth ranged from 50 to 167. Beyond the foreshore was a very short forward dune apron with dune area sand extending to the

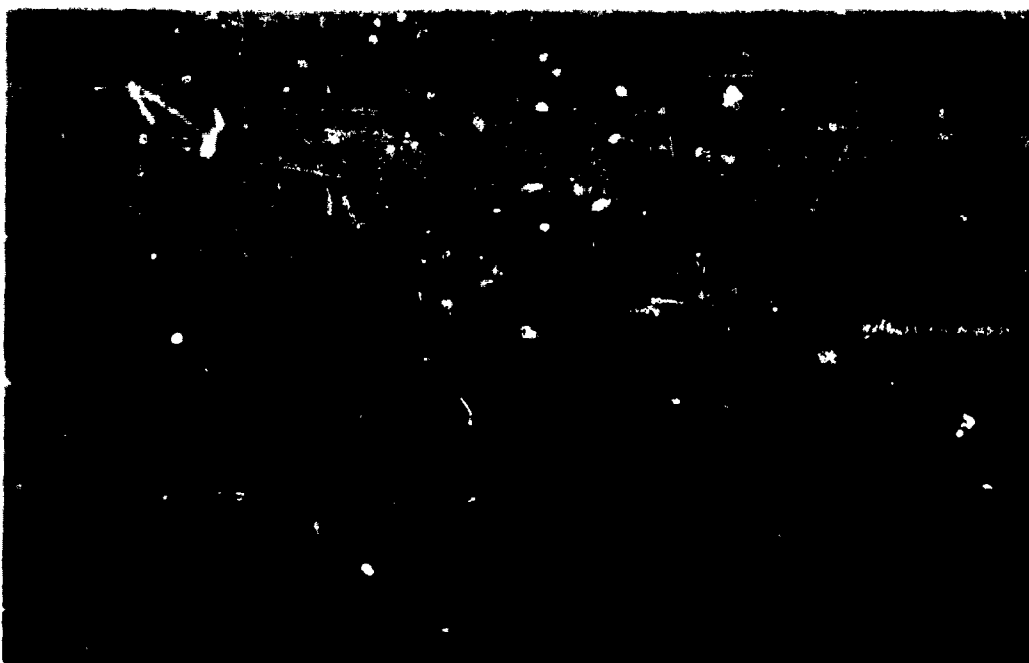
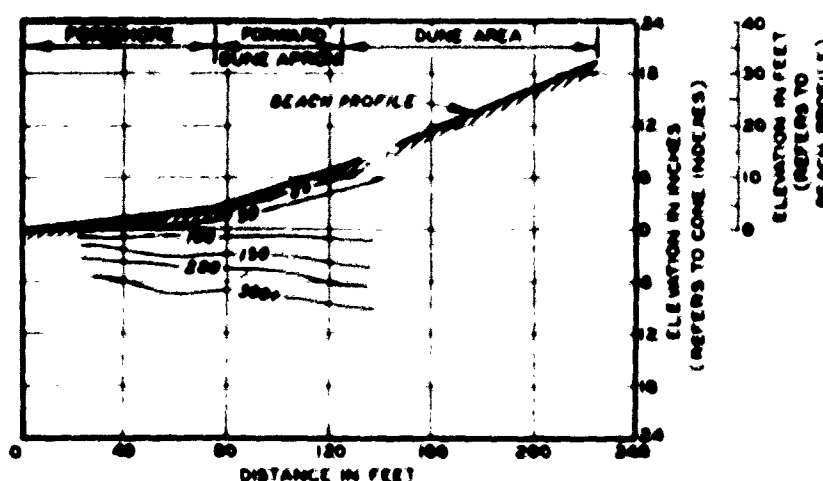


Fig. 31. Onslow Beach,
Camp Lejeune

Fig. 32. Beach profile,
Camp Lejeune



foreshore in some areas. Dune area slopes were short and steep, with only a few low passages through the dunes. Gradation curves for the 0- to 6-in. depth show a poorly graded (SP), fine-textured sand. A representative grain-size curve is shown in plate 4, and supplementary sand data are presented in table 1. All towed-vehicle tests were conducted on the foreshore, parallel to the water's edge. Tests of self-propelled vehicles were conducted on the forward dune apron and dune area.

Instruments Used to Obtain Test Data

47. The cone penetrometer for measuring strength and a hand level for measuring slope were used throughout the three test programs. Tire pressures were checked with laboratory-type test gages during all three test programs. Dynamometers were used only during the Yuma and Camp Lejeune tests; the slip meter was used only at Yuma. These various items of equipment are described in the following paragraphs.

Sand data

48. Cone penetrometer. The cone penetrometer is a field instrument consisting of a 30-deg cone with a 0.5-sq-in. base area mounted on one end of a shaft in such a way that it can be forced into the soil by hand.

The penetrometer in use is illustrated in fig.

33. A proving ring and calibrated-dial assembly are mounted on the other end of the shaft and are used to measure the load applied. The penetration resistance (read from the dial) is termed



Fig. 33. Cone penetrometer in use

cone index (see "Definitions"). This is the same instrument used to measure the trafficability of fine-grained soils.

49. Hand level. A hand level accurate to 0.5% was used for determining the slope prior to each vehicle test. Slope readings were made by placing the hand level in the center of a 6-ft plank adjacent to the vehicle and parallel to the vehicle path. Slope measurements recorded were the average of several measurements around the vehicle.

Vehicle data

50. Tire-pressure gage. The laboratory-type test gages used to regulate tire-inflation pressures during the tests were accurate to 0.25 psi throughout the range of tire pressures tested. Fig. 34 shows a tire-pressure check being made on one of the test vehicles.

51. Dynamometers. The dynamometers used were electrically recording load cells suitable for measuring forces in tension by translating changes in force into changes in electrical energy. These load cells are hermetically sealed and operate without mechanically moving parts. The sensing element is a high-strength load-carrying member to which are bonded special R-4 strain gages that undergo resistance changes precisely proportional to applied strain. The dynamometers, used to measure drawbar pulls during the

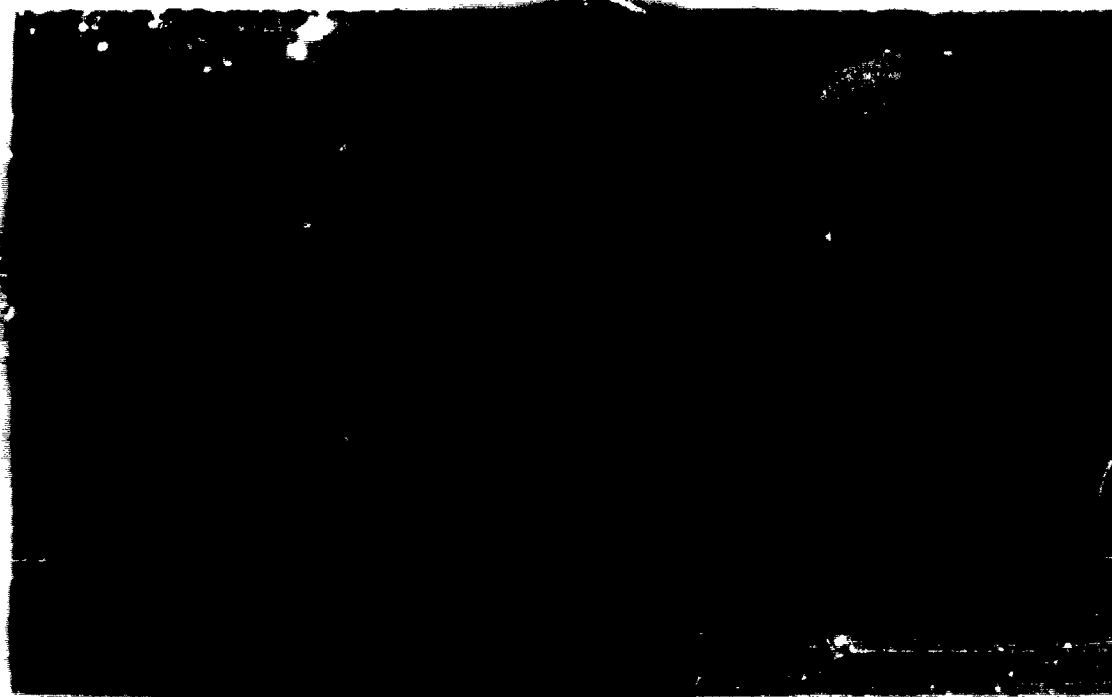


Fig. 34. Tire-pressure check before testing

towing and towed tests, were connected between the test vehicle and the load vehicle, and measured the amount of pull exerted by the towing vehicle. Dynamometers ranged in capacity from 1000 to 50,000 lb, depending upon the amount of force to be measured.

52. Slip meter. The distance a point on the periphery of a wheel or track traveled during a given time and the distance the vehicle traveled during the same time were determined by a slip meter. The meter recorded the number of revolutions the vehicle wheel made while propelling the vehicle, and the number of revolutions made by a nonslipping bicycle wheel trailing the test vehicle and attached to it.

53. Recorder for dynamometer and slip measurements. During the drawbar-slip tests the force exerted on the dynamometer, and the events experienced by the slip meter were amplified and recorded simultaneously as traces on paper tape moving through a six-channel direct-inking recorder. Tests with the 2-1/2-ton M135 utilized all six channels, since electrical contacts were placed on four rear wheels and the bicycle wheel, and one channel was required for recording the dynamometer measurements. Towed-vehicle tests utilized a smaller recorder of the same type since only one channel for recording dynamometer measurements was needed.

54. The complex system of measuring drawbar slip required "instrumenting" an M29C vessel with a recorder, amplifiers, and power supply; this vehicle traveled alongside the test vehicle during testing as shown in

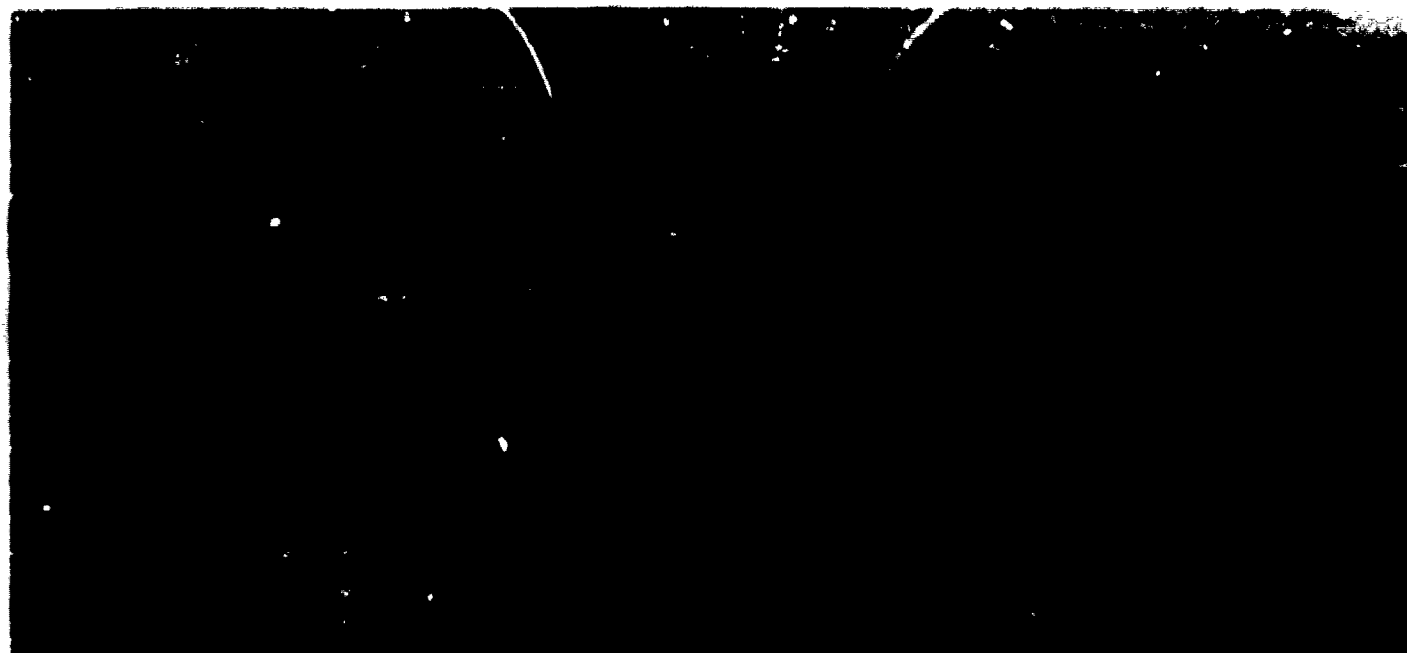


Fig. 35. Towing tests, drawbar pull

fig. 35. Electric cables, connecting the test vehicle and the instrumented vehicle, transmitted the measurements to the recorder. For the simple towed-vehicle tests, recorder, amplifier, and power supply were mounted in the towing vehicle.

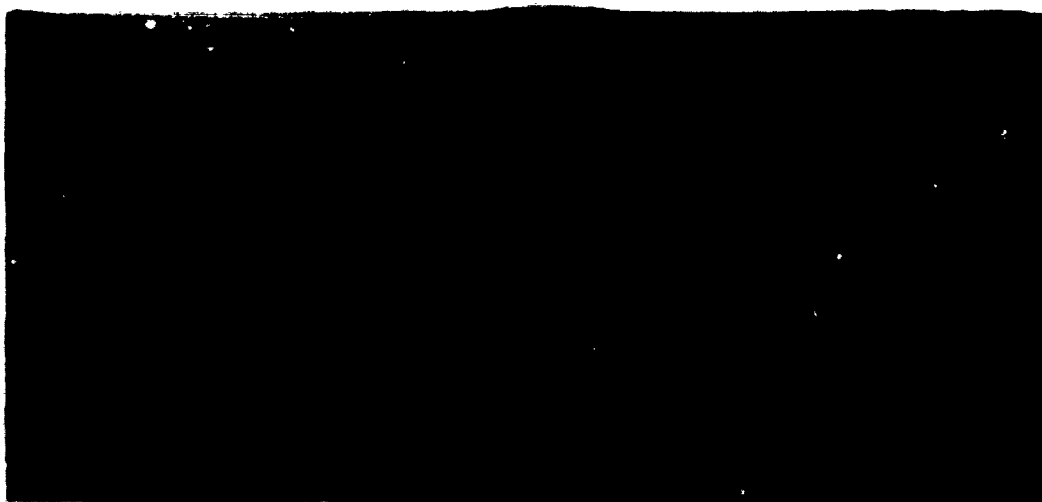
Vehicles Tested

Pacific Islands

55. The vehicles tested were furnished by military units on each island. They included the 1/4-ton M38A1 4x4 truck, the 3/4-ton M37 4x4 truck, the 2-1/2-ton M211 6x6 truck, the 2-1/2-ton M215 6x6 truck, and an unnumbered 2-1/2-ton 6x6 truck. These vehicles are shown in figs. 36 and 37. The test vehicles were equipped with standard equipment and tires, except that the 2-1/2-ton M215 was tested with six 11.00x20 12-ply tires, single tandem (this vehicle normally is equipped with ten 9.00x20 tires). All the vehicles were tested at their rated off-highway payload (nominal capacity) and, in addition, the M215 was tested at one-half the rated payload, and the M211 was tested empty. Vehicle weights, test loads, and tire descriptions are shown in the tabulation on page 32; additional vehicle data are given in table 2.



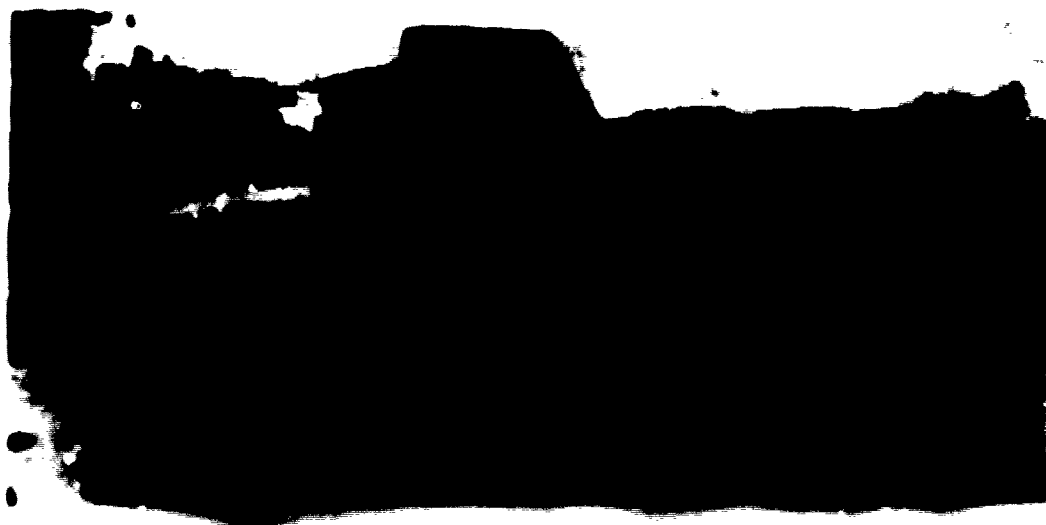
a. 1/4-ton M38A1
4x4 truck



b. 3/4-ton M37
4x4 truck



c. 2-1/2-ton M211
6x6 truck



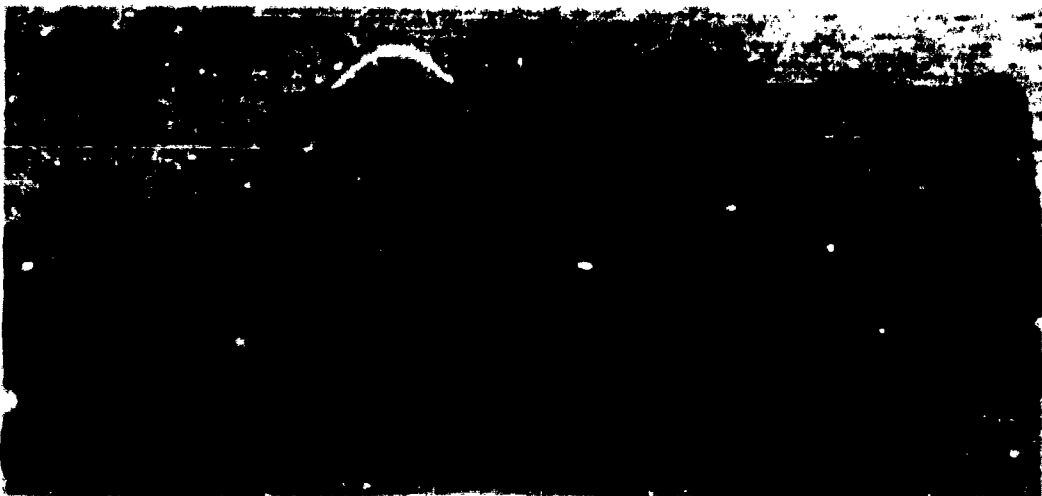
d. 2-1/2-ton M215
6x6 truck

Fig. 36. Self-propelled wheeled vehicles used in tests

a. 2-1/2-ton
6x6 truck



b. 2-1/2-ton M135
6x6 truck



c. 5-ton M41
6x6 truck



d. 5-ton M54
6x6 truck

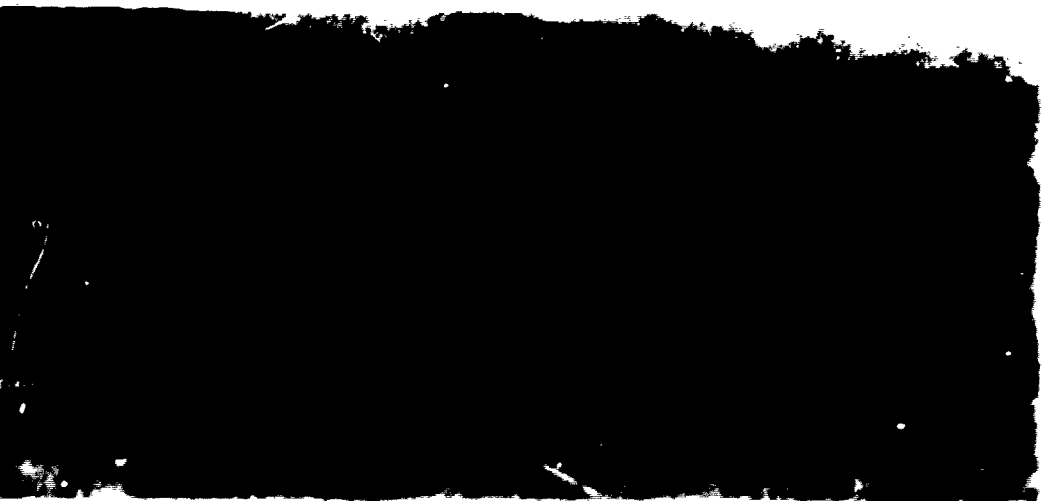


Fig. 37. Self-propelled wheeled vehicles used in tests

Vehicle	Vehicle Wt., lb			Tire Data		
	Empty	Approx Load	Gross	Size	Ply Rating	No.
1/4-ton M38A1 4x4 truck	2,625	500	3,125	7.00x16	6	4
3/4-ton M37 4x4 truck	5,917	1,500	7,417	9.00x16	8	4
2-1/2-ton M211 6x6 truck	13,120	0	13,120	9.00x20	8	10
	13,120	5,000	18,120	9.00x20	8	10
2-1/2-ton M215 6x6 truck	14,820	2,500	17,320	11.00x20	12	6
	14,820	5,000	19,820	11.00x20	12	6
2-1/2-ton 6x6 truck	11,000	4,800	15,800	8.25x20	--	6

56. The truck weights were taken from the identification-data plates inside the cab; however, the 2-1/2-ton 6x6 truck used on Kwajalein had no identification data and its weight was estimated. This truck was very old but still functioned well. Its tire size was 8.25x20, which apparently was not standard for the truck. The drive shaft of the 3/4-ton truck used on Guam broke during a difficult maneuver on the foreshore of NCS Beach. Otherwise, all vehicles tested appeared to be in very good mechanical condition, and were able to spin their wheels when immobilized. The tires on most of the vehicles tested were worn, but otherwise in good condition (no large cuts or bulges).

Yuma, Arizona

57. The vehicles tested were furnished by the Yuma Test Station and are shown in figs. 36, 37, and 38. All wheeled vehicles were equipped with standard military, nondirectional, cross-country tires. The following table lists the vehicles tested and pertinent vehicle data; additional vehicle data are given in table 2.

Vehicle	Wheeled Vehicles Vehicle Wt., lb			Tire Data		
	Empty	Approx Load	Gross	Size	Ply Rating	No.
1/4-ton M38A1 4x4 truck	2,475	500	2,975	7.00x16	6	4
3/4-ton M37 4x4 truck	5,645	0	5,645	9.00x16	8	4
		750	6,275			
		1,500	7,085			
		2,300	7,805			
2-1/2-ton M135 6x6 truck	12,450	0	12,450	11.00x20	12	6
		2,500	15,000			
		5,000	17,330			
		7,500	20,500			
		10,000	22,705			

(Continued)

- a. 1/4-ton M29C cargo carrier (weasel)



- b. 18-ton M4A2 hi-speed tractor



- c. 38-ton M6 hi-speed tractor



Fig. 38. Self-propelled tracked vehicles used in tests

Wheeled Vehicles (Cont'd)

Vehicle	Vehicle Wt., lb			Tire Data		
	Empty	Approx Load	Gross	Size	Ply Rating	No.
5-ton M41 6x6 truck	18,115	0	18,115	14.00x20	12	6
		5,000	24,275			
		10,000	28,175			
		15,000	32,380			
5-ton M54 6x6 truck	20,635	10,000	30,635	11.00x20	12	10

Tracked Vehicles

Vehicle	Vehicle Wt., lb			Track Dim.		Average Contact Pressure, psi
	Empty	Approx Load	Gross	Length in.	Width in.	
1/4-ton M29C weasel	5,970	0	5,970	78	20	1.9
		1,000	6,970			2.2
18-ton M4A2 hi-speed tractor	36,910	0	36,910	126	24	6.1
38-ton M6 hi-speed tractor	76,000	0	76,000	176	22	9.8

58. All vehicles appeared to be in good mechanical condition and, with the exception of the M135 when loaded with 10,000 lb, each vehicle was able to spin its wheels or tracks when immobilized while operating under full load. Testing with the M41 loaded with 15,000 lb was limited because severe side-wall buckling of the tires occurred when the truck was operated with tires inflated to 10-psi pressure.

Camp Lejeune, N. C.

59. The wheeled trailers tested were furnished by the Motor Officer at Camp Lejeune and are shown in fig. 39. The self-propelled tests were conducted with vehicles of the types shown in figs. 36a and b, and fig. 37b. The following table lists the vehicles tested and pertinent vehicle data; additional vehicle data are given in table 2.

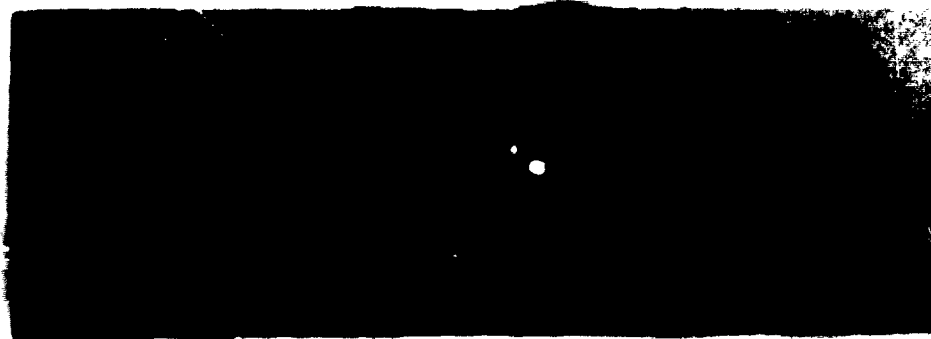
Vehicle	Vehicle Wt., lb			Tire Data		
	Empty	Approx Load	Gross	Size	Ply Rating	No.
<u>Self-propelled Vehicles</u>						
1/4-ton M38A1 4x4 truck	2,775	200	2,775	7.00x16	6	4
3/4-ton M37 4x4 truck	6,067	0	6,067	9.00x16	8	4
2-1/2-ton M135 6x6 truck	12,450	5,000	17,450	11.00x20	12	6

(Continued)

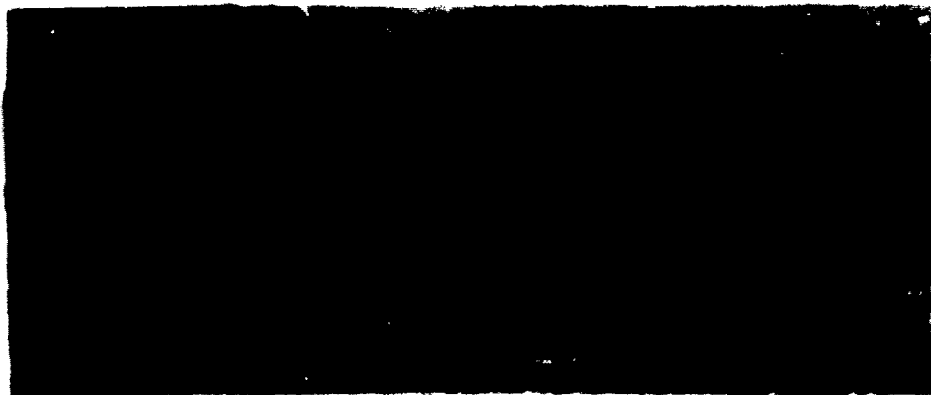
a. 1/4-ton M100 cargo trailer



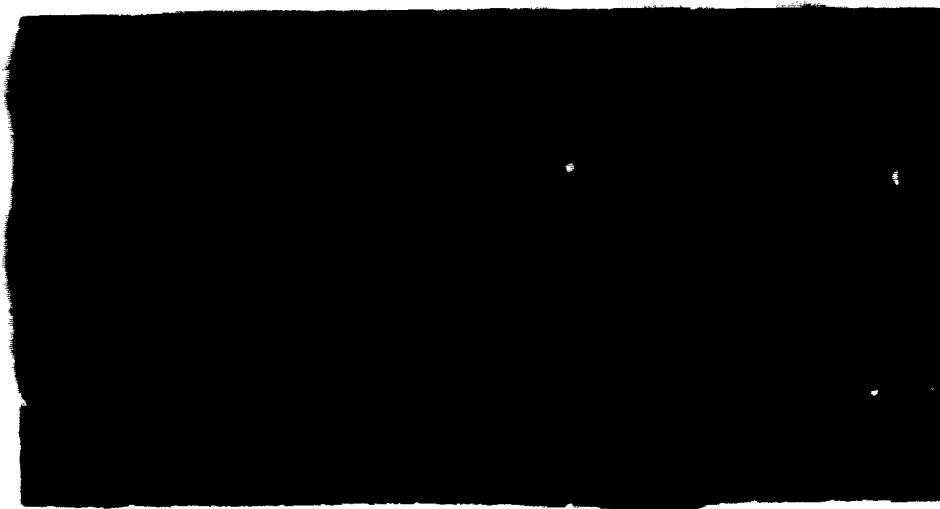
b. 3/4-ton M101 cargo trailer



c. 1-1/2-ton XM105
cargo trailer



d. 37.5-kv generator
trailer



e. 6-ton cargo trailer



Fig. 39. Wheeled trailers used in towed-vehicle tests
at Camp Lejeune, N. C.

Vehicle	Vehicle Wt, lb			Tire Data		
	Empty	Approx Load	Gross	Size	Ply Rating	No.
<u>Towed Wheeled Vehicles</u>						
1/4-ton M100 cargo trailer	569	0 250 500 750	569 782 1,127 1,211	7.00x16	6	2
3/4-ton M101 cargo trailer	1,339	750 1,500 2,250	2,089 2,960 3,679	9.00x16	8	2
1-1/2-ton XM105 cargo trailer	2,450	1,500 3,000 4,500	4,110 5,648 7,482	9.00x20	8	2
37.5-kw generator trailer	7,153	0	7,153	7.00x20	8	4
6-ton cargo trailer	10,960	0 6,000 12,000	10,960 17,160 25,520	10.00x20 (front) 11.00x20 (rear)	10 12	4 4

60. All vehicles tested were in good condition. The three two-wheeled trailers were equipped with standard military tires, and the two four-wheeled trailers were equipped with standard commercially available tires.

Tests Conducted

61. The tests were of three types: single self-propelled vehicle tests, towing tests, and towed-vehicle tests. A single self-propelled vehicle test indicated the ability of the vehicle to negotiate various sand conditions and slopes. Towing tests were made for two general purposes: to determine the maximum drawbar (towing) force the test vehicle could exert while moving slowly forward over a range of soil conditions and slopes, and to develop drawbar pull-slip relations. The towed-vehicle tests were made to measure the force required to tow a given vehicle. The following paragraphs enumerate the types of tests and number of each type

conducted with each vehicle for each of the three general test areas, Pacific islands, Yuma, and Camp Lejeune.

Pacific islands

62. In this test program, 24 beaches located on 7 islands were visited. Vehicle tests were not conducted on 10 of these beaches, but soil classification and cone index data were collected. The vehicle tests on the other 14 beaches were all of the single, self-propelled vehicle type.

63. Single self-propelled tests. The following table shows the number of tests conducted at each beach with each wheeled vehicle.

		Number of Vehicle Tests					
Island	Beach	Vehicle					Total
		M38A1	M37	M211	M215	2-1/2-TT	
Oahu	Mokuleia	7	6	--	1	-	17
	Drone	8	--	--	--	-	8
	Makua	12	57	41	43	-	153
	Crescent	--	40	14	7	-	61
	Bunker	14	--	20	3	-	37
Kwajalein	5	--	1	--	--	-	1
	6	--	4	--	--	3	7
	7	--	--	--	--	1	1
Guam	Nimitz	--	1	--	--	-	1
	Jones	--	2	--	--	-	2
	Tarague	--	3	--	--	-	3
Luzon	Lido	--	1	--	--	-	1
Yuma	Red	34	20	34	--	-	88
	Yellow	--	15	2	--	-	17
Total		75	150	111	57	4	397

64. Other tests. The beaches on which cone index and soil data were obtained but no vehicle tests performed are as follows:

Island	Beach	Island	Beach
Oahu	Pokai Bay 1	Kwajalein	1
	Pokai Bay 2	Guam	Talofoto
	NAD		NCS
	Last		Tumon
Hawaii	Kalapana	Midway Atoll	Officers' Club

Yuma, Arizona

65. Single self-propelled tests. Four wheeled vehicles (M38A1, M37, M135, and M41) were tested at various tire pressures on slopes in the natural dune area. All the vehicles, with the exception of the M38A1, were also tested at various payloads. The following tabulation shows the number of tests conducted with each vehicle.

Number of tests With Each Vehicle				Total
<u>M38A1</u>	<u>M37</u>	<u>M135</u>	<u>M41</u>	<u>Tests</u>
14	102	122	167	405

66. Towing tests. Maximum-drawbar-pull tests (D) were conducted on natural and prepared level and sloping terrain with five wheeled vehicles (M38A1, M37, M135, M41, and M54) and three tracked vehicles (M29C, M4A2, and M6); drawbar pull-slip (S) characteristics were determined only for the M135 2-1/2-ton truck and the M29C weasel. The number of tests conducted with each vehicle on prepared lanes and in the sand dunes is listed below.

Test Area		Number of Vehicle Tests																			
		Wheeled Vehicles										Tracked Vehicles									
		M38A1		M37		M135		M41		M54		Total		M29C		M4A2		M6		Total	
D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Pre- pared lanes		6	0	5	0	31	50	15	0	7	0	64	50	13	32	4	0	3	0	20	32
Sand dunes		4	0	10	0	2	0	0	0	0	0	16	0	3	0	5	0	0	0	8	0
Total		10	0	15	0	33	50	15	0	7	0	80	50	16	32	9	0	3	0	28	32

Camp Lejeune, N. C.

67. At Camp Lejeune, single self-propelled tests were conducted on slopes with three vehicles. Towed-vehicle tests were conducted with five trailers, at various loads and tire pressures, on undisturbed sand (by towing the trailer with a long cable, see fig. 40, page 41), and disturbed sand (by towing a trailer coupled directly behind the towing vehicle, see fig. 39). No towing tests were conducted.

68. Single self-propelled tests. Three wheeled vehicles (M38A1, M37, and M135) loaded to nominal capacities were tested at various tire

pressures on dune slopes. The number of tests made with each vehicle is as follows:

Number of Tests With Each Vehicle			Total Tests
<u>M38A1</u>	<u>M37</u>	<u>M135</u>	
17	29	37	83

69. Towed-vehicle tests. Tests with wheeled trailers were conducted on undisturbed sand, disturbed sand, and asphalt pavement. The following tabulation shows the number of tests conducted with each vehicle.

Test Surface	Number of Tests with Each Trailer					Total
	<u>1/4-ton M100</u>	<u>3/4-ton M101</u>	<u>1-1/2-ton XM105</u>	<u>37.5-kw Generator</u>	<u>6-ton</u>	
Undisturbed sand	16	12	12	4	12	56
Disturbed sand	16	12	12	4	12	56
Asphalt pavement	16	12	12	4	12	56
Total	48	36	36	12	36	168

Vehicle-test Procedures and Data Obtained

Single self-propelled tests

70. All single self-propelled tests were performed in the same manner insofar as possible. Most of the tests on the Pacific islands were performed with vehicles loaded to their off-road payload capacities; the loads were secured to prevent shifting. The tests at Yuma were performed with vehicles empty and loaded to 1/2, 1, and 1-1/2 times their off-road payload capacities. Tire pressures were carefully regulated and checked before each test. The same driver was used with the same vehicle insofar as possible. Each test was made with the vehicle traveling in a straight-line path in low gear, low range, at slow, steady speed, and with all wheels driving. Since previous tests had indicated that the first pass was the most difficult one to make in sand, the tests reported herein were concerned only with one-pass traffic. Test areas were selected on the basis of accessibility, surface smoothness, and absence of vegetation or litter. The tests conducted on beaches were run both parallel and perpendicular to the water's edge. Soils data were obtained, vehicle performance was observed, and pertinent notes were recorded.

Towing tests

71. The vehicle-performance data obtained in these tests consisted of notes concerning immobilizations, general ease or difficulty with which the vehicle traversed the test area, spinning or jerking of wheels, and other pertinent observations. These data are included in tables 3-7.

72. Maximum drawbar pull. The maximum-drawbar-pull tests were performed on prepared lanes and dune slopes at Yuma with the test vehicle towing a second vehicle by means of a cable. As the train moved slowly forward, the load was gradually increased (by application of the brakes on the towed vehicle) until a load condition was established that was thought to be just short of that which would cause immobilization of the test vehicle. This maximum drawbar pull was verified if a slight increase in load caused a halt in the forward progress.

73. The data obtained consisted of continuous measurements of drawbar pull recorded on an oscillograph. The maximum drawbar pull for each test was noted and is given in table 8.

74. Drawbar slip. Drawbar-slip tests were conducted in the same way as the maximum-drawbar-pull tests, except that at several stages between no drawbar pull and maximum drawbar pull records were obtained of the forward speed of the vehicle and the absolute speed of the track or wheel as well as of drawbar pull. The first two measurements permitted the computation of slip. These data are also given in table 8.

Towed tests

75. In these tests, conducted on asphalt pavement and sand at Camp Lejeune, a dynamometer attached to a cable between the towing and towed, trailer-type vehicles was used to measure the towing force. Repetitive tests in the same path were not performed.

76. The vehicle data obtained consisted of towing force required to move the towed vehicle at a slow, steady speed; these data are given in table 9.

77. Long-coupled tests. Tests in which a long cable was used between the two vehicles permitted the offsetting of the towing vehicle slightly so that the towed vehicle straddled the ruts created by the towing vehicle and thus traveled on undisturbed sand. A specially built sled was used to support the tongue of a two-wheel trailer in these tests. This

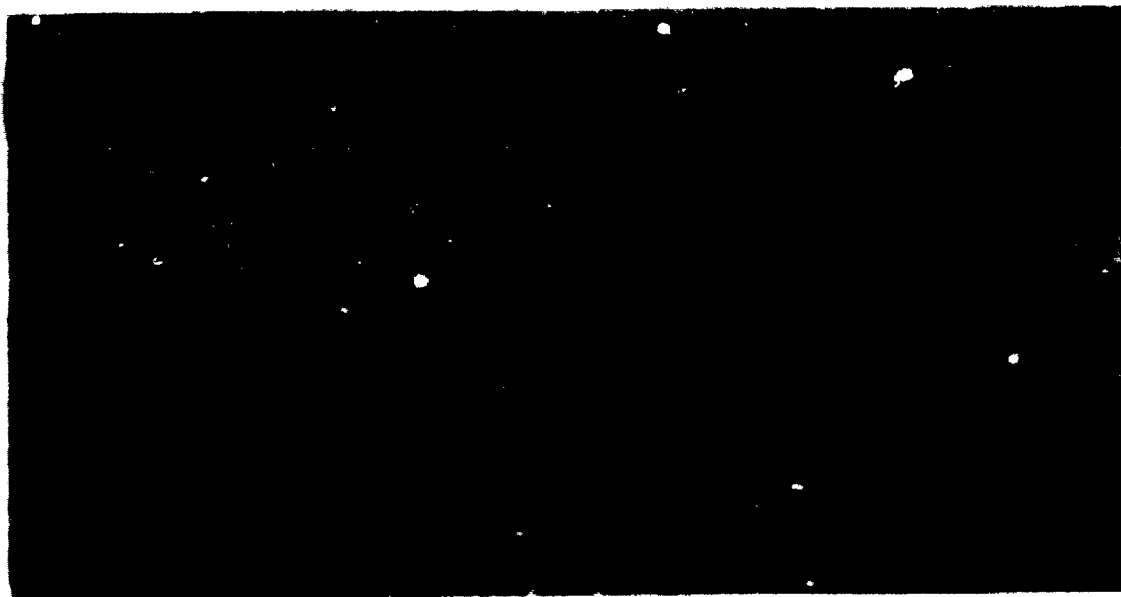


Fig. 40. Long-coupled hitch for towed tests, Camp Lejeune

sled also contained the dynamometer, which was positioned to the rear of the sled so that it measured only the force required to pull the trailer (see fig. 40).

78. Short-coupled tests. The force required to tow a trailer connected to the drawbar pintle of the towing vehicle in normal fashion also was measured by means of a dynamometer between the two vehicles. In these tests the towed vehicle usually operated in sand that had been disturbed by the towing vehicle.

Sand Data Obtained

Cone index

79. In the self-propelled tests, when a vehicle had successfully traversed a given area, it was halted, and a number of cone index measurements were made along its path. The measurements were made fairly close to the ruts but at a distance believed to be outside the zone of soil actually disturbed by the vehicle. When a vehicle was immobilized, the cone index readings were made in the undisturbed areas along both sides of the vehicle. These readings were made at the surface and at 3-in. vertical increments to a depth of at least 15 in. Ten sets of cone index readings usually were made for each test. Average cone indexes for each depth and

each test are shown in tables 3-8. The cone index averages for the 0- to 6-, 6- to 12-, and 0- to 12-in. depths are also shown.

80. For the towing tests, cone indexes representative of the area in which the maximum drawbar pull occurred are shown in table 8. In the tables of data obtained in the towing and towed-vehicle tests, tables 8 and 9, cone index is given only for the 0- to 6-in. depth.

81. In towed-vehicle tests cone indexes were determined before traffic and in the ruts after passage of the vehicle. This was not done in the single self-propelled tests since previous studies on coarse-grained soils have shown that trafficability of the soil usually improves with traffic even though the cone index does not necessarily increase. Average cone indexes for each test are shown in table 9.

Moisture content

82. Quantitative moisture-content determinations were not made for each individual test because the small variation in moisture content that might have occurred between tests on the same component of a beach did not justify the time required to make such measurements. However, a qualitative moisture content in one of the five categories defined below was selected for each test on the basis of appearance and feel of the sand and is shown in tables 3-8. Quantitative measurements of moisture content were made for each major test area, and are tabulated in paragraph 84.

83. The five categories of qualitative moisture contents are defined as follows:

- a. Dry sand. Sand that was light-colored, loose, and free-flowing when poured from the hand was termed "dry." Dry sand usually occurred on the surface of all components of the beaches except the foreshore, but seldom extended deeper than 5 in. before becoming moist. Where test data are available for comparison, sand classed as dry on the basis of visual observation contained less than 1.5% moisture by weight.
- b. Moist sand. "Moist" sand usually lay directly beneath the dry sand layer. It was usually darker in color, showed slight cohesion, and was cooler to the touch. In general, moist sand was found to contain about 1.5 to 5.0 per cent moisture by weight when actual moisture-content determinations were made.
- c. Wet sand. Sand on the foreshore that was being wetted by waves but was not under a finite depth of water during the

time of testing was termed "wet." Wet sand exhibited a considerable amount of cohesion, and free water could be squeezed out of it.

- d. Inundated sand. Sand covered by water during the time of testing was termed "inundated." This term refers to that portion of the foreshore at the time actually covered by water from wave action. NOTE: A spot on the foreshore "inundated" at one moment during the uprush of a wave might become "wet" a few seconds later when the wave receded.
- e. Quick-condition sand. Loose, yielding, wet, or more commonly, inundated sand that had water flowing through it vertically and became liquefied under the moving wheels of a vehicle (thereby causing immobilization of the vehicle) was termed "quick." (Erosion of the sand away from the wheels contributed to the immobilization.)

A discussion of the effect of sand in these five moisture categories on vehicle performance is presented in paragraphs 90 and 91.

84. Quantitative moisture contents for beaches on Oahu and the Yuma Test Station and dune areas are shown in the following table. Moisture contents for Camp Lejeune tests are shown in table 9 and are averages of several moisture-content values obtained in a series of tests on the same area of beach.

Moisture Content (Per Cent)					
Location	Depth, in.				Remarks
	0-3	3-6	6-12	12-18	
<u>Oahu</u>					
<u>Makua Beach</u>					
Foreshore	5.9	7.2	8.4	6.8	
Berm crest	3.8	4.6	4.9	5.3	
Berm backslope	2.2	3.6	4.6	4.4	
Forward dune apron	2.2	3.2	4.4	4.6	
Dune area	1.2	3.4	4.1	7.2	12- to 18-in. depth contained some silt
<u>Mokuleia Beach</u>					
l eshore	6.0	7.8	7.6	---	
Berm crest	5.7	6.0	6.7	---	
Forward dune apron	1.1	1.9	4.5	---	
Dune area	0.7	2.6	5.5	---	
<u>Crescent Beach, Area 1</u>					
Foreshore					
(near water)	25.1	24.1	26.0	---	Free water
Foreshore (inland)	7.1	13.9	23.6	---	3- to 12-in. depth contained free water

(Continued)

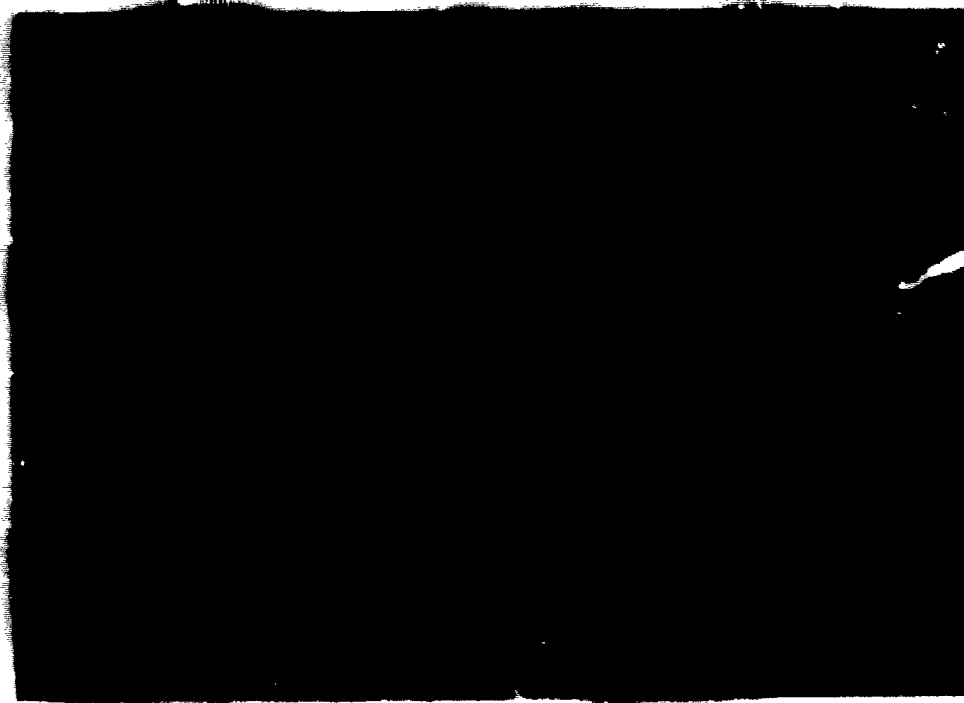
Moisture Content (Per Cent) (Cont'd)					
Location	Depth, in.				Remarks
	0-3	3-6	6-12	12-18	
<u>Oahu (Cont'd)</u>					
<u>Crescent Beach, Area 1 (Cont'd)</u>					
Berm crest	5.7	7.3	8.3	10.1	
Forward dune apron	0.9	3.4	4.8	3.9	
<u>Crescent Beach, Area 2</u>					
Foreshore	10.5	13.6	20.5	24.4	6- to 18-in. depth contained free water
Berm crest	11.3	8.1	17.1	20.3	6- to 18-in. depth contained free water
Berm backslope	5.5	8.3	---	7.8	
Forward dune apron	1.8	2.8	4.4	3.8	
<u>Bunker Beach, Area 1</u>					
Foreshore	4.6	6.5	8.5	8.4	
Berm crest	4.1	4.3	5.2	6.7	
Berm backslope	1.1	1.9	3.6	4.2	
Forward dune apron	0.9	1.9	4.3	4.1	
<u>Bunker Beach, Area 2</u>					
Foreshore	5.2	7.9	10.4	7.3	
Berm crest	9.6	8.3	8.8	8.1	
Berm backslope	3.8	4.6	5.6	7.3	
<u>Drone Beach</u>					
Foreshore	4.2	5.9	8.4	---	
Berm crest	4.8	6.2	6.6	---	
Forward dune apron	0.5	1.0	5.1	---	
Dune area	0.5	2.7	4.5	---	
	<u>0-6</u>	<u>6-12</u>			
<u>Yuma, Arizona</u>					
Test Station area	4.0	1.6			
Dune area	1.9	1.1			

Slopes

85. The slope for each test area was determined as described in paragraph 49. If a vehicle negotiated a slope, several slope readings were made in the area of maximum slope; however, if the vehicle was immobilized, slope readings were made along both sides of the vehicle at the site of the immobilization. Slope measurements for each test are shown in tables 3-8.

Rut depth

86. Rut-depth measurements were made for most tests; however, they are not reliable as a measure of vehicle performance in cases of immobilization or difficult travel because in some immobilizations the vehicle was allowed to spin its wheels longer than in others. In tests where the vehicle left a smooth rut, the rut depth was measured as the vertical distance from the original sand surface to the bottom of the rut. Where spinning occurred and the rut surface was not easily distinguishable, the rut depth was determined by measuring from the center of the wheel to the original sand surface and then subtracting that distance from the distance between the center of the wheel and the bottom of the tire, which was determined while the wheel was resting on a flat rigid surface. Rut-depth measurements for each test are shown in tables 3-9, and several rut configurations are shown in figs. 41 and 42.



a. Dry sand, Makua Beach,
3/4-ton M37 truck



b. 2-in. dry sand, moist
below, Makua Beach,
3/4-ton M37 truck



c. Moist sand, Makua Beach,
2-1/2-ton M211 truck

Fig. 4.1. One-pass rut designs

- a. Moist sand dune area,
Yuma, Arizona, 2-1/2-
ton M135 truck



- b. Wet sand, Crescent Beach,
2-1/2-ton M215 truck



- c. Wet sand, Crescent Beach,
liquefaction in one rut,
2-1/2-ton M215 truck



Fig. 42. One-pass rut designs

PART III: ANALYSIS OF DATA

87. The data collected in this test program are analyzed under four headings: Single Self-propelled Tests, Towing Tests, Towed-vehicle Tests, and Notes and Observations. The conditions and assumptions upon which the analysis is based are described in the following section.

Basis of Analysis

Sand types

88. Three principal types of sand were tested in this program: coral, volcanic, and quartz. The coral and volcanic sands were tested in the Pacific islands, and the quartz sand was tested in the vicinities of Yuma and Camp Lejeune. Field observations and preliminary analysis of the data revealed no significant difference in the performance of the test vehicles as a result of sand type; therefore, all similar vehicle tests on sand are grouped together for analysis purposes.

Sand-trafficability categories

89. In the pilot study, TM 3-240, 13th Supplement, two broad categories of sands were recognized from a trafficability standpoint, clean sands, and sands with fines, poorly drained. Sand in the latter category, when nearly saturated, reacts to traffic in a manner similar to fine-grained soils. It generally contains more than 7% fines. From the sand data reported herein it is apparent that all soils tested were in the clean-sand category. The sand in the Yuma dune area contains about 7% fines and may possibly react as a sand with fines, poorly drained, but it is in a desert area where the moisture content of the soil does not attain a high enough level to permit a poorly drained condition to develop.

Moisture categories

90. These categories are defined in paragraph 83. It was expected that the moisture content of a sand would play an important part in its trafficability characteristics. Dry sands were expected to be loose and yielding at the surface under the horizontal shearing action of a wheel and thus have poor traction capacity. Moist sands were expected to have bearing capacities at least as high as that of dry sand and higher traction

capacities because of increased cohesion between grains due to capillary pressures. Some increase in trafficability was expected with further increase in moisture content for the same reason. However, at some stage of increasing moisture content (at or near saturation), it was expected that the intergranular pressure would be partially relieved by the development of pressure in the pore water and that the bearing and traction capacities would be reduced. This condition was anticipated in inundated or submerged sands because of buoyancy. In sands with a definite flow of water through them, and especially an upward flow or gradient, liquefaction of the sand and immobilization of the vehicle were expected. It was further anticipated that the various degrees of trafficability described above could be measured with the cone penetrometer.

91. As will be brought out subsequently, the general pattern of expected behavior described above did occur in these tests. However, the variation in trafficability with moisture content was such that the sands could be grouped into two categories according to their moisture content, with a third category representing high moisture and a pressure condition of the void pore water. The two categories according to moisture content are "dry-to-moist" and "wet-to-inundated." The third category is referred to as a "quick condition."

92. As will be discussed later, separate curves of cone index vs vehicle performance were drawn for the two categories, and results of the tests conducted on quick-condition sands were plotted with the results of tests of the wet-to-inundated category sands.

Immobilization

93. Dry-to-moist sands. During this test program no immobilizations in which a vehicle had to be towed away by another vehicle occurred on dry and moist sands. In cases in which a vehicle could no longer move forward, it was always able to back out in its own tracks. In some cases a wheeled vehicle was almost immobilized but was able to inch itself forward slowly with violent jerks and a great amount of wheel slip. However, for analysis purposes, these two conditions were considered to be immobilizations.

94. Wet-to-inundated sands. Several wheeled-vehicle immobilizations occurred because of the liquefaction of sand under the tires when the vehicle operated in the surf. (These sand conditions are referred to as

quick conditions in this report.) These vehicles were completely immobilized and had to be towed from the test area.

95. Yuma dune sand. Tests at the Yuma dune area presented a problem not previously encountered in that a vehicle occasionally could travel over an area for which the cone index-slope combination previously determined indicated that the vehicle should become immobilized. In such tests slight shear planes usually appeared in the ruts, indicating that immobilization was imminent. When this happened the tests were rerun as follows: the vehicle was allowed to come to a complete stop on the slope, and if it could not progress from this stopped position, the vehicle was considered to be immobilized. Cone index criteria for vehicle performance on sand dunes are, therefore, somewhat conservative. The fact that the vehicle could traverse an area the first time was probably due to the momentum it developed on the gradually increasing slopes typical of the sand dunes.

Critical soil layer

96. Previous tests on coarse-grained soils (TM 3-240, 13th Supplement) indicated that the best correlations of vehicle performance with cone index measurements were obtained for the 0- to 6-in. sand layer. Other layers were considered in this analysis but none showed better correlations; hence, the 0- to 6-in. layer is used as the critical layer in this analysis also.

Single Self-propelled Tests

Data used and method of analysis

97. The single self-propelled vehicle test program included a total of 885 tests. A summary of data and test results is presented in tables 3-7.

98. Where applicable, test data reported in TM 3-240, 13th Supplement, were also used in this analysis. The data used were results of tests on three trucks, a 3/4-ton with 9.00x16 tires, a 2-1/2-ton with 9.00x20 tires (dual), and a 2-1/2-ton with 11.00x20 tires (single), since these data were considered comparable to data collected during the current test program. Some of the 13th Supplement data on these vehicles were re-evaluated on the basis of sand condition. Data were not used from tests

conducted on (1) prepared sand slopes, (2) sands with more than 7% fines, and (3) crusted desert sands where immobilizations were reported to have occurred after the first pass was completed. Crusted sands were not tested in the current test program. The curves of cone index vs slope reported herein differ only slightly from corresponding curves presented in the 13th Supplement.

99. The method of analysis and the factors considered in this analysis are the same as those described in TM 3-21, 13th Supplement. In brief, the factors considered were soil strength, slope, and vehicle characteristics. Soil strength is important in that it reflects the soil's bearing capacity as well as its capability to permit a vehicle to develop the necessary traction force to propel the vehicle forward. In this report soil strength is expressed in terms of cone index. Slope was considered as a factor because of the increased soil strength required for a given vehicle to negotiate a slope as compared to that required on level terrain. Furthermore, no level, dry or moist sand condition was found that would cause complete immobilization of the vehicles tested; therefore, slopes were used to obtain vehicle immobilizations. A change in tire pressure materially affects the performance of wheeled vehicles; therefore, this vehicle characteristic was also considered as a factor.

100. The method of analysis consisted in plotting the slope and cone index pertinent to all tests with the same vehicle at the same tire pressure, and indicating whether or not immobilization occurred. A line was then drawn that essentially separated the immobilizations and nonimmobilizations. This line thus represented the maximum slope that the vehicle at the given tire pressure could climb, over a range of cone index conditions. Clear-cut separation of immobilizations and nonimmobilizations was not always possible. Consequently, the line was drawn so that the majority of immobilizations would plot above and to the left of the line. In so doing, many nonimmobilizations also plot above and to the left of the separation line. The curve is therefore somewhat conservative. The final position of the line was also influenced by similar lines for the same vehicle at other tire pressures. Curves for the same vehicle at various loads and tire pressures were combined into a family of curves.

5

Cone index-slope-tire
pressure correlations

101. Cone index-slope-tire pressure relations were established for five trucks having tire sizes ranging from 7.00x16, 6-ply rating, to 14.00x20, 12-ply rating. The tire pressures used in the test program ranged from 10 to 45 psi. A maximum of 40-45 psi was used because little or no change in contact area occurred at tire pressures greater than 40 psi and hence little or no change in vehicle performance. Ten psi was used as a lower limit because at pressures less than this, the tire was subject to rim slippage or excessive tire buckling. The relations established for the various vehicles and tires tested are described in the following paragraphs.

102. 1/4-ton, 4x4, M38A1 with 7.00x16 6 PR tires. The following tabulation gives the number of tests of the M38A1 at the various tire pressures shown for which data were taken from table 3 and plotted in plate 5 or 6 according to sand moisture conditions.

Tire Pressure, psi	No. of Tests Plotted	
	Plate 5, Wet- to-inundated Sand	Plate 6, Dry- to-moist Sand
30	11	10
20	3	19
15	0	25
10	13	19
Total	27	73

The results of the five tests at 25 psi and one test at 5 psi are not plotted because of the small number of tests performed at these tire pressures.

103. Twenty-seven tests were run on the wet-to-inundated sand, with a gross vehicle weight of 2975 lb and three tire pressures. An examination of the data plots in plate 5 shows that four tests in which immobilization occurred do not plot on the proper side of the curve. Plotted in fig. 1, test 3-49* (cone index of 39 and slope of 6%) was an immobilization that occurred while the vehicle was traveling at about a 45-deg angle to the slope face, causing a vehicle side tilt of 10%. Had the vehicle been

* First number refers to table number, and second number refers to item number in that table.

operated perpendicular to the slope, it probably would not have been immobilized, as indicated by the location of the plotted point in regard to the separation line. No explanation can be given for test 3-55 (cone index of 62 and slope of 18%) plotting incorrectly in fig. 2. In fig. 3, tests 3-71 (cone index of 62 and slope of 17%) and 3-40 (cone index of 22 and slope zero) plot incorrectly. These were tests in which the vehicle was operating on the foreshore and when the sand was inundated by surf, the vehicle began to sink although cone index measurements indicated that it should have traveled with ease. In test 3-71 the vehicle was operating perpendicular to the water's edge, and it is believed that excessive sinkage was probably due to a combination of liquefaction beneath the wheels and erosion of sand around the wheels by the surf. In the case of test 3-40, the vehicle was operating parallel to the water's edge, causing it to assume a side tilt of 13%.

104. The results of the 73 tests run on dry-to-moist sand with test vehicles operating at 2975 and 3125 lb, at four tire pressures, are shown in plate 6. Two immobilizations plot with the nonimmobilizations: in fig. 2, test 3-8 (cone index of 62 and slope of 6%), and in fig. 3, test 3-18 (cone index of 76 and slope of 10%), both of which were run on Bunker Beach, Oahu. No reason can be given for these tests plotting as outliers. Eleven other tests on Bunker Beach plot on the correct side of the curve.

105. A comparison of plates 5 and 6 indicates that the 1/4-ton M38A1 performs better on wet sands than on moist or dry sands. For example, at 20-psi tire pressure and on soil having a cone index of 40, it can climb a 16% slope on wet sands but only a 3% slope on dry sands.

106. On the basis of one test at 5-psi tire pressure (3-41, not plotted), the M38A1 performance was improved by lowering the tire pressure below 10 psi, but tire life would probably be greatly reduced because of side-wall buckling and rim slippage.

107. 3/4-ton, 4x4, M37 with 9.00x16 8 PR tires. The tabulation on the following page gives the number of tests of the M37 at the various tire pressures shown for which data were taken from table 4 and the 13th Supplement, and plotted in plates 7 and 8 according to sand moisture. Fourteen of the tests listed in table 4 are not plotted in plates 7 and 8. Four of these tests (two at 40-psi, one at 30-psi, and one at 15-psi tire pressure)

were run on negative slopes. Nine were run at miscellaneous tire pressures and do not justify extra plots. One test (4-108) on wet sand at 20 psi was not plotted because it is obviously in error.

Tire Pres- sure psi	No. of Tests From 13th Supplement Plotted		No. of Tests From Table 4 Plotted	
	Plate 7, Wet- to-inundated Sand	Plate 8, Dry- to-moist Sand	Plate 7, Wet- to-inundated Sand	Plate 8, Dry- to-moist Sand
45	0	0	0	15
40	0	7	0	16
30	0	0	0	49
20	2	3	7	50
15	0	5	6	56
10	0	4	17	51
	—	—	—	—
Total	2	19	30	237

108. Thirty-six tests were run on wet-to-inundated sands at tire pressures of 40, 30, 20, 15, 10, and 8 psi. Data plots (plate 7) were made only for the 20-, 15-, and 10-psi tire pressures since only one test was run at each of the other tire pressures. Two hundred and forty-five tests were run on dry-to-moist sand (only 237 tests are plotted in plate 8), mainly at tire pressures of 45, 40, 30, 20, 15, and 10 psi. Curves separating the immobilizations from the nonimmobilizations for both wet-to-inundated sands and dry-to-moist sands are shown for each pressure for which enough data are available.

109. For the wet and inundated sands (plate 7), three tests resulted in immobilizations where the vehicle should have traveled. Test 4-75 (cone index of 23 and slope of zero), plotted in Fig. 2 of plate 7, was an immobilization due to liquefaction, and cone indexes taken around the vehicle did not actually indicate the very soft conditions that probably existed when the vehicle became immobilized.

110. Fig. 3, plate 7, reveals three tests on wet-to-inundated sand that are not on the proper side of the curve. Test 4-94 (cone index of 23 and slope of 5%) was another immobilization due to liquefaction. No explanation can be given for the other two tests plotting incorrectly.

111. On dry and moist sands the M37 was tested at four gross weights, 5645, 6067-6275, 7085-7417, and 7805 lb (see plate 8). All tests are plotted together since a variation in weight apparently did not significantly affect vehicle performance. Seven tests, one each at tire pressures

of 40, 30, 20, and 10 psi and three tests at 15 psi, indicate immobilizations where they should not have occurred according to the separation curve. Four of these occurred at the Yuma dune area: tests 4-176 and 4-244 at 15 psi, test 4-234 at 30 psi, and test 4-239 at 20 psi. For test 4-148 (cone index of 62 and slope of 15%) on Iwo Jima at 10 psi, the truck was operated on a 5% tilt, which may have caused the immobilization.

112. The family of curves for the wet and inundated sands, fig. 4 of plate 7, indicates that there is little difference in vehicle performance at 10-, 15-, and 20-psi tire pressures below a cone index of 30. The family of curves for dry and moist sands, fig. 7 of plate 8, indicates a different pattern. The vehicle performance improves more between 10 and 15 psi than between 15 and 20 psi, but even at 10 psi the M37 cannot climb as steep a slope on any given strength of dry-to-moist sand as it can at 20 psi on wet sand.

113. 2-1/2-ton, 6x6, M211 with 9.00x20 8 PR tires. The following tabulation gives the number of tests of this vehicle for which data were taken from table 5 and the 13th Supplement and plotted in plate 9 according to tire pressure and sand moisture.

Tire Pressure, psi	No. of Tests From 13th Sup- plement Plotted Dry-to-moist Sand	No. of Tests From Table 5 Plotted	
		Wet-to- inundated Sand	Dry-to- moist Sand
45	0	4	24
30	4	0	11
20	3	0	27
15	4	0	5
10	7	11	24
Total	18	15	91

Results of nine tests on dry-to-moist sand shown in table 5 were not plotted in plate 9. Four of these tests at 50-psi and two at 32-psi tire pressure were not plotted because of an insufficient number of tests at the respective tire pressures; three tests, two at 45 psi and one at 10 psi, were run on negative slopes and therefore were not plotted.

114. Fifteen tests were run on wet-to-inundated sands at two vehicle weights, 13,120 and 18,120 lb, and two tire pressures, 45 and 10 psi.

Eleven of the fifteen tests are at 10 psi, and an approximate separation curve between immobilizations and nonimmobilizations is shown for these points (fig. 5, plate 9). The curve shows the M211 to be capable of climbing two to three times steeper slopes at cone indexes of 20 to 60 in wet sand than on dry-to-moist sand. Data on wet-to-inundated sands are insufficient for establishing curves for other tire pressures.

115. One hundred and nine tests run with the M211 at vehicle weights of 13,120 and 18,120 lb on dry-to-moist sands are plotted in plate 9. All tests at the same tire pressure are plotted together since variation in weight apparently did not affect performance. Separation curves were developed. Of the six tests that indicate immobilizations where they should not have occurred, five were run in the Yuma dune area and were reported in the 13th Supplement. The other, test 5-53 (cone index of 38 and slope zero), shown in fig. 3 of plate 9, was an immobilization on the berm crest of Makua Beach, Oahu. In this test, the vehicle was operating on a $\frac{1}{4}\%$ tilt, which no doubt hindered its forward progress.

116. 2-1/2-ton unnumbered truck with six 8.25x20 tires. Four tests were conducted with this vehicle on two Kwajalein beaches. These tests are listed in table 5, items 112 through 115, but as stated earlier no plots are shown because results from such a limited number of tests are inconclusive. A comparison of results of these tests with results of tests of the 2-1/2-ton M211 at 45 psi and the M135 at 40 psi shows that these test results are not out of place.

117. 2-1/2-ton truck with 11.00x20 12 PR tires. Various models of 2-1/2-ton trucks with 11.00x20 tires have been tested during the sand trafficability program. Supplement 13 reports tests on three models: M134, M47, and M135. The M135 was again tested during this test program (at Yuma). The M215 2-1/2-ton truck was tested on the Oahu Island beaches and, as mentioned in paragraph 55, although it is normally equipped with dual tandem 9.00x20 tires, for this test program it was equipped with 11.00x20 tires.

118. The tabulation on the following page lists the number of tests from table 6 and the 13th Supplement that are plotted in plate 10. Three tests, one at 50 psi and two at 18-1/2 psi, were not plotted. The three tests on wet-to-inundated sands (tests 6-17, -36, -55) were plotted, but no

separation curve could be constructed for them. Tests 6-17 and 6-36 at 20 psi were nonimmobilizations on Crescent foreshore; test 6-55 at 10 psi was an immobilization due to liquefaction of the sand when hit by surf.

Tire Pressure, psi	No. of Tests From 13th Sup- plement Plotted	No. of Tests From Table 6 Plotted	
	<u>Dry-to-moist Sand</u>	<u>Wet-to- inundated Sand</u>	<u>Dry-to- moist Sand</u>
40	1		14
30	14		44
20	26	2	64
15	16		45
10	13	1	43
Total	70	3	210

119. A total of 213 tests were conducted in the current program on dry-to-moist sand at vehicle weights of 12,450, 14,950-15,000, 17,320-17,450, and 19,820-20,500 lb. All tests are plotted together, however, since a variation in weights apparently did not affect vehicle performance. The plots also include 70 tests from the 13th Supplement.

120. Twenty-nine of the total number of 280 tests on dry-to-moist sand do not plot properly. Eight of these tests are immobilizations where the vehicle should have traveled, and three of these eight tests are from the 13th Supplement. The five remaining immobilizations that do not plot properly occurred during the 1957 test program at Yuma; one test can be seen in fig. 2, plate 10; one in fig. 3; one in fig. 4; and two in fig. 5. The remaining twenty-one outliers are nonimmobilizations that plot above and to the left of the separation curve, thus indicating that the curves are somewhat conservative. Test records do not reveal any reasons for these tests being outliers.

121. 5-ton, 6x6, M41 with 14.00x20 12 PR tires. Vehicle-performance plots for the 5-ton M41 are shown in plate 11. Figs. 1-4 show plots of cone index vs per cent slope at four tire pressures (30, 20, 15, and 10 psi), and the family of tire-pressure curves is shown in fig. 5. This vehicle was tested only at the Yum dune area on dry-to-moist sand.

122. The tabulation on the following page lists the number of tests of the M41 at each tire pressure given in table 7 and plotted in plate 11.

<u>Tire Pressure, psi</u>	<u>No. of Tests From Table 7 Plotted, Dry-to-moist Sand</u>
30	44
20	49
15	46
10	28
Total	<u>167</u>

123. The tests were run at four vehicle weights, 18,115, 24,275, 28,175, and 32,380 lb, but all are plotted together as the variations in weight did not affect vehicle performance. Twelve tests do not plot on the proper side of the separation curve or near enough to it to be considered borderline tests, and two of these tests (in figs. 1 and 2, plate 11) are immobilizations where the vehicle should have traveled. Test records do not reveal any reasons for these tests being outliers.

124. Suitable test areas with low cone indexes and flatter slopes were not found in the sand dune area; therefore, the separation lines for the low slopes are merely estimated and shown as dashed lines in the various plots in plate 11.

Towing Tests

125. The towing tests with self-propelled vehicles (five wheeled and three tracked) were conducted principally on harrowed sand lanes in the Yuma Test Station area, with a few conducted on natural sand in the Yuma dune area. Summary data and test results for all towing tests are presented in table 6.

126. The tests were conducted to determine the relation between towing ability and varying weights and tire pressures of individual vehicles, and also to compare towing abilities of vehicles on harrowed sand and undisturbed sand. However, changes in the test program precluded conclusive testing on undisturbed sand; therefore, this analysis deals only with the harrowed-sand tests, although data from a few tests on undisturbed sand are included in table 6.

127. Analysis of towing-test data is presented by vehicle types: wheeled vehicles and tracked vehicles. Under each vehicle type the

analysis consists of (1) a comparison of maximum drawbar pull with vehicle characteristics, (2) drawbar pull vs slip, and (3) a comparison of computed maximum drawbar pulls vs actual drawbar pulls measured on the test slopes.

Wheeled vehicles

128. Maximum drawbar pull vs tire pressure and test weights.

Twenty-eight maximum-drawbar-pull tests were run on level harrowed sand at the Yuma Test Station with five vehicles at four different tire pressures for each vehicle. The 2-1/2-ton M135 was tested with three loads; all others were tested with their respective recommended cross-country payloads. These tests and average maximum drawbar pull-tire pressure curves for each vehicle are shown in figs. 1-5, plate 12.

129. The maximum drawbar pull of a given vehicle increased with a reduction in tire pressure. The maximum drawbar pulls for all vehicles tested at 10-psi tire pressure ranged from 22.2% of test weight for the 5-ton M54 at 30,635 lb up to 36.0% for the 2-1/2-ton M135 at 12,450 lb. The 3/4-ton M37 test (8-14) was not considered since examination of fig. 2, plate 12, shows this test is probably in error. At 30-psi tire pressure the maximum drawbar pulls ranged from 9.4% for the 1/4-ton M38A1 at 2975 lb to 16.1% for the 2-1/2-ton M135 at 12,450 lb.

130. Fig. 3, plate 12, shows the effect of varying loads on the performance of the 2-1/2-ton M135 truck. As the load was increased in approximately 5000-lb increments, the maximum drawbar pull decreased about 2.5% at all tire pressures. The maximum percentage of pull developed was 36.0 at 10 psi and test weight of 12,450 lb (truck empty).

131. A comparison of the towing capabilities of vehicles of similar size but equipped with different tires can be made by examining the data for the two 5-ton trucks (both tested with a 10,000-lb payload) in figs. 4 and 5, plate 12. The 5-ton M41 with 14.00x20 tires (single) had about 5% more drawbar ability at all tire pressures than the 5-ton M54 with 11.00x20 tires (dual).

132. Drawbar pull vs wheel slip. These tests were run on the 2-1/2-ton M135 at three loads and four tire pressures to determine the effect of varying loads on its drawbar pull-slip characteristics. Results of tests with the M135 are shown in figs. 1-3, plate 13.

133. Maximum drawbar pull occurred at about 25% slip for all loads

tested at 10-psi tire pressure; as tire pressure was increased, maximum drawbar pull occurred at a lower percentage of wheel slip for all loads. The rate of decrease in maximum drawbar pull in regard to increased tire pressure was uniform, and at 30-psi tire pressure maximum drawbar pull occurred at about 15% wheel slip for all loads.

134. Comparison of computed maximum drawbar pull with actual drawbar pull measured in tests on harrowed sand slopes. Maximum-drawbar-pull data shown in table 8 for the five wheeled vehicles were used to determine the correlation between computed and actual maximum drawbar pulls on slopes of harrowed sand. The computed drawbar pulls on slopes were developed from measured drawbar pulls on level sand by the formula:

$$P' = P \cos \phi - W \sin \phi$$

where

P' = maximum drawbar pull on slope, computed

P = maximum drawbar pull on level, measured

W = gross weight of vehicle, lb

ϕ = angle of the slope, deg

135. Sixty determinations of maximum drawbar pull were made on harrowed sand, 28 on level sand, and 32 on slopes. The following table shows the measured and computed results and the difference between them. A comparison of computed and actual test results is shown graphically by the round symbols in plate 14.

Tire Pressure psi	Meas Max Drawbar Pull on Level Sand		Meas Max Drawbar Pull on Slopes			Computed Max Drawbar Pull on Slopes, lb	Difference	
	lb	Item No.	Slope %	lb	Item No.		lb	%
		Table 8			Table 8			
		<u>1/4-ton M38A1 Truck - 2,975 lb</u>						
15	550	3	10	200	6	250	+50	25.0
		<u>3/4-ton M37 Truck - 7,085 lb</u>						
10	1400	14	10	1000	15	751	-316	24.9

(Continued)

* $\frac{\text{Computed} - \text{Measured}}{\text{Measured}} \times 100.$

136. From an examination of the preceding table it can be seen that the computed drawbar pulls are usually slightly higher than those actually obtained in the tests. This is probably explained by the fact that even though the sand was essentially in the same condition for both slopes and level lanes, the rear wheels sank deeper than the front ones on slopes, thus increasing the actual slope that the test vehicle was attempting to climb.

137. The average percentage of absolute deviation between computed and actual test results was 10.0. Considering sign, the computed pulls were an average of 5.7% higher than measured pulls. The large percentage deviations for the lightweight 1/4-ton and 3/4-ton trucks are probably attributable to the small magnitudes of the pulls and the relative inaccuracy of the dynamometer in the low range.

Tracked vehicles

138. Maximum drawbar pull vs vehicle test weight. Nine maximum-drawbar-pull tests were run on level harrowed sand with three vehicles: M29C weasel at 5970 lb and 6970 lb; 18-ton M4A2 hi-speed tractor at 36,910 lb; and 38-ton M6 hi-speed tractor at 76,000 lb. Data for these tests are presented in table 8, and average drawbar pull for each vehicle is shown graphically in plate 15.

139. In these tests the tracked vehicles had a maximum drawbar-pull ability ranging from 50 to 65% of their test weight. (The highest drawbar-pull ability of wheeled vehicles was around 35% when operating at 10-psi tire pressure.) The weasel, the lightest of the vehicles (5970 and 6970 lb) and the one with the lowest contact pressure (1.9 and 2.2 psi), developed the highest drawbar-pull ability (62-65%) of the three tracked vehicles tested. The M6, the heaviest vehicle and the one with the highest contact pressure (76,000 lb and 9.8 psi, respectively), developed the lowest drawbar-pull ability (50%). Tests are needed on a wider range of vehicles and sand conditions in order to clarify the relations between the maximum drawbar pull of tracked vehicles and the sand on which they operate.

140. Drawbar pull vs track slip. Tests were run on the M29C weasel to show the relations of drawbar pull, track slip, and vehicle weight. Table 8 lists tests on this vehicle for three sand conditions: before harrowing (tests 131-137), after one pass of the harrow (tests 138-148),

and after completion of harrowing (tests 149-155, and 161-176). One pass of the harrow did not leave the test lane uniform enough in strength for reliable testing. Data from items 149 through 155 and 168 through 176 are shown in fig. 4 of plate 13, in which drawbar pull is correlated with track slip and changes in vehicle weight. This plot indicates no change in track slip for the maximum drawbar pull when the vehicle weight is increased 1000 lb, i.e., the track slip at maximum drawbar pull for both weights is 37%. But for the same drawbar pulls below the maximum, track slip is greater for the lesser weight.

141. Comparison of computed and measured maximum drawbar pulls on harrowed sand slopes. Computed maximum drawbar pulls on slopes were developed from applicable measured maximum drawbar pulls on level sand by means of the formula given in paragraph 134. Nine measurements of maximum drawbar pull on slopes were made. A comparison of computed and actual test results is shown graphically by the square symbols in plate 14. The following table lists actual test results, computed maximum drawbar pulls, and the differences between the two.

<u>Meas Max Drawbar Pull on Level Sand</u>		<u>Meas Max Drawbar Pull on Slope</u>		<u>Computed Max Drawbar Pull on Slopes, lb</u>		<u>Difference</u>	
<u>lb</u>	<u>Item No. Table 8</u>	<u>Slope %</u>	<u>lb</u>	<u>Item No. Table 8</u>		<u>lb</u>	<u>%*</u>
<u>1/4-ton M29C Weasel, 5,970 lb, Contact Pressure = 1.9 psi</u>							
3,250	146	20	2,000	156	2,000	+250	1.0
3,250	146	15	2,300	157	2,300	+250	1.1
<u>1/4-ton M29C Weasel, 6,970 lb, Contact Pressure = 2.2 psi</u>							
4,400	165	15	2,600	177	3,320	+720	27.7
4,400	165	15	3,000	178	3,320	+320	4.6
<u>18-ton M4A2 H1-speed Tractor, 36,910 lb, Contact Pressure = 6.1 psi</u>							
20,000	179	8	15,000	180	16,960	+1960	13.1
20,000	179	12.5	15,000	181	15,262	+262	1.7
20,000	179	15	12,000	182	14,300	+2300	19.2
<u>38-ton M6 H1-speed Tractor, 76,000 lb, Contact Pressure = 9.8 psi</u>							
38,000	188	8	29,000	189	31,829	+2829	9.6
38,000	188	12.5	28,000	190	28,267	+267	1.0
Avg (regardless of sign)							8.8

* $\frac{\text{Computed} - \text{Measured}}{\text{Computed}} \times 100.$

142. The average deviation (expressed as a percentage difference between computed and measured drawbar pull) is 8.8% for all vehicles tested, and for all tests the computed drawbar pulls are higher than those actually measured. In examining the summary of test data in table 8 it may be noted that cone index for tests of the two hi-speed tractors on level sand (items 179 and 188) was much higher than the cone indexes on slopes. Had the cone indexes on slopes been the same as on level ground the maximum drawbar pulls developed might have been closer to computed results.

Towed-vehicle Tests

143. The towed-vehicle test program included tests on two- and four-wheeled trailers. One hundred and sixty-eight tests were run with five trailers (three two-wheeled and two four-wheeled), at loads varying from empty to 1-1/2 times their payload capacities, and at four tire pressures. A summary of the test conditions and results is presented in table 9.

144. Tests were conducted on asphalt pavement, undisturbed sand, and disturbed sand. The analysis of data was made only for tests conducted on sand, since towing-force requirements of all vehicles on asphalt were in the range of only 1.0 to 2.0%. The towing force on asphalt is a measure of the internal mechanical friction of the vehicle wheels plus the external frictional rolling resistance of the wheels on a hard, essentially unyielding, surface. In this report the forces (which were small) required to overcome the internal resistance are included in the gross towing force required on sand.

145. The results of tests on undisturbed sand, made by towing the test vehicle with a long cable as described in paragraph 77, are shown in plate 16 as open symbols. Results of tests on disturbed sand, made with the test vehicle towed at close hitch behind the towing vehicle, are shown in plate 16 as closed symbols.

146. A good correlation exists between the towing force required, cone index before traffic, and tire pressures for all vehicles. Apparently, disturbance of the sand by the towing vehicles had little or no measurable effect on the towing force required for the trailers since, for the range of cone indexes tested, rut depths were shallow and little or no

change in strength occurred after passage of the test vehicle.

147. A family of tire-pressure curves for towing force required vs cone index (before traffic) is shown in fig. 8, plate 16. The curves (if extrapolated) tend to converge at cone indexes above 200 and towing forces below 2%, and "fan out" uniformly to a cone index of 75 (which is near the lowest cone indexes measured) where the towing force required ranges from 10% at 10-psi tire pressure to 23% at 60-psi pressure. The average deviation (in per cent towing force required) of individual tests from the average line for each tire pressure is approximately 1.0%.

148. In summary, it appears that towing force required (per cent of test weight) is a function of sand strength and tire pressure for the range of vehicle weights tested (empty to 1-1/2 times payload capacity). The effect of number of wheels (two or four), tire arrangement (single or dual), and number of axles (one or two) on towing force is small when considered independently of the effects of test weight, tire pressures, and sand strength. Tests are needed of additional vehicles on lower-strength sands and on sands different from those at Camp Lejeune in order to determine more fully the relations between vehicle characteristics and towing-force requirements over a wide range of sand conditions.

Notes and Observations

149. During the course of the approximately 900 single self-propelled vehicle tests on beach and desert areas, a few observations were made of several immeasurable factors that nevertheless influence vehicle mobility. These observations are discussed in the following paragraphs.

Liquefaction and erosion

150. Several wheeled-vehicle immobilizations occurred on inundated beach sands when slopes were about 1 1/4% and the beach face was inundated by wave action. It is believed that along with the slope factor, liquefaction and erosion of sand from around the wheels by the surf contributed to the immobilizations. On several occasions when immobilizations did not occur, it was observed that the top 2 to 4 in. of sand in the ruts was liquefied. Had the proper combination of loading and drainage occurred simultaneously, sand beneath the wheels might have liquefied to a depth that would have caused immobilization.

151. Observations of vehicles operating in the surf also revealed that if a vehicle was stalled or purposely stopped for a few minutes, erosion of sand from around the wheels by wave action usually resulted in an immobilization.

152. Immobilizations did not occur on inundated sands as long as the water was not moving over or through the sand, as in lagoon areas of clean sand protected from the open sea or areas where water was trapped during periods of low tides.

Borderline conditions

153. When a vehicle is immobilized in sand it is usually because of traction failure. Traction failure is the inability of the sand surface to resist the horizontal dynamic stresses applied to it by a powered wheel or track. Thus, the thrust necessary to propel the vehicle cannot be developed. Close observation revealed that a vehicle operating on a slope-strength combination borderline between immobilizations and nonimmobilizations will leave slight shear planes in its ruts. These conditions were retested by repeating the operation parallel to the old ruts, but on the rerun the vehicle was allowed to come to a complete stop in the area under question and start again. In nearly every case the vehicle could not complete passage through the area. This was done to check the assumption that the reason a vehicle usually negotiated a borderline condition was that the momentum it developed in making its approach to the test area carried it through. In tests in which the vehicle did not leave these slight shear planes, it had no trouble in moving from a stopped position. For tests run on sand where the slope-strength combinations were much below the borderline conditions, immobilizations occurred almost simultaneously with the beginning of traction failure.

Effects of vehicle characteristics

154. Tire pressure. Tire pressure is the single vehicle characteristic that has the most influence on the performance of a given vehicle in sand. Careful adjustment of tire pressures is essential in conducting accurate tests or obtaining the expected performance from a vehicle. It was found that in order to achieve the accuracy desired, low tire pressures had to be measured with a pressure gage more accurate than the usual "stick gages." Most stick gages register only as low as 10 psi and have been

found in some cases to be as much as 3 psi off at low pressures.

155. Careful and constant regulating of tire pressures during testing was essential because of the tire-pressure changes that resulted from changes in tire temperature. At least four conditions were encountered that caused tire temperatures and hence tire pressures to vary during testing: (1) changes in ambient air temperature during testing; (2) operation of the tires in wet and inundated sand after the tire pressure had been adjusted on warm dry sand; (3) starting tests on sand after the vehicle had been operating on a hard surface at high speeds; and (4) permitting wheels to slip for an extended period of time.

156. Tire pressure also apparently has an effect on the peculiar action of vehicle "jerking" when traction failure occurs. For the 2-1/2-ton and 5-ton trucks, the "jerking" action was violent at higher tire pressures and much more gentle at the lower tire pressures of 10 and 15 psi.

157. Tire condition. All military vehicles tested were equipped with the standard nondirectional cross-country tire; however, the physical condition of these tires varied considerably as some were new, some recapped, and some had little or no tread. Although it is generally thought that tire condition has some effect on vehicle performance, the observations made during this test program do not appear to bear this out. This is indicated by the fact that although the same tires or vehicles were not used for the complete test program, the performance of a given type of vehicle and size of tire was consistent.

158. The theory that tire conditions (within the range of tire conditions tested) have little effect on vehicle performance in coarse-grained soils is also supported by measurements of the contact area of the tires on the 3/4-ton M37 tested at Yuma. This vehicle was equipped on one side with two newly recapped tires and on the other side with two old, well-worn tires; however, the contact areas for these tires were practically the same at a given tire pressure, with neither set consistently greater or smaller than the other. Some difference in the shape of the tire print was apparent, however; worn tires generally produce a more rectangular pattern than new or newly recapped tires.

159. Rut configuration. Ruts made by the 2-1/2-ton and 5-ton trucks operating at low tire pressures (10 and 15 psi) on the soft harrowed sand

contained a slight bulge (convex upward) along the center of the rut surface. This bulge was approximately $1/4$ to $1/2$ in. in height with respect to the depth along the sides of the rut wall. Ruts made in tests in the undisturbed sand areas at low tire pressures showed an indication of this bulge but it was not nearly so pronounced as in the harrowed sand. The higher strength of the undisturbed sand yielded less to rutting and hence less bulging occurred in the center of the rut. This configuration, although slight, may be a clue to the confining effect of the side walls of the tire on the sand beneath the tire, and may be the cause of the improvement in vehicle performance in sand when tire pressures are reduced.

160. Transmission type. Vehicles with both automatic and manual transmissions were used throughout the test program. No conclusive observations were made as to the advantage of one over the other from the standpoint of vehicle performance. It is recognized, however, that the automatic transmission does eliminate the "driver effect" more than the mechanical transmission by partially assisting in a smooth movement from a stopped position on slopes. It may be possible that for a few tests near the borderline conditions of cone index-slope as described in paragraph 153, the positive connection of the mechanical transmission may have caused the tires to shear the sand surface initially and to start a process of shearing that eventually led to immobilizations, whereas an automatic-transmission type vehicle might not have become immobilized.

Sand strength

161. The use of the cone penetrometer and other instruments for measuring the existing strength of the 0- to 6-in. layer of soil was discussed in the 13th Supplement of the "Trafficability of Soils" series. The following paragraphs discuss the relations of sand strength (as measured by the cone penetrometer) and other sand characteristics.

162. Variations of strength with depth. The standard test procedure for all vehicle tests included the collection of cone index data to a depth of 15 in. or greater whenever possible. The best correlation between cone index and vehicle performance was obtained by considering average before-traffic cone index for the 0- to 6-in. depth; measurements taken at the surface, 3-in., and 6-in. depths are used in determining the average value. Except for a few cases, the strength of a sand consistently increased with

depth. It was found essential that the cone index be read at exactly the correct depth. The increase in strength with depth is usually of sufficient magnitude that, unless the cone index measurements are made with considerable care, the results can be very erroneous. The following table shows an example of what would happen if measurements were made 1 in. below the prescribed depths. For this example it was assumed that the data shown in table 6 for item 40 were correctly taken. Cone index was plotted against depth, and a curve was drawn. Readings were then taken at depths 1 in. lower than those prescribed, and the two were compared.

<u>Depth</u> <u>in.</u>	<u>Cone</u> <u>Index</u>	<u>Depth</u> <u>in.</u>	<u>Cone</u> <u>Index</u>
0	2	1	9
3	38	4	62
6	128	7	160
9	<u>240</u>	10	<u>284</u>
Avg 0- to 6-in. layer	56		77

163. An examination of test 40 (cone index 56, slope 15%, fig. 4 of plate 10) reveals what would happen to this test were it plotted at a cone index of 77 rather than at 56. The test was an immobilization that would plot on the wrong side of the line of separation if plotted at a cone index of 77. The fact that large differences in average readings can be introduced by reading cone index values at improper depths may well explain why some of the tests plot near or on the wrong side of the line of separation.

164. Variations of strength with moisture. As shown by plots of vehicle slope-climbing ability vs cone index, a given vehicle at a given tire pressure can operate more easily on a wet sand than on a dry or moist sand of equal cone index. This precludes any correlation that might be attempted between strength (as measured by the cone penetrometer) and vehicle performance without considering moisture condition of the sand. However, use of the cone index as a measure of expected vehicle performance in actual operation would give the lower limit of performance expected and, as moisture content increases, the performance of the vehicle would increase accordingly until a near-saturated state is reached and then the vehicle performance is less predictable. Any refinement that includes moisture condition will improve the over-all accuracy of measuring sand trafficability.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

165. The following conclusions are based on analysis of the data collected in the three test programs reported herein. The basic guide for these test programs was the findings reported in the 13th Supplement of the "Trafficability of Soils" series; therefore, these conclusions are also applicable for all coarse-grained soil tests conducted to date.

Single self-propelled wheeled vehicles

- a. Vehicle performance expressed in cone index-slope climbing ability terms is influenced by the moisture condition of the sand. Wet-to-inundated sands are more trafficable than dry-to-moist sands. Inundated sands, however, are apt to be in a quick condition if the water is in motion over and through the sand. Quick condition sands are not able to support traffic.
- b. The performance of self-propelled vehicles on dry-to-moist sands, as defined by the cone index-slope climbing curves, is the same regardless of sand source (quartz, volcanic, or coral) or location (beach or desert).
- c. Payload variations from empty to 1-1/2 times the rated load had no major effect on the slope-climbing ability of the self-propelled vehicles tested.

Towing tests with self-propelled vehicles

- a. The maximum drawbar pull for wheeled vehicles on level harrowed sand ranges between 20 and 40% of their gross weight; tracked vehicles are capable of maximum drawbar pulls of as much as 50 to 60% of their test weight.
- b. Load increase on the 2-1/2-ton M135 from empty to 10,000 lb decreased the maximum towing-force ability by 2.5% of the test weight at all tire pressures tested. For a given tracked vehicle (1/4-ton M29C), an increase in test weight of 1000 lb reduces the maximum towing-force ability by 3.5% of the test weight.
- c. The single-tandem 5-ton M71 has a 5% higher drawbar-pull ability than the dual-tandem 5-ton M54.
- d. For wheeled vehicles, maximum drawbar pull occurs at about 25% wheel slip for all loads at 10-psi tire pressure. At 30-psi tire pressure, maximum drawbar pull occurs at approximately 15% wheel slip. For tracked vehicles, track

slip is 37% at maximum drawbar pull for the 1/4-ton M29C at two test weights. At lower drawbar pulls, the percentage of track slip is less for the lighter load.

- e. Towing-force ability on harrowed sand slopes can be computed from test results on level harrowed sand, with an average difference of about 10% between actual and computed results.

Towed-vehicle tests

- a. Towing-force requirements for wheeled trailers can be correlated with cone index and tire pressure.
- b. For the tire pressures tested, sand disturbance by the towing vehicle has little effect on towing-force requirements when the towed and towing vehicles are operated at the same tire pressures.

Recommendations

166. It is recommended that:

- a. A rapid method be developed for confident recognition of the three moisture conditions of sand that are important from the trafficability standpoint--dry to moist, wet to inundated, and quick condition.
- b. Additional single self-propelled vehicle tests be made, with emphasis on wheeled vehicles of more than 5-ton capacity.
- c. Detailed studies of the effect of wheel load, tire pressure, and other vehicle characteristics on performance of vehicles in sand be continued.
- d. Towing tests on undisturbed sand with a range of military vehicles be conducted.
- e. Additional towed-vehicle tests, including tests with tractor-trailer combinations, be conducted.
- f. Work be conducted on procedures to derive means of evaluating performance of vehicles not tested.
- g. Vehicle tests on gravel beaches be conducted.
- h. Work on estimating the trafficability of untested beaches be continued.

Table 1

Physical Properties of Sand from the 0- to 6-in. Depth at Test Sites

Location	Beach	Sand Origin	Mechanical Analysis, %				Uniformity Coefficient**	Median Diameter** mm	Effective Diameter** mm	Specific Gravity	Unified Soil Classification		
			Coarse Sand	Medium Sand	Fine Sand	Fines**					Symbol	Note	
Oahu, T. H.	Mokuleia	Coral	0	92	8	0	1.62	0.61	0.42	2.73	SP	Medium sand	
	Dryden	Coral	0	97	3	0	1.56	0.71	0.50	---	SP	Medium sand	
	Mahua	Coral	0	77	23	0	1.37	0.50	0.38	2.74	SP	Fine to medium sand	
	Crescent	Coral	0	12	88	0	1.58	0.28	0.19	2.80	SP	Fine sand	
	Bunker	Coral	0	49	51	0	1.58	0.41	0.26	2.83	SP	Medium to fine sand	
	Pohai Bay 1	Coral	3	87	10	0	1.46	0.57	0.41	---	SP	Medium sand	
	Pohai Bay 2	Coral	3	85	12	0	1.63	0.58	0.38	---	SP	Fine to medium sand	
	MAD	Coral	0	73	27	0	1.41	0.50	0.37	---	SP	Fine to medium sand	
	Leist	Coral	0	98	2	0	1.40	0.66	0.50	---	SP	Medium sand	
	Kalapana	Volcanic	0	76	24	0	1.84	0.56	0.32	---	SP	Fine to medium sand	
Kauai, T. H. Honaleinai	1	Coral	0	9	91	0	2.27	0.22	0.11	---	SP	Fine sand	
	5	Coral	10	50	40	0	4.69	0.51	0.13	2.79	SP	Fine to medium sand	
	6	Coral	0	28	69	3	3.26	0.26	0.10	---	SP	Medium to fine sand, some silt	
	7	Coral	0	13	87	0	2.42	0.20	0.09	---	SP	Medium to fine sand	
	Himits	Coral	0	9	91	0	1.47	0.22	0.17	---	SP	Fine sand	
	Jones	Coral	4	89	7	0	1.70	0.73	0.47	---	SP	Medium sand	
	Tarague	Coral	1	23	76	0	1.64	0.32	0.22	---	SP	Medium to fine sand	
Luson, P. I. Midway Two Jim	MCB	Coral	0	52	48	0	2.35	0.41	0.13	---	SP	Fine to medium sand	
	Talofoto	Volcanic	0	19	79	2	1.75	0.25	0.16	---	SP	Medium to fine sand, some silt	
	Tun-3	Coral	0	20	80	0	2.45	0.22	0.11	---	SP	Medium to fine sand	
	Lido	Coral	3	55	42	0	2.57	0.47	0.21	---	SP	Fine to medium sand	
	Officers' Club	Coral	0	56	44	0	2.27	0.44	0.27	---	SP	Fine to medium sand	
	Red	Volcanic	0	64	36	0	1.92	0.48	0.26	2.71	SP	Fine to medium sand	
	Yellow	Volcanic	5	88	7	0	2.40	0.91	0.49	2.72	SP	Medium sand	
	Yuma Test Site												
	Test station	---	Quartz	0	21	75	4	2.75	0.28	0.12	---	SP-SM	Medium to fine sand, some silt
	Dune area	---	Quartz	0	19	74	7	3.50	0.23	0.08	---	SP-SM	Medium to fine sand, some silt
Camp Lejeune Test Site													
Onslow		Quartz	0	0	100	0	0.76	0.21	0.25	2.68	SP	Fine sand	

* Coarse sand--per cent by weight of sample retained on No. 10 U. S. Standard sieve (2.00 mm) but passing No. 4 sieve (4.75 mm).
 Medium sand--per cent by weight of sample retained on No. 40 U. S. Standard sieve (0.42 mm) but passing No. 10 sieve (2.00 mm).
 Fine sand--per cent by weight of sample retained on No. 200 U. S. Standard sieve (0.075 mm) but passing No. 40 sieve (0.42 mm).
 See Definitions, paragraph 5.

Table 2
Vehicle Data

Vehicle	Empty Weight lb	Approx Load lb	Test Weight lb	Width in.	Rim Diam in.	Fly Rating	No. of Tires	Tire Description		Average Contact Pressure psi [§]	Average Tire Print, in. [†] Length Width	
								Tire Pressure psi	Total Contact Area sq in. [‡]			
Pacific Islands Test Program												
Self-propelled Wheeled Vehicles††												
1/4-ton M38A1 4x4 truck	2,625	500	3,125	7.00	16	6	4	30	100.4	31.1	6.5	5.0
								20	133.8	23.4	7.4	5.3
								15	164.4	19.0	8.4	5.4
								10	188.6	16.6	8.6	5.6
3/4-ton M37 4x4 truck	5,917	1,500	7,417	9.00	16	8	4	30	224.4	33.0	8.7	7.4
								20	-----	-----	---	---
								15	297.8	24.9	10.8	7.6
								10	341.7	21.7	11.9	7.6
2-1/2-ton M211 6x6 truck	13,120	5,000	18,120	9.00	20	8	10	30	401.3	45.2	8.4	9.64
								20	454.9	39.8	9.0	9.94
								15	508.7	35.6	9.7	10.04
								10	591.5	30.6	10.9	10.24
2-1/2-ton M225 6x6 truck	14,820	2,500	17,320	11.00	20	12	6	30	399.0	43.4	11.2	7.1
								20	449.6	38.5	11.9	7.3
								15	502.2	34.5	13.0	7.4
								10	569.6	30.4	14.4	7.5
	5,000	19,820	11.00	20	12	6	30	426.1	46.5	11.8	7.0	
							20	492.2	40.3	13.0	7.4	
							15	530.5	37.4	13.4	7.5	
							10	577.6	32.6	14.5	7.6	
2-1/2-ton un-numbered 6x6 truck	11,000 est	4,600	15,600	8.25	20	--	6	50	-----	-----	-----	-----
Yuma Test Program												
Self-propelled Wheeled Vehicles††												
1/4-ton M38A1 4x4 truck	2,475	500	2,975	7.00	16	6	4	30	98.6	30.2	6.7	4.4
								20	121.7	24.4	7.5	4.7
								15	141.3	21.1	8.2	4.8
								10	167.5	17.8	9.2	5.0
3/4-ton M37 4x4 truck	5,645	0	5,645	9.00	16	8	4	30	178.7	31.6	7.8	6.7
								20	217.4	26.0	8.6	7.2
								15	247.3	22.8	9.1	7.5
								10	290.9	19.4	10.2	7.6
	750	6,275	9.00	16	8	4	30	197.7	31.7	8.0	7.1	
							20	236.2	26.6	8.8	7.3	
							15	262.5	23.9	9.4	7.5	
							10	306.0	20.5	10.7	7.6	
2-1/2-ton M135 6x6 truck§	12,450	0	12,450	11.00	20	12	6	30	223.1	31.8	9.0	7.2
								20	265.7	26.7	9.9	7.5
								15	301.0	23.5	10.7	7.6
								10	338.8	20.9	11.6	7.6
	2,300	7,805	9.00	16	8	4	30	241.2	32.4	9.0	7.2	
							20	281.1	27.8	10.2	7.6	
							15	317.4	24.6	10.7	7.6	
							10	363.6	21.5	12.2	7.7	
	5,000	17,350	11.00	20	12	6	30	324.9	38.3	9.9	6.3	
							20	372.8	33.4	10.7	6.6	
							15	436.9	28.5	11.8	6.9	
							10	499.8	24.9	12.9	7.1	
	10,000	22,705	11.00	20	12	6	30	415.4	41.3	11.7	6.8	
							20	494.0	35.1	12.8	7.2	
							15	546.1	30.6	13.9	7.5	
							10	637.7	27.2	15.1	7.8	
								30	550.0	41.3	13.6	7.5
								20	638.3	35.6	14.9	7.7
								15	710.4	32.0	15.9	8.0
								10	823.8	27.6	17.6	8.4

(Continued)

- Determined from tire prints on a hard surface.
- Computed by dividing test weight by total contact area, except where noted.
- † Average of greatest length and width of each tire.
- †† Empty weights from data plate on each vehicle; tire prints made for one side of vehicle only.
- ‡ Dual tires are considered as one for determining width.
- § Vehicles weighed on platform scales and tire prints made for all tires.
- § Total contact area, average contact pressure, and average tire print not determined for 15,000- and 20,000-lb test weight.

Table 2 (Continued)

Vehicle	Tire Description												
	Empty Weight lb	Approx Load lb	Test Weight lb	Width in.	Rim Diam in.	Fly Rating	No. of Tires	Tire Pressure psi	Total Contact Area	Average Contact Pressure	Average Tire Print, in.		
									sq in.	psi	Length	Width	
Yuma Test Program (Continued)													
Self-propelled Wheeled Vehicles (Continued)													
5-ton M41 6x6 truck	18,115	0	18,115	14.00	20	12	6	30	568.0	31.3	11.9	8.9	
								20	684.6	26.5	13.3	9.4	
								15	788.8	23.0	14.6	9.5	
								10	915.9	19.8	16.3	9.9	
	5,000	24,275	14.00	20	12	6	30	689.6	35.2	13.3	9.4		
							20	852.5	28.5	15.6	9.9		
							15	970.3	25.0	16.9	10.2		
							10	1197.2	20.3	19.9	10.7		
	10,000	26,175	14.00	20	12	6	30	795.7	35.4	14.8	10.0		
							20	955.3	29.5	16.5	10.3		
							15	1062.4	26.5	17.8	10.7		
							10	1339.2	21.8	20.5	11.1		
15,000	32,380	14.00	20	12	6	30	919.9	35.6	16.0	10.4			
						20	1078.3	30.0	18.2	10.6			
						15	1211.1	26.7	19.8	10.9			
						10	1480.2	21.9	22.6	11.3			
5-ton M54 6x6 truck	20,635	10,000	30,635	11.00	20	12	10	30	773.4	39.6	12.8	12.04	
								20	1004.6	30.5	15.1	12.94	
								15	1128.4	27.2	16.7	13.14	
								10	1307.6	23.4	18.2	13.74	
Self-propelled Tracked Vehicles													
	Test Weight lb	One Track in. Length Width		Both Tracks Total Contact Area sq in.		Average Contact Pressure psi							
1/4-ton M29C weasel	5,970	78	20	3,120		1.9							
	6,970	78	20	3,120		2.2							
18-ton M4A2 hi-speed tractor	36,910	126	24	6,048		6.1							
38-ton M5 hi-speed tractor	76,000	176	22	7,754		9.8							
Camp Lejeune Test Program													
Self-propelled Wheeled Vehicles													
1/4-ton M38A1 4x4 truck	2,775	200	2,975	7.00	16	6	4	30	98.6	30.2	6.7	4.4	
								20	121.7	24.4	7.5	4.7	
								15	141.3	21.1	8.2	4.8	
								10	167.5	17.8	9.2	5.0	
3/4-ton M37 4x4 truck	6,067	0	6,067	9.00	16	8	4	30	178.7	31.6	7.8	6.7	
								20	217.4	26.0	8.6	7.2	
								15	247.3	22.8	9.1	7.5	
								10	290.9	19.4	10.2	7.6	
2-1/2-ton M113 6x6 truck	12,450	5,000	17,450	11.00	20	12	6	30	419.4	41.3	11.7	6.8	
								20	494.0	35.1	12.8	7.2	
								15	566.1	30.6	13.9	7.5	
								10	637.7	27.2	15.1	7.8	

(Continued)

1 Dual tires are considered as one for determining width.

20 Vehicles weighed on platform scales.

25 Total contact area, average contact pressure, and average tire print length and width are assumed to be same as Yuma, Ariz., data.

Table 2 (Continued)

Vehicle	Empty Weight lb	Approx Load lb	Test Weight lb	Width in.	Rim Diam in.	Ply Rnt- ing	No. of Tires	Tire Description				Average Tire		Distribution of Weight, lb	
								Tire Pres- sure psi	Total Con- tact Area sq in.	Aver- age Con- tact Pres- sure psi	Print, in.	Length	Width	Tongue	Wheels
Camp Lejeune Test Program (Continued)															
Towed Wheeled Vehicles ⁶⁶															
1/4-ton M100 cargo trailer	569	0	569	7.00	16	6	2	25	29.9	16.5 ⁶⁷	4.4	4.4	75	494	
								20	31.4	15.7 ⁶⁷	4.7	4.6			
								15	37.7	13.1 ⁶⁷	5.0	4.7			
								10	41.2	12.3 ⁶⁷	5.2	4.7			
								25	31.0	22.8 ⁶⁷	4.8	4.2			
								20	33.0	21.4 ⁶⁷	4.8	4.3			
	250	782	7.00	5	6	2	15	38.6	18.3 ⁶⁷	5.1	4.8	75	707		
							10	44.7	15.8 ⁶⁷	5.6	5.0				
							25	43.7	23.5 ⁶⁷	5.7	5.0				
							20	47.1	21.8 ⁶⁷	5.9	5.0				
							15	54.5	18.8 ⁶⁷	6.0	5.2				
							10	61.5	16.7 ⁶⁷	7.0	5.2				
500	1,127	7.00	16	6	2	25	47.0	23.8 ⁶⁷	6.0	5.2	101	1,026			
						20	51.2	21.8 ⁶⁷	6.6	5.1					
						15	55.7	20.0 ⁶⁷	6.6	5.2					
						10	65.0	17.2 ⁶⁷	7.4	5.3					
						25	58.3	33.4 ⁶⁷	6.5	5.8					
						30	71.3	27.3 ⁶⁷	6.7	6.4					
3/4-ton M101 cargo trailer	1,339	750	2,089	9.00	16	8	2	20	81.6	23.9 ⁶⁷	7.0	6.6	140	1,343	
								10	111.5	17.5 ⁶⁷	8.6	7.1			
								45	75.7	36.7 ⁶⁷	7.0	6.8			
								30	96.3	28.8 ⁶⁷	8.0	7.2			
								20	113.9	24.4 ⁶⁷	8.8	7.5			
								10	155.7	17.8 ⁶⁷	10.9	7.6			
	1,500	2,960	9.00	16	8	2	45	90.5	38.4 ⁶⁷	7.6	7.2	183	2,777		
							30	104.6	33.2 ⁶⁷	8.2	7.5				
							20	132.3	26.2 ⁶⁷	9.8	7.7				
							10	171.2	20.3 ⁶⁷	11.8	7.7				
							45	100.5	37.4 ⁶⁷	9.0	7.0				
							30	121.6	30.9 ⁶⁷	9.9	7.1				
1-1/2-ton M105 cargo trailer	2,450	1,500	4,110	9.00	20	8	2	20	144.7	26.0 ⁶⁷	11.3	7.4	352	4,758	
								10	196.0	19.2 ⁶⁷	13.7	7.6			
								45	120.9	43.9 ⁶⁷	10.1	7.4			
								30	140.5	37.8 ⁶⁷	10.6	7.5			
								20	188.6	28.1 ⁶⁷	13.4	7.7			
								10	269.7	19.7 ⁶⁷	17.0	8.0			
	3,000	5,648	9.00	20	8	2	45	145.4	49.4 ⁶⁷	11.0	7.5	340	5,308		
							30	177.5	40.4 ⁶⁷	12.6	7.7				
							20	224.4	32.0 ⁶⁷	15.0	7.9				
							15	262.8	27.5 ⁶⁷	17.1	8.0				
							60	258.5	42.4	7.1	5.5				
							45	307.5	35.6	7.6	6.1				
6-ton cargo trailer	10,960	0	10,960	10.00	20	10	4) ⁶⁷	30	358.3	30.6	8.2	6.6			
								15	461.9	23.7	9.3	7.2			
								60	377.2	45.5	8.4	6.8			
								45	433.3	39.6	9.0	7.1			
								30	498.1	34.4	9.8	7.4			
								15	660.5	26.0	12.0	7.5			
	6,000	17,140	10.00	20	10	4) ⁶⁷	4)	60	490.4	52.0	9.8	7.3			
								45	533.8	47.8	10.6	7.5			
								30	638.0	40.0	11.6	7.5			
								15	799.6	31.9	13.7	7.4			
								60	128.5	55.7	8.2	4.9			
								45	146.2	42.9	8.8	5.0			
37.5-amp generator trailer	7,153	0	7,153	7.00	20	8	4	30	175.4	40.8	9.8	5.1			
								15	243.8	29.3	12.4	5.0			

⁶⁶ Vehicles weighed on platform scales and tire prints made for all tires.

⁶⁷ Computed from weight on axle instead of total test weight.

⁶⁸ 10.00mm tires on front axles and 11.00mm tires on rear axles.

Table 3

Summary of Data and Test Results, Single Self-propelled Vehicle Tests
1/4-ton V.C.M., 4x4 Truck (Four 7.00x16 Tires)

Item No.	Location	Beach	Beach Area*	Test No.	Slope No.	Tire Pressure psi	Immobilized	Cone Index at Depth of						Remarks		
								0 in.	1 in.	6 in.	9 in.	12 in.	15 in.		6 in.	12 in.
Pacific Islands Test Program																
Vehicle Test Weight 3,125 lb, Approximate Load 500 lb																
1	Oahu	Malua	MS	57	4	30	Yes	2	23	60	92	136	102	28	96	Seed dry to 2 in., moist below
2		Malua	MS	56	0	30	No	2	30	56	75	114	146	29	82	Slight jerking motion
3		Malua	DA	69	0	30	No	2	34	116	214	268	304	31	206	Dry sand, easy travel
4		Malua	DA	70	0	30	No	2	26	80	148	222	23	36	150	Dry sand, slight jerking motion
5		Malua	EC	71	0	30	Yes	2	20	56	86	100	4	26	81	Moist sand
6		Malua	MS	58	6	25	Yes	2	25	60	84	116	24	20	87	Seed dry to 2 in., moist below
7		Beaker	MS	270	9	20	Yes	2	47	108	174	252	304	52	178	Wheels spinning
8		Beaker	MS	271	6	20	Yes	5	50	130	206	230	274	62	189	Seed dry to 1-1/2 in., moist below
9		Beaker	MS	272	5	20	No	5	44	110	160	142	104	53	137	Seed dry to 1-1/2 in., moist below
10		Beaker	MS	269	5	20	No	4	35	114	196	268	304	51	193	Seed dry to 1 in., easy travel
11		Drone	PDA	76	5	20	Yes	2	20	61	105	146	145	28	104	Seed dry to 4 in., wheels spinning
12		Drone	PDA	77	4	20	No	2	38	92	142	162	194	44	132	Seed dry to 4 in., slight spinning
13		Malua	MS	59	2	20	Yes	2	20	70	116	130	90	31	105	Wheels spinning
14		Malua	MS	61	1	20	No	2	28	72	126	134	154	34	111	Seed dry to 3 in., slight spinning
15		Malua	EC	72	0	20	Yes	2	20	56	86	100	86	26	81	Moist sand, wheels spinning
16		Malua	MS	60	0	20	No	2	28	75	102	108	121	35	75	Seed dry to 4 in., no difficulty
17		Drone	PDA	78	10	15	Yes	2	18	50	88	105	103	23	31	Seed dry to 5 in., wheels spinning
18		Beaker	PDA	275	10	15	Yes	2	70	156	178	182	226	76	172	Seed dry to 2-1/2 in., wheels spinning
19		Beaker	PDA	79	8	15	No	2	38	94	162	216	236	45	157	Easy travel
20		Beaker	PDA	276	8	15	No	2	54	120	174	24	---	50	173	Easy travel
21		Beaker	MS	274	8	15	Yes	2	40	90	166	234	---	44	171	Seed dry to 1-1/2 in.
22		Beaker	MS	277	6	15	No	2	48	120	132	216	234	98	156	Seed dry to 4 in.
23		Beaker	PDA	278	6	15	No	2	52	104	152	192	---	53	149	Easy travel
24		Malua	MS	63	5	15	Yes	2	26	56	74	82	90	28	71	Seed dry to 2 in., violent jerking motion
25		Malua	MS	62	4	15	No	2	28	72	108	103	104	34	74	Seed dry to 2 in., some wheel spinning
26		Beaker	MS	273	3	15	No	2	48	104	218	238	220	51	187	Easy travel
27		Drone	EC	80	0	15	No	2	24	56	78	86	93	27	49	Moist sand, considerable effort
28		Malua	EC	73	0	15	Yes	2	24	63	69	77	91	23	63	Moist sand, jerking motion
29		Beaker	PDA	282	18	10	Yes	2	38	100	166	208	---	47	155	Seed dry to 2-1/2 in.
30		Beaker	PDA	280	16	10	No	2	70	136	208	304	---	72	215	Easy travel
31		Beaker	PDA	279	14	10	No	2	44	166	182	196	220	65	185	Easy travel
32		Drone	PDA	81	13	10	Yes	2	15	45	67	71	75	21	61	Seed dry to 4 in., jerking motion
33		Drone	PDA	82	10	10	Yes	2	27	69	112	156	180	33	112	Seed dry to 4 in., jerking motion
34		Beaker	MS	281	9	10	No	2	40	100	124	176	200	47	133	Easy travel
35		Malua	MS	61	6	10	Yes	5	29	52	72	79	81	29	67	Moist sand, jerking motion
36		Malua	MS	64	6	10	Yes	2	32	64	104	126	92	33	74	Moist sand, slight jerking motion
37		Malua	PDA	83	7	10	No	2	34	108	170	206	206	41	171	Easy travel
38		Drone	EC	74	0	10	No	2	24	43	69	77	94	23	63	Moist sand, easy travel
39		Malua	EC	75	0	10	No	2	25	45	72	96	100	26	71	Moist sand, difficult travel
40		Malua	PS	67	0	10	Yes	2	16	46	80	115	155	22	81	Irregular sand, 1 1/2 in.
41		Malua	PDA	66	13	5	No	2	28	74	138	208	260	36	141	Dry sand, easy travel
42	Two Jam	Red	PS	74	16	30	Yes	10	42	60	68	80	174	40	52	Seed wet
43		Red	PS	73	15	30	No	5	40	145	110	324	---	60	189	Seed wet
44		Red	PS	75	14	30	Yes	10	42	54	4	66	108	35	67	Seed wet, wheels spinning

* See "Beach Tests" under "Definitions" in text.
ec 1/4 in. depth.

Test No.	Location	Beach Area	Beach Area	Tire Pressure	Immo- bilized	Cone Index at Depth of					Cone Index Averages			Remarks
						0 in. 3 in. 6 in. 9 in. 12 in. 15 in.					0- to 6-in. 6- to 12-in. 12-in. to 18-in.			
						0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	0- to 6-in.	6- to 12-in.	
Pacific Islands Test Program (Continued)														
Vehicle Test Weight 3,125 lb, Approximate Load 500 lb (Continued)														
45	Iwo Jima (Continued)	Red	PS	30	No	8	75	70	165	300+	51	170+	124+	Sand wet, easy travel
46		Red	PS	30	Yes	5	35	44	48	82	28	58	43	Sand wet, wheels spinning
47		Red	PS	30	Yes	5	35	45	50	100	26	65	47	Sand wet
48		Red	PS	30	Yes	5	45	62	72	82	37	72	53	Sand wet
49		Red	PS	30	Yes	10	48	58	78	78	39	71	54	Sand wet, 10% tilt
50		Red	PS	30	No	5	36	72	88	100	36	87	61	Sand wet
51		Red	PS	30	No	5	42	60	65	80	36	68	50	Sand dry to 3 in., wet below, 8% tilt
52		Red	PS	30	No	5	36	45	50	52	29	49	38	Sand wet, wheels spinning
53		Red	PS	20	Yes	5	72	102	152	175	60	143	101	Sand moist, wheels spinning
54		Red	PS	20	Yes	5	35	52	62	68	31	61	44	Sand moist
55		Red	PS	20	Yes	5	32	130	183	300+	62	204+	134+	Sand wet, some spinning
56		Red	PS	20	No	5	40	160	205	300+	42	222+	150+	Sand wet, easy travel
57		Red	PS	20	Yes	10	40	65	88	60	38	71	53	Sand moist
58		Red	PS	20	No	10	35	48	55	85	31	63	47	Sand wet, 10% tilt
59		Red	PS	10	Yes	5	32	40	68	100	28	65	50	Sand dry to 3 in., wet below
60		Red	PS	10	Yes	10	38	42	58	68	33	59	45	Sand wet, wheels spinning
61		Red	PS	10	No	10	40	62	92	205	37	120	82	Sand wet
62		Red	PS	10	Yes	5	30	54	115	300+	31	158+	102+	Sand wet, wheels spinning
63		Red	PS	10	Yes	8	40	50	95	300+	33	148+	99+	Sand wet, wheels spinning
64		Red	PS	10	Yes	5	25	42	90	100	24	77	52	Sand moist
65		Red	PS	10	Yes	3	31	65	70	75	33	70	49	Sand dry to 2 in., moist below
66		Red	PS	10	Yes	3	32	62	78	72	32	71	49	Sand dry to 3 in., moist below
67		Red	PS	10	Yes	5	25	42	90	100	24	77	52	Sand moist
68		Red	PS	10	No	5	72	102	152	175	60	143	101	Sand moist, easy travel
69		Red	PS	10	No	3	38	55	68	105	32	76	54	Sand wet
70		Red	PS	10	Yes	3	32	52	90	168	29	101	68	Sand wet, wheels spinning
71		Red	PS	10	Yes	15	62	110	190	300+	62	200+	135+	Inundated, quick condition
72		Red	PS	10	No	5	33	53	88	165	30	102	69	Sand wet, easy travel
73		Red	PS	10	No	9	30	55	110	300+	31	154+	101+	Sand wet, 12% tilt
74		Red	PS	10	Yes	5	25	42	60	90	24	64	44	Sand wet, 12% tilt
75		Red	PS	10	No	5	35	45	40	50	28	45	35	Sand wet
Tuna Test Program														
Vehicle Test Weight 2,975 lb, Approximate Load 500 lb														
76	Iwo Jima	Red	PS	30	Yes	17	96	124	218	269	77	202	143	Sand dry on surface, moist below
77		Red	PS	30	Yes	17	104	149	230	245	90	243	145	Sand dry on surface, moist below
78		Red	PS	30	No	17	113	145	172	206	92	174	130	Sand dry on surface, moist below
79		Red	PS	30	Yes	15	139	110	203	246	78	193	141	Sand dry on surface, moist below
80		Red	PS	30	No	17	130	155	267	300+	97	247+	176+	Sand dry, easy travel
81		Red	PS	20	Yes	14	76	127	176	227	79	177	126	Sand dry on surface, moist below
82		Red	PS	20	No	14	117	102	185	276	74	188	137	Sand dry on surface, moist below
83		Red	PS	15	Yes	10	75	59	72	108	45	80	63	Sand dry on surface, moist below
84		Red	PS	15	No	15	106	108	190	300+	76	199+	144+	Sand dry on surface, moist below
85		Red	PS	15	No	10	97	118	218	265	75	200	142	Sand dry on surface, moist below
86		Red	PS	15	No	10	106	126	191	260	81	198	139	Sand dry on surface, moist below
87		Red	PS	15	Yes	8	74	109	224	300+	64	211+	143+	Sand dry on surface, moist below

• See "Beach Tests" under "Definitions" in text.

• 15-in. length.

Sheet 2 of 3 sheets

* See "Beach Areas" under "Deflections" in text.
 ** 18-in. depth.

Table 3 (Continued)

Item No.	Location	Beach	Beach Area	Test Slope No.	Tire Pressure psi	Immo-bilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Remarks		
							1 in.	3 in.	6 in.	9 in.	12 in.	1 1/2 in.	0- to 6-in.	6- to 12-in.		12- to 18-in.	
Yuma Test Program (Continued)																	
Vehicle Test Weight 2,975 lb, Approximate Load 500 lb (Continued)																	
88	Dune area			86	30	10	Yes	6	45	74	104	134	171	42	105	73	Sand dry on surface, moist below
89	(Continued)			87	23	10	No	7	108	154	161	172	194	90	162	120	Sand dry on surface, moist below
Camp Lejeune Test Program																	
Vehicle Test Weight 2,215 lb, Approximate Load 200 lb																	
90	Onslow Beach	PDA		23	30	25	Yes	19	72	104	192	300*	300*	65	199*	137*	Moist sand
91		PDA		25	24	25	Yes	16	132	246	300*	300*	300*	132	---	---	Moist sand
92		PDA		22	13	25	No	15	102	245	300*	---	---	121	---	---	Moist sand
93		PDA		24	12	25	No	17	92	253	300*	---	---	121	---	---	Moist sand
94		PDA		27	23	20	Yes	17	72	208	300*	---	---	99	---	---	Moist sand
95		PDA		29	20	20	Yes	17	62	143	257	300*	---	74	233*	156*	Moist sand
96		PDA		26	14	20	No	19	104	252	300*	---	---	125	---	---	Moist sand
97		PDA		28	12	20	No	16	82	242	300*	---	---	113	---	---	Moist sand
98		PDA		31	30	15	Yes	16	136	260	300*	---	---	136	---	---	Moist sand
99		PDA		34	21	15	Yes	17	56	75	127	280	300*	50	161	111	Moist sand
100		PDA		30	20	15	No	17	62	143	257	300*	---	74	233*	156*	Moist sand
101		PDA		35	19	15	No	13	55	62	162	300*	---	50	181*	128*	Moist sand
102		PDA		32	17	15	No	18	91	189	257	300*	---	99	249*	171*	Moist sand
103		PDA		33	17	15	No	18	124	233	300*	---	---	126	---	---	Moist sand
104		PDA		37	16	15	Yes	16	76	99	164	281	---	57	181	123	Moist sand
105		PDA		36	12	15	No	14	121	264	300	---	---	133	---	---	Moist sand
106		PDA		38	20	10	No	13	55	190	270*	370*	---	66	253*	166*	Moist sand

Table 4

Summary of Data and Test Results, Single Self-propelled Vehicle Tests
3/4-ton M37, 4x4 Truck (Four 9.0x16 Tires)

Item No.	Location	Beach Area	Beach Area No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of					Core Index Averages			Remarks		
							0 in. to 15 in.					0- to 12-in.					
							0 in.	3 in.	6 in.	9 in.	12 in.	0- to 6-in.	6- to 12-in.	12- in.			
Pacific Islands Test Program																	
Vehicle Test Weight 14,417 lb, Approximate Load 11,900 lb																	
1	Oahu	Mokuleia	DA	1	0	45	No	2	29	96	185	274	---	42	165	117	Sand dry to 5 in., moist below, slight jerking motion
2		Makua	DA	199	4	40	Yes	5	46	86	196	240	300	46	177	117	Sand dry to 2 in., moist below, wheels spinning
3		Makua	DA	198	3	40	Yes	5	45	82	195	144	254	45	111	77	Sand dry to 2 in., moist below, wheels spinning
4		Makua	DA	203	2	40	Yes	5	31	62	100	156	226	33	106	71	Sand dry to 2 in., moist below, wheels spinning
5		Makua	DA	205	2	40	No	5	57	126	192	244	300	63	201	133	Moist sand
6		Makua	DA	197	1.5	40	No	5	45	95	172	264	300	49	178	117	Moist sand, some spinning
7		Makua	DA	200	1	40	No	5	36	94	132	174	186	45	133	86	Sand dry to 2 in., moist below, some spinning
8		Makua	DA	202	0	40	Yes	2	31	70	114	156	252	34	123	61	Sand dry to 2 in., moist below, wheels spinning
9		Makua	DA	204	0	40	Yes	5	40	102	170	260	300	49	177	115	Moist sand
10		Makua	DA	196	0.1	40	No	4	66	142	230	300	300	71	224	148	Moist sand, easy travel
11		Makua	DA	201	0.5	40	No	2	45	90	162	216	280	48	158	104	Sand dry to 2 in., moist below, easy travel
12		Makua	DA	212	8	30	Yes	5	41	100	146	214	256	49	153	101	Sand dry to 2 in., moist below, wheels spinning
13		Makua	DA	210	6	30	Yes	2	40	96	176	264	300	46	179	116	Sand dry to 2 in., moist below, wheels spinning
14		Makua	DA	211	5	30	No	5	146	288	360	300	300	190	250	202	Sand dry to 2 in., moist below, easy travel
15		Makua	DA	200	4	30	No	2	54	116	220	280	300	57	205	134	Sand dry to 2 in., moist below, easy travel
16		Makua	DA	208	3	30	No	1	142	240	300	300	300	117	260	190	Sand moist, easy travel
17		Makua	DA	207	3	30	No	5	66	126	196	272	300	66	184	133	Sand moist, some spinning
18		Makua	DA	206	3	30	Yes	2	30	94	152	220	240	49	152	96	Sand moist, wheels spinning
19		Makua	DBB	213	0	30	Yes	5	7	56	69	78	74	13	66	44	Sand dry to 2 in., wheels spinning
20		Mokuleia	DA	2	2	30	Yes	2	26	47	201	267	300	38	185	117	Sand dry to 5 in., moist below, jerking motion
21		Makua	DBB	6	0.2	30	Yes	2	26	58	94	124	300	29	92	61	Sand moist, jerking motion
22		Crescent	DBB	102	4	22	Yes	5	40	47	125	143	170	45	118	70	Sand moist, jerking motion
23		Crescent	DB	116	14	20	Yes	2	19	44	77	124	171	22	82	53	Insulated, quick sand, sank quickly
24		Makua	DBA	231	14	20	Yes	5	32	105	118	148	200	54	124	86	Sand moist, wheels spinning
25		Crescent	DB	122	1	20	Yes	7	47	73	53	97	114	40	84	61	Sand moist, wheels spinning
26		Crescent	DBA	246	4	20	No	5	74	132	198	256	288	64	195	129	Sand dry to 2 in., easy travel
27		Crescent	DB	243	7	20	Yes	5	46	100	160	244	300	50	168	111	Sand moist, wheels spinning
28		Crescent	DBA	123	7	20	Yes	2	33	64	91	118	171	33	91	62	Sand dry to 3 in., wheels spinning
29		Crescent	DB	121	7	20	No	2	17	50	113	184	225	23	116	73	Insulated area
30		Crescent	DB	120	5	20	No	3	22	44	73	119	96	23	79	52	Sand wet, easy travel
31		Crescent	DBA	245	5	20	No	5	54	96	130	181	242	52	191	95	Sand dry to 1 in., moist below, easy travel
32		Makua	DB	215	5	20	Yes	5	17	72	110	122	126	41	105	71	Sand moist
33		Makua	DBA	230	4	20	Yes	5	34	76	134	178	300	40	129	86	Sand moist, wheels spinning
(continued)																	

• See "Beach Types" under "Definitions" in text.

Table 4 (Continued)

Item No.	Location	Beach Area	Beach Area	Test No.	Slope	Time Pressure psi	Immobilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Butt Depth in.	Remarks	
								0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	0- to 12-in.				
														0- to 6-in.	6-in. to 12-in.			12-in. to 18-in.
Pacific Islands Test Program (Continued)																		
Vehicle Test Weight 7,417 lb, Approximate Load 1,500 lb (Continued)																		
34	Oahu	Malua	228	214	3	20	Yes	5	35	70	84	96	98	37	83	58	Send dry to 2 in., moist below	
35	(Continued)	Crescent	242	242	3	20	No	5	58	114	204	290	284+	59	189	126	Send moist, no trouble	
36		Crescent	244	244	3	20	No	5	45	126	148	210	268+	59	161	107	Send moist, easy travel	
37		Crescent	247	247	3	20	No	2	64	94	110	110	108	53	105	76	Send dry to 3 in., moist below	
38		Malua	216	216	0	20	Yes	5	33	59	82	92	87	32	78	54	Send moist	
39		Crescent	119	119	0	20	No	4	23	46	81	126	194	24	84	56	Send wet, easy travel	
40		Maui	68	68	0	20	No	2	25	108	200	260	194	45	189	119	Send dry to 6 in.	
41		Crescent	109	109	0	20	No	10	58	124	120	135	132	64	127	90	Send moist, easy travel	
42		Crescent	110	110	0	20	Yes	6	21	26	34	48	68	18	36	27	Inundated, quick condition, quickly sunk	
43		Crescent	129	129	24	15	Yes	6	18	37	75	136	193	20	83	54	Inundated, quick cond., quickly stuck	
44		Crescent	131	131	16	15	Yes	6	28	43	87	112	198	26	81	56	Inundated, quick cond., quickly stuck	
45		Crescent	130	130	14	15	No	8	38	77	97	120	180	41	98	68	Send wet, some slippage	
46		Crescent	126	126	14	15	Yes	4	24	42	60	124	188	23	81	54	Inundated area	
47		Crescent	116	116	14	15	No	4	17	36	60	106	172	19	67	44	Inundated area, easy travel	
48		Crescent	117	117	14	15	Yes	2	28	52	90	162	260	30	104	68	Send dry to 5 in., tilt 35	
49		Malua	233	233	14	15	Yes	5	52	106	118	148	200	54	124	86	Send dry to 1 in., wheels spinning	
50		Crescent	252	252	13	15	Yes	2	35	82	118	162	240	40	121	80	Send dry to 3 in., wheels spinning	
51		Crescent	253	253	10	15	Yes	2	36	103	164	254	284	47	174	112	Send dry to 3 in., wheels spinning	
52		Crescent	255	255	10	15	Yes	2	40	99	138	194	262	47	144	95	Send dry to 3 in., wheels spinning	
53		Crescent	127	127	10	15	Yes	2	36	81	120	166	216	40	122	81	Send dry to 2 in., wheels spinning	
54		Crescent	128	128	10	15	Yes	2	39	76	135	181	246	39	131	87	Send dry to 2 in., wheels spinning	
55		Crescent	125	125	9	15	Yes	2	32	64	104	143	169	34	175	70	Send dry to 3 in., slight jerking motion	
56		Crescent	248	248	6	15	No	2	42	124	172	170	200	56	155	102	Send dry to 3 in., easy travel	
57		Crescent	251	251	7	15	Yes	3	31	64	90	104	188	31	80	55	Send moist, wheels spinning	
58		Crescent	124	124	7	15	No	2	33	100	124	104	171	33	91	62	Send dry to 3 in., easy travel	
59		Malua	220	220	7	15	Yes	5	31	100	124	104	104	45	109	73	Send dry to 2 in., moist below	
60		Crescent	240	240	6	15	No	3	62	133	111	158	230	66	134	93	Send dry to 3 in., 5/8 tilt, easy travel	
61		Crescent	250	250	5	15	No	5	59	111	156	225	300+	58	165	112	Send moist, easy travel	
62		Crescent	254	254	4	15	No	2	53	118	158	216	272	58	164	112	Send dry to 3 in., easy travel	
63		Crescent	256	256	4	15	No	2	55	124	122	152	244	60	135	92	Send moist, easy travel	
64		Malua	232	232	4	15	No	5	38	76	134	178	300+	60	129	86	Send dry to 1 in., moist below, some difficulty	
65		Malua	234	234	3	15	No	5	36	64	144	168	238	36	120	80	Send moist	
66		Malua	235	235	3	15	No	5	44	94	134	174	238	44	133	91	Send moist	
67		Malua	236	236	3	15	Yes	5	39	52	74	92	180	32	75	54	Send moist, wheels spinning	
68		Malua	219	219	2	15	No	5	39	80	94	106	144	61	93	65	Send moist, slight jerking but moving easily	
69		Maui	3	3	1	15	No	2	30	103	158	202	300+	45	164	105	Send dry to 5 in., easy travel	
70		Maui	4	4	0	15	Yes	2	25	49	68	91	64	25	66	45	Send moist, wheels spinning	
71		Maui	6	6	0	15	No	5	32	100	126	145	300+	46	124	82	Send moist, easy travel	
72		Maui	9	9	0	15	No	5	32	79	137	173	300+	39	130	85	Send moist, easy travel	
73		Maui	10	10	0	15	Yes	2	27	54	60	70	300+	29	63	43	Send moist, wheels spinning	
74		Maui	11	11	0	15	Yes	2	28	64	57	58	300+	31	60	42	Send moist, wheels spinning	
75		Maui	12	12	0	15	Yes	5	23	42	55	50	46	23	49	35	Send wet, sink quickly	
76		Maui	217	217	0	15	No	5	46	66	94	126	154	36	96	64	Send moist, some slippage	
77		Maui	218	218	0	15	No	5	40	73	112	168	174	39	112	80	Send moist, easy travel	
78		Maui	7	7	-2	15	Yes	5	26	57	56	50	300+	29	54	38	Send moist, jerking motion	

(Continued)

Table 4 (Continued)

Item No.	Location	Beach Area	Beach Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Remarks			
							0 in.	1 in.	2 in.	3 in.	4 in.	6 in.	12 in.	18 in.				
Pacific Islands Test Program (Continued)																		
Vehicle Test Weight 7,417 lb, Approximate Load 1,500 lb (Continued)																		
79	Oahu	Crescent	FD4	132	15	10	Yes	4	30	64	143	161	206	33	113	74	--	Sand dry to 6 in., moist below, wheels spinning
80	(Continued)	Makua	FD4	229	13	10	No	5	51	114	130	132	156	57	125	86	1.5	Sand dry to 1 1/2 in., moist below, easy travel
81		Makua	BC	15	10	10	Yes	5	32	81	111	137	100+	39	110	73	--	Sand moist, wheels spinning
82		Crescent	FB	114	7	10	No	5	26	53	102	152	224	28	102	68	3	Sand wet to inundated, easy travel
83		Makua	MS	226	7	10	Yes	5	24	36	54	86	120	22	59	41	3	Sand moist
84		Makua	MS	239	7	10	Yes	5	30	61	81	79	88	32	74	51	3	Sand moist, wheels spinning
85		Makua	MS	241	7	10	Yes	2	34	63	83	99	113	33	82	56	8	Sand moist
86		Makua	MS	225	6	10	Yes	5	27	46	62	90	128	26	66	46	7	Sand dry to 1 in.
87		Crescent	FB	113	6	10	No	8	24	44	78	106	142	25	76	52	3.5	Sand wet, 1 1/2 tilt, easy travel
88		Makua	MS	222	6	10	No	5	44	66	84	108	136	38	67	61	9	Sand moist, easy travel
89		Makua	MS	224	5	10	No	5	29	55	79	106	124	30	80	55	6	Sand dry to 2 in., easy travel
90		Makua	MS	221	5	10	No	5	30	71	112	86	100	35	90	61	5	Sand moist
91		Makua	MS	227	5	10	No	5	36	42	70	86	86	34	73	52	5	Sand moist, easy travel
92		Makua	MS	238	5	10	No	5	28	80	128	106	106	37	105	69	5	Sand dry to 3 in., moist below, easy travel
93		Makua	MS	240	5	10	No	2	31	77	126	116	98	37	106	70	5	Easy travel
94		Makua	FB	17	5	10	Yes	5	28	57	53	64	61	23	51	37	--	Inundated, quick cond, quickly stuck
95		Makua	BC	228	3	10	No	5	30	50	66	72	76	28	63	45	5	Sand moist, easy travel
96		Makua	BC	14	2	10	No	5	32	60	90	115	300+	12	88	40	--	Sand moist, some difficulty
97		Makua	FB	16	1	10	No	5	27	50	81	96	300+	27	76	52	--	Sand wet, easy travel
98		Makua	BC	237	4	10	No	5	25	53	72	106	114	27	84	56	5	Sand moist, easy travel
99		Makua	FB	11	0	10	No	2	24	67	96	76	300+	31	80	53	12	Sand moist
100		Makua	BC	11	0	10	No	3	25	57	78	81	67	28	72	49	6	Sand moist
101		Crescent	FB	111	0	10	No	10	50	76	112	118	112	45	102	73	5	Inundated, 2 1/2 tilt, easy travel
102		Crescent	FB	112	0	10	No	3	20	44	64	90	125	22	66	44	3.5	Inundated, 3 1/2 tilt, easy travel
103		Crescent	FB	115	0	10	No	4	19	33	56	90	126	19	60	40	7	Surface moist, wetter with depth
104	Ranaloa In	6	FB	6	12.8	50	Yes	24	75	178	260+	---	---	92	---	---	1.5	Surface moist, wetter with depth
105		6	FB	1	16	40	Yes	14	65	95	158	---	---	51	---	---	1.5	Surface moist, wetter with depth
106		5	FB	5	13	42	No	18	86	250	300+	---	---	118	---	---	2.0	Surface moist, wetter with depth
107		6	FB	6	13	30	Yes	12	63	120	213	---	---	95	---	---	4.5	Surface moist, wetter with depth
108		6	FB	4	14.5	20	Yes	17	73	133	212	---	---	74	---	---	--	Surface moist, wetter with depth
109	Oahu	Bluffs	FB	1	8.5	45	No	16	63	100	170	230	---	60	167	116	2.5	Tire pressure 32 psi front, 45 psi rear, easy travel
110		Jones	FB	24	25	32	Yes	8	29	57	105	190	220	31	117	78	--	Sand moist
111		Taruga	FB	3	20	32	Yes	6	32	80	125	215	260+	40	140	92	--	Sand moist
112		Jones	FB	2	13.5	32	No	10	47	100	157	240+	---	52	172	115	2.5	Sand moist
113		Taruga	FB	34	20	20	Yes	8	36	78	110	180+	---	41	123	82	--	Sand moist
114		Taruga	FB	36	21.5	15	Yes	8	35	80	138	180+	---	41	133	85	--	Sand moist
115		Lido	FB	1	18	40	Yes	15	66	130	300+	---	---	97	---	---	--	Sand moist, truck empty
116		Red	FB	2	6	45	Yes	9	39	62	79	92	9100	37	77	56	1	Sand moist, 1 1/2 tilt
117		Red	FB	1	4	45	Yes	5	34	61	54	51	7500	33	55	41	6	Sand moist, 1 1/2 tilt
118		Red	FB	3	4	45	Yes	11	54	73	73	72	75	46	73	57	10.5	Sand moist, 1 1/2 tilt
119		Red	FB	5	2.5	45	Yes	8	52	85	98	92	55	40	92	67	8	Sand moist, 10 1/2 tilt
120		Red	FB	4	2	45	No	10	42	82	92	78	75	45	84	61	8	Sand moist, 7 1/2 tilt
121		Red	BC	6	1	45	Yes	8	41	65	76	77	85	36	73	53	5	Sand moist, 10 1/2 tilt
122		Yellow	BC	21	1	30	Yes	5	35	60	135	215	300+	43	157	90	6	Sand dry to 2 in., moist below 2 1/2 tilt

(Continued)

Table 4 (Continued)

I-4 No.	Location	Beach Area	Beach Test No.	Slope %	Tire pressure psi	Inflated	Cone Index at Depth of						Cone Index Averages by Soil Layers		Remarks	
							0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	0- to 6-in.	6- to 12-in.		
							0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	0- to 6-in.	6- to 12-in.		
Pacific Islands Test Program (Cont. used)																
Vehicle Test Weight 7,411 lb, Approximate Lvs. 1,700 lb (Continued)																
122	1-00 Jima	Yellow	22	3	30	Yes	3	15	35	45	58	95	18	46	Sand moist	11
124	(Cont'r used)	Yellow	24	3	30	Yes	6	45	70	180	300+	300+	40	180+	Sand moist, 6% tilt	--
125		Yellow	26	1	30	Yes	8	44	65	112	165	168	39	114	Sand moist, 14% tilt	10
126		Yellow	23	0	30	No	5	50	112	300+	---	---	---	---	Sand dry to 2 in., 6% tilt	5
127		Yellow	25	0	30	No	5	49	65	168	190	170	40	141	Sand moist, 5% tilt	8
128		Red	10	10	20	Yes	3	48	65	75	70	90	40	70	Sand moist, 5% tilt	9
129		Red	13	8	20	Yes	5	36	52	58	65	101	31	58	Sand moist, 14% tilt	10
130		Red	9	6	20	No	5	45	65	90	100	115	36	85	Sand wet	3-5
131		Red	12	6	20	No	5	38	64	79	68	90	36	70	Sand wet, 1% tilt	8
132		Red	7	5	20	Yes	9	44	71	75	78	80	41	75	Sand moist, 5% tilt, wheels spinning	9
133		Red	8	5	20	No	10	46	64	80	75	95	41	73	Sand moist, 5% tilt, wheels spinning	6
134		Red	11	2	20	No	7	42	81	95	122	218	42	99	Sand moist, 5% tilt	6
135		Yellow	28	24	10	Yes	10	35	82	136	142	300+	42	121	Sand moist	7
136		Yellow	35	24	10	Yes	10	45	78	130	172	212	44	127	Sand wet	11
137		Red	15	22	10	Yes	8	45	78	68	70	75	44	72	Sand wet	9
138		Red	18	22	10	Yes	8	45	42	50	60	113	32	51	Sand wet	5
139		Red	16	21	10	No	5	42	58	61	150	275	32	90	Sand wet	4
140		Red	17	21	10	Yes	8	44	64	66	70	65	40	67	Sand wet	9
141		Red	14	20	10	No	5	45	32	112	178	208	44	111	Sand wet	2
142		Yellow	29	20	10	Yes	6	45	92	135	162	200	48	130	Sand moist	10
143		Yellow	30	20	10	Yes	10	45	100	168	188	300+	51	152	Sand wet	--
144		Red	19	17	10	No	7	40	62	65	72	60	46	64	Sand wet	3
145		Yellow	34	17	10	No	10	39	108	122	140	300+	52	140	Sand wet	3
146		Red	20	17	10	Yes	8	40	55	110	275	---	31	147	Inundated	12
147		Yellow	31	15	10	Yes	10	40	120	168	188	168	48	124	Sand moist	5
148		Yellow	32	15	10	Yes	5	40	120	148	132	162	62	141	Sand moist, 5% tilt	8
149		Yellow	32	10	10	No	5	40	112	150	180	---	62	147	Sand moist, 4% tilt	6
150		Yellow	27	14	8	Yes	8	45	70	140	175	---	38	128	Inundated area - not plotted	8

Yarn Test Program

Vehicle Test Weight 3,645 lb, No Load

Dune area	15-1	17-5	30	Yes	5	108	194	300+	300+	300+	102	265	181	----	Sand dry on surface, moist below
	15-1	17-5	30	Yes	5	84	110	220	300+	---	68	210	145	----	
	15-3	15	30	No	12	113	148	239	296	300+	91	288	162	1.90	
	15-4	11-5	30	Yes	5	70	82	101	135	222	46	106	75	----	
	15-5	10-5	30	No	10	114	136	268	300+	---	87	235	166	1.90	
	15-6	9-5	30	No	7	112	176	210	263	248	98	270	150	1.00	
	15-7	9-5	30	Yes	5	58	91	136	174	224	51	134	93	----	
	15-8	8-5	30	No	6	40	118	168	238	268	68	181	126	2.0	
	15-9	7	30	No	6	44	158	222	244	284	86	208	145	1.25	
	16-0	13-5	20	Yes	5	76	102	124	160	200	61	129	93	----	
	16-1	17-5	20	Yes	5	111	149	238	296	300+	83	288	160	----	
	16-2	16-5	20	Yes	5	98	145	275	286	332	83	235	162	----	
	16-3	16	20	No	6	116	163	224	218	140	95	202	145	1.75	
	16-4	14	20	No	5	107	168	248	300+	---	97	239	166	1.90	
	16-5	14	20	Yes	5	45	63	74	94	148	48	77	56	----	
	16-6	13-5	20	No	5	73	135	214	274	296	71	208	140	1.90	
	16-7	9-5	20	Yes	5	44	68	116	176	---	49	134	92	----	

(Continued)

Table 4 (Continued)

Item No.	Location	Bench Area	Bench Test Slope No.	Tire Pressure psi	Immo-bilized	Comp Index at Depth of					Comp Index Averages by Soil Layers			Remarks	
						0 in.	1 in.	6 in.	9 in.	12 in.	15 in.	0- to 6-in.	6-12 in.		12-in. to 12-in.
Yum Test Program (Continued)															
Vehicle Test Weight 5,645 lb, No Load (Continued)															
168	Dune area (Continued)		123	9.5	20	Yes	5	58	91	136	174	224	51	93	Sand dry on surface, moist below
169			124	9.5	20	Yes	5	51	80	110	148	216	45	79	
170			141	21	15	Yes	5	88	117	222	260	288	70	138	
171			132	20	15	No	5	107	162	286	300+	300+	91	172	
172			136	17.5	15	Yes	5	66	146	274	300+	---	72	158	
173			133	15	15	Yes	3	21	38	66	82	66	21	42	
174			140	15	15	Yes	7	88	102	128	164	194	66	98	
175			137	14	15	No	5	98	216	288	300+	---	106	181	
176			138	14	15	Yes	5	88	127	160	162	172	73	108	
177			139	14	15	Yes	5	58	38	34	36	32	34	34	
178			134	13	15	No	5	108	166	14	260	284	93	169	
179			135	9.5	15	No	5	67	116	196	270	292	63	131	
180			142	21	10	No	5	38	117	222	260	288	70	138	
181			141	14.5	10	Yes	5	55	85	110	136	170	48	78	
182			140	19.5	10	No	5	97	182	300+	---	---	95	177	
183			151	17.5	10	Yes	5	58	100	128	156	198	54	188	
184			143	16	10	No	5	146	212	284	300+	---	121	189	
185			145	16	10	Yes	5	43	100	132	136	160	49	123	
186			146	16	10	No	5	82	164	230	244	300+	84	147	
187		148	14	10	Yes	5	34	41	38	40	39	27	40		
188		144	8.5	10	Yes	5	25	38	104	176	248	23	70		
189		147	8.5	10	No	5	58	130	216	280	219	78	146		
Vehicle Test Weight 6,275 lb, Approximate Load 750 lb															
190	Dune area		159	12	30	Yes	5	89	132	218	300+	---	78	150	Sand dry on surface, moist below
191			156	11	30	Yes	5	89	128	194	246	300+	74	132	
192			158	10	30	Yes	10	59	76	145	142	184	48	79	
193			152	9.5	30	Yes	5	75	137	234	280	300+	72	146	
194			153	8.5	30	No	5	91	176	272	300+	---	91	169	
195			154	8.5	30	Yes	5	65	99	141	197	232	56	101	
196			157	8	30	No	5	112	188	260	288	292	102	171	
197			155	7	30	No	6	92	172	244	288	300+	90	160	
198			160	7	30	No	5	115	159	285	300+	---	93	173	
199			144	19.5	20	Yes	5	97	171	208	277	300+	91	152	
200			168	16	20	Yes	5	72	151	280	300+	---	76	162	
201			162	15	20	No	5	94	160	246	300+	---	87	161	
202			161	14	20	No	5	87	163	260	300+	---	85	163	
203			163	14	20	No	5	108	166	188	160	198	93	125	
204			166	12	20	Yes	5	87	110	155	190	184	67	101	
205			167	9.5	20	No	5	86	165	289	300+	---	85	137	
206			165	8.5	20	No	5	67	166	236	290	300+	79	153	
207			170	17.5	15	No	5	108	166	248	278	300+	93	161	
208			171	17.5	15	Yes	5	58	65	127	240	300+	36	97	
209			175	17.5	15	Yes	5	67	74	75	71	62	49	58	
210			176	16.5	15	No	5	114	178	240	280	300+	99	163	
211			169	16	15	No	5	73	138	180	272	300+	132	130	
212			173	11.5	15	No	5	103	137	232	300+	---	82	155	
213			172	10.5	15	No	5	78	109	147	180	222	64	145	
214			180	26.5	10	Yes	5	90	146	138	258	300+	80	149	

(Continued)

Table 4 (Continued)

Item No.	Location	Beach Area	Beach Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of						Cone Index Averages by Soil Layers			Remarks	
							0 in. 1 in. 3 in. 6 in. 9 in. 12 in. 15 in.						0- to 6-in. 6- to 12-in. 12- to 18-in.				
Yum Test Program (Continued)																	
Vehicle Test Weight 6,275 lb, Approximate Load 750 lb (Continued)																	
215	Dune area (Continued)		178	24	10	Yes	5	108	135	171	244	300+	83	183	133	Sand dry on surface, moist below	----
216			179	21	10	No	5	113	164	181	248	256	94	198	142		----
217			182	17.5	10	No	5	146	208	288	300+	---	116	265	197		----
218			177	17.5	10	Yes	5	48	61	55	56	64	38	57	45		----
219			181	16.5	10	Yes	5	42	54	64	135	187	34	91	64		----
220			176	16	10	No	5	102	140	167	186	224	82	164	120	----	
Vehicle Test Weight 7,085 lb, Approximate Load 1,500 lb																	
221	Dune area		64	13	30	Yes	16	106	151	277	300+	---	34	246	172	Sand dry on surface, moist below	----
222			70	11	30	Yes	12	80	119	172	218	280	70	170	120		----
223			71	11	30	No	13	105	147	240	298	300	88	278	161		----
224			74	17.5	20	Yes	14	103	143	203	209	254	87	185	134		----
225			75	17	20	Yes	11	52	66	136	254	299	43	152	104		----
226			76	16	20	No	14	90	119	187	227	242	74	178	127		----
227			83	22	15	Yes	10	105	158	269	299	292	91	242	168		----
228			77	18.5	15	Yes	10	83	154	258	300+	---	82	237	161		----
229			84	30	10	Yes	10	55	68	112	142	220	44	107	77		----
230			85	25.5	10	No	8	80	134	280	300	214	74	238	160		----
Vehicle Test Weight 7,805 lb, Approximate Load 2,300 lb																	
231	Dune area		185	13	30	Yes	5	107	180	247	286	296	97	238	165	Sand dry on surface, moist below	----
232			186	8.5	30	No	5	113	154	226	251	223	91	210	149		1.5
233			188	8.5	30	Yes	5	82	109	199	296	300+	65	201	138		2.75
234			189	8	30	Yes	5	75	156	242	300+	---	85	233	160		----
235			187	7	30	Yes	5	69	112	159	244	272	63	172	118		----
236			190	7	30	No	5	117	173	242	282	288	97	232	163		1.75
237			191	3.5	30	No	7	163	254	292	300+	---	141	282	203		1.0
238			195	18.5	20	Yes	5	102	170	268	300+	---	93	246	169		1.0
239			194	12	20	Yes	5	101	174	272	300+	---	77	189	170		----
240			193	8.5	20	No	5	98	127	195	244	288	85	233	160		----
241			192	6	20	No	5	95	156	242	300+	---	65	170	134		----
242			197	21	15	No	5	104	169	256	296	300+	93	244	168		1.0
243			196	18.5	15	Yes	5	97	122	148	216	247	75	162	118		----
244			199	16	15	Yes	5	75	175	179	288	288	85	214	144		----
245			198	15	15	Yes	5	59	99	72	70	43	61	67	53		----
246			198	14	15	Yes	5	34	37	41	54	64	44	44	34		----
247			199	10.5	15	No	5	106	149	209	276	300+	87	211	149		----
248			200	8.5	15	No	5	116	180	228	276	300+	100	288	161		----
249			190	18.5	10	Yes	5	83	77	31	112	89	55	91	74		----
250			171	17.5	10	No	5	115	166	258	300+	---	95	241	169		1.0
251			172	16	10	No	5	79	118	177	259	300+	67	186	128		1.5
252			173	16	10	Yes	5	43	81	76	112	188	61	96	67		----

(Continued)

Table 4 (Continued)

Item No.	Location	Beach Area	Beach No.	Slope %	Tire Pressure psi	Inno-bilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Part Depth in.	Remarks		
							0 in.	1 in.	6 in.	9 in.	12 in.	15 in.	6 to 12 in.	12 in.			12 in.	12 in.
							0 in.	1 in.	6 in.	9 in.	12 in.	15 in.	6 to 12 in.	12 in.			12 in.	12 in.
Camp Lejeune Test Program																		
Vehicle Test Weight 12,500 lb., No Load																		
253	Onslow Beach	FDA	72	12	45	Yes	16	81	183	274	300*	---	---	94	171*	Moist sand		
254		FDA	68	9	45	Yes	17	85	173	300*	---	---	---	92	---	1.5		
255		FDA	71	6	45	No	15	84	217	300*	---	---	---	109	---	---		
256		FDA	67	8	45	No	17	117	342	300*	---	---	---	125	---	---		
257		FDA	70	6	45	Yes	14	80	175	300*	---	---	---	90	---	---		
258		FDA	73	0	45	No	17	94	180	300*	---	---	---	97	---	---		
259		FDA	69	6	45	No	15	126	254	300*	---	---	---	142	---	---		
260		FDA	78	15	40	Yes	17	86	111	227	300*	---	---	91	213*	---		
261		FDA	80	12	40	Yes	15	71	155	267	300*	---	---	81	240*	---		
262		FDA	74	10	40	No	15	95	236	300*	---	---	---	116	---	---		
263		FDA	76	9	40	No	18	102	207	297	300*	---	---	139	268*	1.0		
264		FDA	79	9	40	No	16	84	184	300*	---	---	---	96	---	---		
265		FDA	75	6	40	No	15	88	238	300*	---	---	---	114	---	---		
266		FDA	77	8	40	No	15	69	120	253	300*	---	---	68	218*	1.1		
267		FDA	84	21	30	Yes	20	65	82	77	180	300*	---	96	113	85		
268		FDA	82	21	30	Yes	18	109	212	253	300*	---	---	113	248*	178*		
269		FDA	86	16	30	Yes	18	77	186	300*	---	---	---	94	---	---		
270		FDA	83	12	30	No	17	126	170	244	300*	---	---	105	238*	172*		
271		FDA	85	11	30	No	17	91	231	300*	---	---	---	113	---	---		
272		FDA	81	7	30	No	16	122	179	272	300*	---	---	106	246	178*		
273		FDA	80	21	20	Yes	19	113	229	300*	---	---	---	120	---	---		
274		FDA	88	17	20	Yes	18	89	174	247	300*	---	---	90	237*	164*		
275		FDA	87	1	20	No	15	81	177	263	300*	---	---	92	247*	148*		
276		FDA	89	15	20	No	15	87	205	275	300*	---	---	102	290*	176*		
277		FDA	129	12	10	Yes	20	173	253	300*	---	---	---	149*	---	---		
278		FDA	131	24	10	No	15	147	290*	300*	---	---	---	149*	---	---		
279		FDA	127	22	10	No	15	95	171	242	298*	300*	---	97	217*	153*		
280		FDA	130	20	10	No	15	152	265	300*	---	---	---	145*	---	---		
281		FDA	128	16	10	No	15	143	287	300*	---	---	---	145*	---	---		

Table 5

Summary of Data and Test Results, Single Self-Propelled Vehicle Tests

2-1/2-ton M21, 6x6 Truck (Ten 9.00x20 Tires)

2-1/2-ton Unarmored 6x6 Truck (Six 9.75x20 Tires)

Item No.	Location	Beach Area	Beach Test No.	Slope %	Tire Pressure psi	Immobilized	Core Index Averages by Soil Layers						Remarks	
							Core Index at Depth of							
							0 in. to 6 in.	6 in. to 12 in.	12 in. to 18 in.	18 in. to 24 in.	24 in. to 30 in.	30 in. to 36 in.		
Pacific Islands Test Program, M21 Truck														
Vehicle Test Weight 13,120 lb, No Load														
1	Iwo Jima	Yellow	37	14	45	Yes	10	72	130	300+	---	---	5	Seal moist
2		Yellow	36	9	45	No	5	90	170	240	---	---	2	Seal dry to 2 in., wet below
3		Red	67	26	10	Yes	4	32	52	65	125	60	9	Seal wet
4		Red	66	22	10	Yes	4	22	52	116	300+	---	9	Seal wet
5		Red	69	18	10	No	5	35	50	55	140	300+	4	Seal wet, some difficulty
6		Red	92	18	10	Yes	3	35	48	70	58	780	12	Seal moist
7		Red	90	17	10	Yes	5	30	48	60	80	1080	8	Seal moist
8		Red	91	14	10	No	5	52	75	105	185	---	---	Seal wet
Vehicle Test Weight 18,120 lb, Approximate Load 5,000 lb														
9	Oahu	Barrier	137	7	45	Yes	5	34	78	180	236	119	79	Seal moist, severe jerking motion
10		Barrier	136	6	45	Yes	7	45	116	196	238	156	104	Seal moist, slight jerking motion
11		Barrier	167	6	45	Yes	5	34	77	110	131	106	71	Seal moist, severe jerking motion
12		Barrier	138	5	45	Yes	5	49	103	148	179	141	96	Seal moist, severe jerking motion
13		Barrier	173	4	45	Yes	5	30	72	106	142	107	71	Seal moist, 7 1/2 tilt, wheels spinning
14		Barrier	171	3	45	Yes	5	28	67	113	161	114	75	Seal moist, wheels spinning
15		Barrier	166	2	45	Yes	5	34	76	110	166	109	73	Seal moist, slight jerking motion
16		Barrier	170	1.5	45	Yes	5	28	67	113	161	114	75	Seal moist
17		Barrier	172	1	45	Yes	5	28	60	100	128	96	64	Seal moist, wheels spinning
18		Barrier	133	1	45	No	8	56	114	157	130	134	93	Seal moist, slight turn
19		Barrier	134	0	45	No	7	34	108	137	205	150	102	Seal moist, easy travel
20		Barrier	135	0	45	No	5	38	100	127	167	131	87	Seal moist, easy travel
21		Barrier	160	0	45	Yes	5	30	69	67	93	125	49	Seal moist, 1 1/2 tilt, some spinning
22		Barrier	168	0	45	No	5	36	75	113	140	102	76	Seal moist, easy travel
23		Barrier	169	0	45	No	5	35	75	113	140	109	74	Seal moist, some spinning
24		Barrier	159	-1	45	No	5	30	69	67	93	126	49	Seal moist, 1 1/2 tilt, some spinning
25		Barrier	179	3	32	Yes	5	35	80	138	204	141	92	Seal dry to 2-1/2 in., moist below, jerking motion
26		Barrier	175	0	32	No	6	43	82	188	192	134	90	Seal dry to 2-1/2 in., easy travel
27		Barrier	179	7	30	Yes	5	42	112	176	258	182	119	Seal moist
28		Barrier	179	5	30	Yes	5	37	86	140	204	143	94	Seal moist, wheels spinning
29		Barrier	260	5	30	Yes	5	42	108	186	268	187	122	Seal dry to 2 in., moist below
30		Barrier	262	5	30	Yes	5	42	100	150	202	151	100	Seal dry to 2 in., moist below
31		Barrier	140	3	30	Yes	5	36	94	142	196	143	94	Seal moist, severe jerking motion
32		Barrier	181	2	30	Yes	5	26	67	63	76	62	43	Seal moist
33		Barrier	258	2	30	No	5	40	86	170	232	175	118	Seal moist
34		Barrier	261	2	30	No	5	40	110	182	274	182	118	Seal dry to 2 in.
35		Barrier	161	0	30	Yes	5	37	67	105	189	100	64	Seal moist, gentle jerking motion
36		Barrier	160	0	30	No	6	49	94	178	204	159	107	Seal moist, easy travel
37		Barrier	257	0	30	No	2	56	150	180	234	161	120	Seal dry to 2 in., slight slipping
38	Crested		146	3	20	Yes	3	34	67	137	193	119	91	Seal dry to 6 in.
39	Crested		149	5	20	Yes	3	36	92	140	198	143	94	Seal moist, jerking motion
40	Barrier		263	8	20	Yes	5	42	128	160	274	191	126	Seal moist

(Continued)

0 See "Beach Tests" under "Deflation" in text.
 00 10-in. depth.

Table 5 (Continued)

No.	Location	Beach Area	Beach	Tire Pressure psi	Slope	Test No.	Immobilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Remarks		
								0 in.	1 in.	6 in.	12 in.	15 in.	0- to 6-in.	6- to 12-in.	12- to 18-in.			
																	Art Depth in.	
Pacific Islands Test Program, M211 Truck (Continued)																		
Vehicle Test Weight 18,120 lb, Approximate Load 5,000 lb (Continued)																		
41	Oahu (Continued)	Bunker	MS	20	6	265	Yes	5	52	118	132	204	272	58	151	102	8	Sand moist, 7 1/2 tilt
42		Bunker	MS	20	6	266	Yes	5	46	90	132	172	264	47	131	89	6	Sand moist
43		Bunker	MS	20	6	268	Yes	5	52	106	146	180	190	54	131	90	6	Sand dry to 1-1/2 in., moist below
44		Crescent	FDA	20	5	145	Yes	5	36	68	143	193	271	43	141	93	8	Sand moist, jerking motion
45		Crescent	FDA	20	4	144	No	3	37	99	161	210	292	46	157	102	6	Sand moist
46		Crescent	FDA	20	3	141	No	5	37	91	149	204	290	44	148		9	Sand moist, slight jerking motion
47		Maui	MS	20	2.5	184	Yes	5	32	52	80	106	108	30	79	77	6.5	Sand moist
48		Bunker	MS	20	2.5	264	No	5	34	106	202	290	308	48	199	127	6	Sand moist, 7 1/2 tilt
49		Bunker	MS	20	2	267	No	5	39	128	268	300	300	57	232	148	5	Sand dry to 1-1/2 in., easy travel
50		Maui	MS	20	1.5	185	Yes	5	35	58	84	112	160	33	85	59	9.5	Sand moist
51		Crescent	MS	20	1	143	No	4	49	96	131	154	208	50	127	87	4	Sand moist, easy travel
52		Maui	MS	20	1	186	Yes	5	32	56	71	86	114	31	71	50	10	Sand moist, wheels spinning
53		Maui	EC	20	0	162	Yes	5	37	72	114	141	165	38	109	74	9	Sand dry to 2 in., up tilt
54		Maui	DA	20	0	182	Yes	5	25	44	72	86	104	25	67	46	9	Sand moist, wheels spinning
55		Maui	MS	20	0	183	No	5	48	86	124	164	246	46	125	85	--	Sand moist, easy travel
56		Crescent	FDA	15	1	146	Yes	5	34	90	141	214	286	43	148	37	8	Sand moist, jerking motion
57		Crescent	FDA	15	1	149	Yes	2	33	82	135	180	248	39	132	86	8	Sand dry to 2 in., jerking motion
58		Crescent	FDA	15	1	147	No	5	34	90	141	214	286	43	148	97	8	Sand moist
59		Maui	MS	15	2.5	188	Yes	5	33	64	90	108	144	34	87	60	12	Sand moist, wheels spinning
60		Maui	MS	15	1	187	No	5	31	61	89	136	178	32	95	64	6	Sand moist, slight spinning
61		Crescent	FDA	10	11	154	Yes	5	32	66	119	186	248	33	124	81	8	Sand moist, wheels spinning
62		Maui	FDA	10	11	176	Yes	5	37	87	154	219	275	43	153	100	8	Sand moist, wheels spinning
63		Crescent	FDA	10	10	151	Yes	3	36	92	126	181	242	44	133	88	8	Sand moist, wheels spinning
64		Crescent	FDA	10	8	154	Yes	2	32	85	129	167	213	40	127	83	8	Sand moist, wheels spinning
65		Maui	MS	10	8	195	Yes	5	31	69	66	88	108	28	68	48	9	Sand moist, jerking motion
66		Maui	DA	10	7	165	Yes	2	35	77	112	160	253	38	116	77	9	Sand dry to 6 in., severe jerking motion
67		Maui	FDA	10	7	177	No	5	44	90	168	261	304	46	171	114	2	Sand moist, easy travel
68		Crescent	FDA	10	6	150	No	2	33	82	135	180	248	39	132	86	2	Sand moist, some spinning
69		Maui	MS	10	6	194	No	5	33	64	86	120	152	34	90	62	5	Sand moist
70		Maui	MS	10	5.5	190	Yes	5	32	77	67	74	86	31	64	47	12	Sand moist
71		Crescent	FDA	10	5	153	No	2	34	95	127	169	271	40	127	83	3	Sand moist
72		Maui	MS	10	5	156	Yes	2	30	6	110	178	205	33	118	77	6	Sand dry to 3 in., moist below, wheels spinning
73		Maui	MS	10	5	191	No	5	31	59	84	102	108	32	82	50	7	Sand moist, no trouble
74		Maui	MS	10	5	193	No	5	35	62	100	116	170	34	93	64	4	Sand moist
75		Maui	EC	10	4	157	Yes	4	35	63	104	150	238	34	105	71	6	Sand moist, wheels spinning, slight turn
76		Maui	MS	10	4	174	No	5	32	64	101	140	175	34	102	68	8	Sand moist
77		Maui	FDA	10	4	175	No	5	38	75	111	172	230	39	120	81	6	Sand moist, easy travel
78		Maui	MS	10	4	189	No	5	31	62	90	114	126	33	84	60	5.5	Sand moist, easy travel
79		Maui	MS	10	4	192	No	5	39	73	108	148	204	39	110	75	4	Sand moist, easy travel
80		Maui	MS	10	2	155	No	2	28	65	134	152	270	32	130	84	5	Sand dry to 3 in., moist below
81		Maui	EC	10	0	158	No	5	37	71	106	135	165	38	105	71	4.5	Sand moist, easy travel
82		Maui	EC	10	0	163	No	5	36	65	91	117	146	35	98	63	4	Sand moist, easy travel
83		Maui	DA	10	4	164	No	3	23	77	120	180	271	32	123	73	4	Sand dry to 6 in.
84		Maui	EC	10	12	142	Yes	5	48	86	91	95	95	46	91	55	9	Sand moist
85		Maui	EC	10	11	143	Yes	4	40	58	130	155	190	47	108	85	--	Sand inundated, quick sand, quickly sand
86	Iso Jim	Maui	MS	10	11	158	Yes	25	115	168	280	308	...	103	144	164	7	Sand dry to 2-1/2 in., moist below

(Continued)

Table 5 (Continued)

Item No.	Location	Beach Area	Beach Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Remarks		
							0 in. 1 in. 6 in. 9 in. 12 in. 15 in.					0- to 6-in. 6- to 12-in. 12- to 15-in.					
Pacific Islands Test Program, M211 Truck (Continued)																	
Vehicle Test Weight 18,120 lb, Approximate Load 5,000 lb (Continued)																	
87	Iwo Jima	Red	40	10	45	Yes	10	105	115	208	300+	---	77	208+	143+	Sand moist	6
88	(Continued)	Red	39	9	45	No	6	114	300+	---	---	---	140+	---	---	Sand wet	2
89		Red	57	8	45	No	30	65	140	300+	---	---	78	---	---	Sand dry to 3 in., hard crust	3
90		Red	38	7	45	Yes	16	160	247	300+	---	---	141	---	---	Sand wet, quick condition, quickly sank	5
91		Red	55	7	45	Yes	22	75	136	178	182	188	78	119	119	Sand moist	4
92		Red	56	7	45	Yes	12	55	98	118	118	125	55	111	80	Sand dry to 3 in., moist below	9
93		Red	53	6	45	No	29	88	170	205	212	170	96	146	141	Crusted sand to 1 in.	6
94		Red	54	4	45	No	30	75	110	105	130	140	72	115	90	Crusted sand to 1 in.	3
95		Red	41	-1.5	45	No	5	58	49	58	62	278	37	56	46	Sand moist	5
96		Red	44	11	20	Yes	5	45	61	75	88	152	77	75	55	Sand moist	9
97		Red	46	11	20	Yes	5	36	155	190	220	300	75	188	175	Sand dry to 3 in.	4
98		Red	48	10	20	No	14	90	170	193	300+	---	91	221+	153+	Sand dry to 3 in.	1.5
99		Red	51	10	20	Yes	5	40	58	60	62	90	34	60	45	Sand moist	9
100		Red	52	8	20	No	5	38	62	70	85	102	35	72	52	Sand dry to 3 in.	5
101		Red	47	7	20	No	5	94	170	242	210	125	90	207	144	Sand moist	2
102		Red	49	5	20	Yes	10	65	90	200	230	300	55	173	119	Sand dry to 3 in.	5
103		Red	50	4	20	No	5	62	102	158	215	300	56	158	108	Sand dry to 3 in.	3
104		Red	45	3	20	No	5	55	94	86	90	90	51	90	66	Sand moist	8
105		Red	65	38	10	Yes	5	48	70	100	105	117	41	92	66	Sand wet	6
106		Red	64	37	10	Yes	5	25	45	70	70	65	25	62	43	Sand wet	5
107		Red	63	24	10	No	20	55	82	180	300+	---	52	187+	127+	Sand wet	2
108		Red	62	21	10	No	5	42	55	60	70	168	34	62	46	Sand wet	3
109		Red	60	19	10	No	5	40	55	60	65	95	33	60	45	Sand wet	3
110		Red	61	14	10	No	5	28	52	62	145	75	28	86	58	Crusted sand 1/2 in., wet below	4
111		Red	59	13	10	No	10	42	72	85	95	300	41	84	61	Sand wet	3
Pacific Islands Test Program, 2-1/2-ton Thunderbolt 7 wch																	

Pacific Islands Test Program, 2-1/2-ton Unpowered 7 wt

Vehicle Test Weight 15,000 lb, Approximate Load 4,800 lb																
112	Kanajale	6	75	14	50	No	60	98	300	---	---	---	153	---	---	2
113		6	75	14	50	No	31	77	133	260	300	---	80	231	160	2
114		7	75	13	50	Yes	33	77	190	248+	---	---	100	---	---	---
115		6	75	0	50	No	20	55	128	300	---	---	68	---	---	5

Table 6

Summary of Data and Test Results, Single Self-propelled Vehicle Tests
2-1/2-ton M215 and M135, 6x6 Trucks (Six 11.00x20 Tires)

Item No.	Location	Beach	Beach Area	Test Slope Mo. %	Tire Pressure psi	Immobilized	Cone Index at Depth of						Net Size, in. Width	Remarks		
							by Roll Layers									
							0 in.	1 in.	6 in.	9 in.	12 in.	15 in.			0- to 6-in.	6- to 12-in.
Pacific Islands Test Program - M215 Truck																
Vehicle Test Weight 11,000 lb., Approximate Load 2,000 lb.																
1	Oahu	Bunker	EC	55	40	No	60	136	178	224	218	7	179	120	6	Sand moist, easy travel
2		Makua	DA	47	40	Yes	25	95	140	140	230	43	125	80	13	Sand dry, some difficulty
3		Bunker	EC	54	40	No	60	136	178	224	218	67	179	120	6	Sand moist, easy travel
4		Makua	DA	42	30	Yes	25	85	116	148	286	41	116	77	14	Sand dry, slow creep forward
5		Makua	EC	46	30	Yes	45	90	110	118	157	46	106	73	16	Sand moist
6		Bunker	EC	53	30	No	60	148	192	148	124	70	163	110	11	Sand moist
7		Makua	EC	47	20	Yes	39	70	67	92	93	44	90	62	15	Sand dry on surface, moist below
8		Makua	EC	45	20	No	45	90	110	118	137	46	126	73	10	Sand moist, easy travel
9		Makua	EC	43	20	No	34	80	118	130	168	39	109	73	11	Sand dry on surface, moist below
10		Makua	EC	44	20	No	42	107	124	152	160	50	127	85	--	Sand dry on surface, moist below
Vehicle Test Weight 19,000 lb., Approximate Load 5,000 lb.																
11	Oahu	Makua	EC	18	50	Yes	30	78	142	195	234	37	138	90	17	Sand dry to 3 in., moist below
12		Makua	EC	19	40	Yes	30	78	142	195	234	37	138	90	17	Sand dry to 3 in., moist below
13		Makua	DA	25	40	Yes	28	95	190	248	284	41	178	112	11	Sand dry to 3 in., moist below
14		Makua	EC	20	30	Yes	25	85	116	148	286	41	116	70	18	Sand dry to 3 in., moist below
15		Crescent	EC	104	20	Yes	40	66	128	194	280	43	146	90	12	Sand dry to 3 in., moist below
16		Crescent	EC	105	20	Yes	40	63	124	184	260	42	130	87	12	Sand dry to 6 in., moist below
17		Crescent	EC	103	20	No	42	76	68	104	112	43	89	64	9	Sand moist, slight jerking motion
18		Crescent	EC	107	20	No	46	104	148	222	240	51	158	104	6	Sand wet, easy travel
19		Makua	EC	21	20	Yes	26	60	114	149	215	29	108	70	18	Sand dry to 3 in., moist below
20		Makua	EC	40	20	Yes	34	51	71	68	67	29	70	50	16	Sand moist, wheels jerking
21		Makua	EC	31	20	Yes	28	63	103	112	190	38	93	66	16	Sand moist, wheels jerking
22		Makua	EC	35	20	Yes	31	76	79	56	54	36	70	49	8	Sand moist
23		Makua	EC	34	20	No	38	158	282	170	300	73	240	156	1	Sand moist, easy travel
24		Makua	EC	40	20	Yes	36	70	129	184	202	46	128	84	11	Sand moist, wheels spinning
25		Crescent	EC	106	20	No	42	90	134	254	294	45	167	104	8	Sand dry to 6 in., moist below
26		Makua	EC	86	20	No	39	64	162	252	272	42	166	108	7	Sand moist, easy travel
27		Makua	EC	54	20	Yes	35	66	120	148	122	34	108	72	18	Sand moist, wheels spinning
28		Makua	EC	91	20	No	30	84	140	158	174	39	127	84	11	Sand moist, some other planing
29		Makua	EC	85	20	No	33	82	148	194	274	39	138	90	5	Sand moist, easy travel
30		Makua	EC	89	20	No	40	98	172	200	206	47	157	102	10	Sand moist
31		Makua	EC	38	20	Yes	31	63	112	152	188	37	157	102	16	Sand moist
32		Makua	EC	27	20	No	28	79	190	248	284	41	178	112	5	Sand dry to 5 in., moist below
33		Makua	EC	27	20	Yes	14	28	57	56	50	14	60	27	17	Sand moist, 1/2 tilt, wheels spinning
34		Makua	EC	33	20	No	32	78	125	160	190	37	145	76	8	Sand moist, easy travel
35		Crescent	EC	101	20	No	28	60	101	124	142	22	101	30	10	Sand wet, easy travel
36		Crescent	EC	102	20	No	30	63	101	124	142	22	101	30	10	Sand wet, easy travel
37		Makua	EC	87	15	Yes	34	74	128	144	126	37	115	76	10	Sand dry to 3 in., moist below
38		Makua	EC	88	15	Yes	33	60	123	175	148	34	122	80	14	Sand dry to 3 in., moist below
39		Makua	EC	95	15	Yes	30	100	174	268	300	54	181	111	15	Sand dry to 6 in., moist below
40		Makua	EC	100	15	Yes	36	128	240	270	300	54	213	136	10	Sand dry to 6 in., moist below
41		Makua	EC	98	15	Yes	40	80	124	170	290	43	125	85	12	Sand dry to 6 in., moist below
42		Makua	EC	97	15	No	68	116	176	300	300	62	197	132	1.5	Sand dry to 6 in., moist below
43		Makua	EC	96	15	No	66	136	176	300	300	62	197	132	1.5	Sand dry to 6 in., moist below
44		Makua	EC	99	15	No	55	123	176	290	290	60	183	121	2	Sand moist, easy travel
45		Makua	EC	22	15	No	28	60	101	124	142	22	101	30	10	Sand moist
46		Makua	EC	32	15	No	28	60	101	124	142	22	101	30	10	Sand moist, easy travel
47		Makua	EC	30	15	Yes	27	60	101	124	142	22	101	30	10	Sand moist, wheels spinning

(Continued)

See Beach Test under "Deficiencies" in text.

Table 5 (Continued)

Item No.	Location	Beach Area	Beach Test Slope No.	Tire Pressure psi	Immobilized	Core Index at Depth of					Core Index Averages by Soil Layers					Remarks
						0 in.	1 in.	2 in.	3 in.	4 in.	5-10 in.	10-12 in.	12-18 in.	18-24 in.	24-30 in.	
Pacific Islands Test Program - M35 Truck (Continued)																
Vehicle Test Weight 12,820 lb, Approximate Load 5,000 lb (Continued)																
48	Oahu (Cont'd)	MB	93	15	No	2	30	64	106	180	224	32	137	89	7	Dead moist, easy travel
49		MB	94	15	No	2	35	64	74	74	70	34	71	50	9	Dead moist, easy travel
50		BC	36	15	No	2	31	75	79	56	54	36	70	40	8	Dead moist
51		BC	37	15	No	2	31	68	81	103	108	34	65	58	8	Dead moist, easy travel
52		PDA	39	18	Yes	2	46	136	192	276	300	51	191	124	7	Dead dry to 6 in., moist below, wheels spinning
53		PDA	40	14	No	2	40	97	197	253	300	46	183	118	6	Dead dry to 6 in., moist below, easy travel
54		MB	21	10	No	5	32	70	127	122	108	36	106	71	4	Dead moist, easy travel
55		PS	24	10	Yes	2	34	60	60	95	86	32	78	54	18	Dead inundated frequently by surf, quick cond
56	Neuville	BC	28	10	No	1	14	26	37	56	90	14	40	27	6	Dead moist, easy travel
57		PS	29	10	No	2	32	90	120	163	184	41	118	77	4	Dead moist, easy travel
Yuma Test Program - M35 Truck																
Vehicle Test Weight, 12,450 lb, No Load																
58	Desert area	B-75	10.5	30	No	5	87	148	252	296	---	80	232	158	3.5	Dead dry on surface, moist below
59		B-73	10.5	30	Yes	5	87	148	272	296	300+	80	232	158	3.5	
60		B-71	9	30	Yes	5	100	208	292	300+	---	104	267	181	---	
61		B-72	8	30	No	5	116	204	280	300+	---	108	261	181	---	
62		B-76	8	30	Yes	5	76	120	194	230	---	67	261	181	2.5	
63		B-77	7	30	No	5	98	140	176	164	142	80	153	113	3.0	
64		B-73	7	30	Yes	5	73	126	186	288	280	68	180	124	4.5	
65		B-74	6	30	No	5	71	150	232	292	---	75	231	154	---	
66		B-85	15	20	Yes	5	67	112	160	216	242	61	153	117	3.5	
67		B-83	14	20	Yes	5	72	133	193	188	215	72	171	119	---	
68		B-80	13	20	Yes	10	68	140	208	300+	---	73	263	161	---	
69		B-81	12	20	Yes	5	94	168	248	280	292	89	232	159	2.5	
70		B-86	11	20	No	5	136	164	300+	---	---	92	---	---	---	
71		B-84	10	20	No	5	108	172	225	190	---	94	136	140	2.0	
72		B-82	10	20	No	5	98	170	228	240	252	91	213	148	2.0	
73		B-79	9	20	No	5	90	154	244	252	236	81	217	149	1.25	
74		B-93	20	15	Yes	5	87	80	108	126	154	44	105	73	1.0	
75		B-87	19	15	Yes	5	89	117	120	96	50	72	111	56	---	
76		B-84	18	15	No	10	120	203	296	300+	---	111	266	186	---	
77		B-82	17.5	15	No	10	91	183	270	300+	---	95	251	171	2.00	
78		B-86	17	15	No	10	108	158	208	272	---	78	196	141	1.50	
79		B-89	15	15	No	10	114	146	208	252	254	90	202	146	1.50	
80		B-75	15	15	Yes	5	40	62	68	92	106	29	67	49	2.0	
81		B-80	12	15	Yes	5	60	93	103	132	172	54	111	81	---	
82		B-91	9	15	No	10	70	126	206	280	300+	49	204	146	---	
83		B-86	26	10	No	5	38	108	276	300+	---	36	253	173	---	
84		B-99	22	10	Yes	5	39	72	96	118	136	39	96	66	6.5	
85		B-107	21.5	10	Yes	5	40	37	35	15	35	27	36	30	---	
86		B-108	20	10	Yes	5	42	58	61	35	36	33	63	35	---	
87		B-101	10	10	Yes	5	81	77	91	112	69	55	93	74	---	
88		B-97	16.5	10	No	5	113	126	278	300+	---	91	236	165	1.5	
					No	5	47	86	104	126	134	44	103	72	---	
Vehicle Test Weight 15,200 lb, Approximate Load 2,500 lb																
89	Desert area	B-117	17	20	Yes	5	108	170	226	288	300+	80	268	159	---	Dead dry on surface, moist below
90		B-119	16	20	No	5	94	156	228	276	300+	85	280	158	---	
91		B-120	12	20	Yes	5	111	144	171	171	300+	57	177	98	---	
92		B-118	11	20	No	5	126	174	244	288	300+	108	234	167	---	

(Continued)

Table 6 (Continued)

Run No.	Location	Beach Area	Beach Test No.	Blow No.	Tire Pressure psi	Immobilized	Case Index at Depth of										Remarks
							0 in.	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	
Tonn Test Program - 10,000 lb. (Continued)																	
Vehicle Test Weight 15,000 lb., Approximate Load 2,500 lb. (Continued)																	
94	Dune area (Cont'd)		B-116	36	15	Yes	5	90	114	166	235	284	70	172	122	---	Hard dry on surface, moist below
95			B-115	24	15	No	5	94	136	186	266	296	79	191	136	13.5	2.0
96			B-114	24	15	Yes	5	84	107	138	187	142	67	117	86	---	---
97			B-111	23	15	No	5	129	195	252	300+	---	103	249	176	---	---
98			B-110	20	15	No	5	112	172	236	300+	---	96	263	169	12.0	1.25
99			B-113	20	15	No	5	96	152	204	276	300+	64	211	147	12.0	1.50
100			B-112	14	15	Yes	5	61	91	117	163	197	52	124	87	---	---
101			B-108	30	10	Yes	5	70	136	244	296	300+	70	225	150	---	---
102			B-108	27	10	Yes	5	64	126	264	300+	---	65	230	152	---	---
103			B-107	25	10	No	5	76	170	268	300+	---	64	246	164	---	---
104			B-103	25	10	No	10	91	162	231	288	---	82	227	156	---	---
105			B-105	24	10	Yes	10	84	107	138	189	142	67	118	90	---	---
106			B-104	22.5	10	No	10	102	144	232	280	232	85	219	154	---	---
107			B-109	22	10	No	5	62	96	136	142	280	56	125	89	18.5	4.5
Vehicle Test Weight 17,330 lb., Approximate Load 3,000 lb.																	
108	Dune area		B-39	13	30	No	5	72	142	236	300+	---	73	233	155	---	Hard dry on surface, moist below
109			B-38	11	30	Yes	5	71	140	236	296	300+	72	231	154	---	---
110			B-36	11	30	Yes	5	53	80	105	193	210	46	126	87	---	---
111			B-34	11	30	Yes	5	73	145	194	232	264	76	190	131	---	---
112			B-31	10	30	No	5	100	166	272	292	300+	90	243	167	---	---
113			B-30	10	30	Yes	5	76	125	234	276	288	69	212	143	---	---
114			B-29	10	30	No	8	85	166	236	284	300+	86	209	156	---	---
115			B-28	10	30	Yes	8	93	146	194	280	261	82	187	132	---	---
116			B-37	9.5	30	No	5	81	156	238	292	300+	81	209	155	---	---
117			B-32	8.5	30	Yes	5	65	99	141	197	232	56	146	101	---	---
118			B-33	7	30	No	5	92	172	244	288	300+	90	235	160	---	---
119			B-35	6	30	No	5	79	129	127	158	216	70	138	100	---	---
120			B-44	16	20	No	7	108	152	212	236	240	89	200	143	---	---
121			B-40	16	20	Yes	8	86	120	184	208	180	74	123	123	---	---
122			B-48	13	20	Yes	10	96	134	232	284	280	80	173	155	---	---
123			B-47	13	20	Yes	5	54	78	76	59	73	44	71	53	---	---
124			B-46	12	20	Yes	7	94	71	88	127	172	45	94	65	---	---
125			B-45	12	20	No	5	104	176	248	300+	---	67	257	176	---	---
126			B-43	10.5	20	No	13	110	149	184	300+	---	87	211	151	---	---
127			B-43	10	20	No	5	84	114	192	242	276	68	183	127	---	---
128			B-41	8	20	No	5	70	94	174	267	286	54	178	122	---	---
129			B-53	20	15	No	10	120	160	264	300+	---	90	261	167	---	---
130			B-52	19	15	No	10	96	154	232	300+	---	87	235	162	---	---
131			B-51	18.5	15	Yes	5	84	132	286	284	300	74	234	146	---	---
132			B-56	18	15	No	5	113	156	260	288	300+	91	235	144	---	---
133			B-54	16	15	Yes	5	54	66	66	66	76	48	63	50	---	---
134			B-58	15	15	No	10	82	100	478	274	292	76	177	125	---	---
135			B-49	11	15	Yes	5	68	78	76	59	73	44	71	53	---	---
136			B-50	11.5	15	No	10	116	169	184	300+	---	89	211	151	---	---
137			B-57	11	15	Yes	5	87	136	240	300+	---	83	239	162	---	---
138			B-55	10.5	15	No	5	124	172	252	190	186	94	205	165	---	---
139			B-48	9	10	Yes	10	90	64	96	128	164	44	94	70	---	---
140			B-49	28	10	Yes	5	85	113	107	118	196	44	111	84	---	---
141			B-49	28.5	10	Yes	5	80	144	210	272	300+	76	229	142	---	---
142			B-41	24	10	Yes	5	167	130	164	200	274	94	164	124	---	---
143			B-42	23.5	10	No	15	79	177	186	177	172	75	167	116	---	---
144			B-70	22.5	10	No	5	100	77	77	108	152	63	87	73	---	---

Sheet 3 of 5 sheets

(Continued)

Table 6 (Continued)

Item No.	Location	Beach Area	Beach Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of					Cone Index Averages by Soil Layers		Remarks
							0 in.	1 in.	2 in.	3 in.	4 in.	0- to 6-in.	6- to 12-in.	
Tum Test Program - P-15 Truck (Continued)														
Vehicle Test Weight 17,330 lb, Approximate Load 5,000 lb (Continued)														
145	Dune area (Cont'd)	B-64	21.5	10	Yes	10	116	225	224	235	249	117	229	163
146		B-62	20	10	No	5	82	148	200	264	288	78	204	140
147		B-65	19	10	No	10	88	110	143	183	253	69	145	107
148		B-60	17	10	No	9	110	98	152	236	292	72	162	121
149		B-59	16	10	No	5	57	76	90	95	178	46	87	65
150		B-61	15	10	No	5	112	176	244	300+	---	98	240	167
Vehicle Test Weight 20,500 lb, Approximate Load 1,500 lb														
151	Dune area	B-9	19	30	Yes	10	121	193	289	300+	---	108	261	183
152		B-8	18	30	Yes	10	125	193	283	300+	---	109	259	182
153		B-12	16	30	Yes	10	91	137	175	194	181	79	168	121
154		B-7	15	30	Yes	10	129	202	284	300+	---	114	262	185
155		B-6	13	30	No	10	113	208	280	300+	---	115	263	182
156		B-5	13	30	Yes	10	103	183	211	285	300+	99	233	162
157		B-4	12	30	No	10	113	190	260	300+	---	104	250	175
158		B-1	12	30	No	10	97	148	220	277	300+	85	222	154
159		B-11	11	30	Yes	10	121	132	182	194	227	88	166	128
160		B-10	10	30	No	10	154	193	244	299	296	119	245	180
161		B-2	10	30	Yes	10	70	100	148	175	183	60	141	101
162		B-3	9	30	No	10	105	162	253	300+	300+	92	239	166
163		B-19	22	20	Yes	10	135	178	235	288	300+	108	234	169
164		B-18	22	20	No	10	126	167	236	280	300+	101	228	164
165		B-15	20	20	No	10	120	196	282	296	300+	109	257	180
166		B-13a	19	20	Yes	10	123	165	264	296	300+	99	242	172
167		B-13a	16	20	Yes	10	107	167	206	194	171	95	190	138
168		B-17	15	20	No	10	140	212	300+	300+	---	121	271	192
169		B-14	14	20	No	10	123	198	194	252	296	90	195	143
170		B-13a	13	20	No	10	123	165	244	296	300+	99	242	172
171		B-13b	12	20	No	10	107	167	206	194	199	75	190	138
172		B-40	22	15	Yes	5	59	126	217	264	280	61	202	134
173		B-42	16	15	No	5	42	64	100	132	144	36	99	68
174		B-43	16	15	No	5	61	117	196	272	300+	61	195	130
175		B-21	15.5	15	No	5	60	110	170	280	300+	50	167	113
176		B-27	22.5	10	No	10	86	144	244	268	288	80	219	150
177		B-45	22	10	Yes	5	59	126	217	264	280	61	202	134
178		B-44	14.5	10	No	5	61	117	196	272	300+	61	195	130
179		B-25	12	10	No	5	42	64	100	132	144	36	99	68

Cone Index Test Program - B-15 Truck

Vehicle Test Weight 17,450 lb, Approximate Load 5,000 lb

Item No.	Location	Beach Area	Beach Test No.	Slope %	Tire Pressure psi	Immobilized	0 in.	1 in.	2 in.	3 in.	4 in.	0- to 6-in.	6- to 12-in.	Remarks
180	Dune area	B-9	206	15	30	Yes	13	50	206	300+	---	103	---	---
181		B-8	209	15	30	Yes	17	113	212	300+	---	115	---	---
182		B-12	227	14	30	Yes	16	100	201	300+	---	106	---	---
183		B-7	223	12	30	Yes	15	91	207	300+	---	104	---	---
184		B-6	222	11.5	30	Yes	15	75	174	300+	---	88	---	---
185		B-5	224	6	30	No	20	145	223	300+	---	129	---	---
186		B-4	230	6	30	No	27	177	223	300+	---	128	---	---
187		B-1	225	6	30	No	30	171	300+	---	---	167+	---	---
188		B-11	226	5	30	No	19	153	300+	---	---	157+	---	---
189		B-10	233	20	30	Yes	20	117	217	300+	---	119	---	---

(Continued)

Table 6 (Continued)

Team No.	Location	Beach Area	Beach No.	Slope %	Tire Pressure psi	Laminarized	Core Index at Depth of					Core Index Averages by Sol. Layers			Remarks	
							0 in.	1 in.	2 in.	3 in.	4 in.	0- to 6-in.	6- to 12-in.	12-in. to 24-in.		
							Camp Lejeune Test Program - M13 Truck (Continued)					0- to 6-in.				
Vehicle Test Weight 17,450 lb, Approximate Load 5,000 lb (Continued)																
190	Onslow Beach (Cont'd)	FDA	231	14	30	Yes	16	86	172	300+	---	---	91	---	---	
191		FDA	232	13	30	Yes	20	75	100	119	126	280+	65	116	86	
192		FDA	233	12	30	No	20	91	166	300+	---	---	92	---	---	
193		FDA	234	12	30	Yes	19	85	198	300+	---	---	96	---	---	
194		FDA	235	12	30	No	21	100	161	280	---	---	97	228	162	
195		FDA	236	11	30	No	10	65	170	300+	---	---	89	---	---	
196		FDA	237	11	30	No	21	99	203	300+	---	---	108	---	---	
197		FDA	238	26	30	Yes	20	91	198	300+	---	---	103	---	---	
198		FDA	239	26	30	Yes	21	118	265	300+	---	---	121	---	---	
199		FDA	240	25	30	Yes	12	162	196	300+	---	---	124	---	---	
200		FDA	241	25	30	Yes	36	105	148	280	300+	---	98	227	164	
201		FDA	242	24	30	Yes	21	119	186	300+	---	---	108	---	---	
202		FDA	243	22	30	Yes	29	149	245	300+	---	---	141	---	---	
203		FDA	244	19	30	No	28	131	201	300+	---	---	120	---	---	
204		FDA	245	19	30	No	22	132	235	300+	---	---	130	---	---	
205		FDA	246	18	30	No	30	129	214	300+	---	---	126	---	---	
206		FDA	247	15	30	No	23	126	220	300+	---	---	123	---	---	
207		FDA	248	20	15	No	31	149	239	300+	---	---	140	---	---	
208		FDA	249	20	15	No	30	179	260	300+	---	---	139	---	---	
209		FDA	250	35	10	Yes	32	137	236	300+	---	---	115	---	---	
210		FDA	251	35	10	Yes	24	114	160	240	300+	---	99	237	174	
211		FDA	252	33	10	No	33	143	236	300+	---	---	138	---	---	
212		FDA	253	30	10	No	24	129	242	300+	---	---	132	---	---	
213		FDA	254	27	10	No	20	116	194	268	300+	---	107	251	178	
214		FDA	255	26	10	No	25	82	182	272	300+	---	96	251	178	
215		FDA	256	25	10	No	31	137	236	300+	---	---	115	---	---	
216		FDA	257	22	10	No	25	126	226	300+	---	---	126	---	---	

Table 7
Summary of Data and Test Results, Single Self-Propelled Vehicle Tests
5-ton Wt., 6x6 Truck (Six 14.00x20 Tires)
Yuma Test Program -- Dune Area

Item No.	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of							Cone Index Average by Soil Layers			Frt. Size, in.		Remarks
												0- to 6-in.	6- to 12-in.	12- to 18-in.	Width	Depth	
					0 in.	1 in.	6 in.	9 in.	12 in.	15 in.	0- to 6-in.	6- to 12-in.	12- to 18-in.				
Vehicle Test Weight 18,115 lb. No Load																	
1	457	13	30	Yes	5	74	108	148	180	219	59	143	99	-----	-----	Sand dry on surface, moist below	
2	460	12.5	30	Yes	5	77	151	228	298	294	78	124	151	-----	-----		
3	461	11.5	30	Yes	5	50	84	116	176	219	46	125	86	-----	-----		
4	456	11	30	Yes	5	70	91	107	142	185	55	113	81	-----	-----		
5	463	10	30	Yes	5	59	110	163	272	300	58	182	122	-----	-----		
6	465	9.5	30	Yes	5	55	91	120	153	208	54	121	81	-----	-----		
7	467	9	30	No	5	104	150	168	162	156	86	160	118	26-1/2	3-1/2		
8	466	7	30	No	5	100	170	240	292	300	92	234	161	14	1-1/2		
9	464	7	30	No	5	99	171	232	290	300	98	232	160	15	1		
10	458	7	30	Yes	5	61	104	141	180	230	58	142	99	-----	-----		
11	462	6.5	30	No	5	53	140	232	300	---	69	221	148	-----	-----		
12	459	5	30	No	5	82	129	180	243	300	72	184	128	14	4		
13	448	2.5	20	Yes	5	74	110	191	266	292	63	189	129	-----	-----		
14	441	18	20	No	5	77	102	220	226	224	81	201	138	14	2-1/2		
15	444	18	20	Yes	5	94	90	100	112	112	56	139	78	-----	-----		
16	446	16	20	Yes	5	36	44	50	62	50	28	34	41	-----	-----		
17	449	15	20	No	5	80	116	206	262	300	62	195	124	16	2-1/2		
18	451	14	20	Yes	5	71	92	133	190	244	51	139	99	-----	-----		
19	447	14	20	Yes	5	24	37	45	34	40	22	35	27	-----	-----		
20	440	14	20	No	5	75	116	177	212	212	65	168	117	-----	-----		
21	445	13	20	No	10	100	174	254	296	300	95	241	167	14-1/2	2-1/2		
22	450	12.5	20	No	10	84	130	188	212	280	75	181	129	14-1/4	2-1/4		
23	453	12	20	No	5	84	121	176	208	296	71	169	117	14	1		
24	452	11	20	No	5	82	126	176	222	240	71	175	122	17-1/2	3-1/2		
25	454	11	20	No	5	78	109	155	169	196	64	144	10	19	4		
26	455	11	20	No	5	67	92	114	153	192	55	120	86	-----	-----		
27	443	6.5	20	No	5	72	105	155	176	200	61	140	102	-----	-----		
28	456	28	15	Yes	5	44	104	188	288	300	51	197	121	-----	-----		
29	437	25.5	15	Yes	5	46	64	88	150	190	59	101	72	-----	-----		
30	434	24.5	15	No	5	74	162	228	300	---	80	210	124	15-1/2	1-1/2		
31	432	24	15	Yes	5	70	81	4	134	136	54	105	78	-----	-----		
32	431	22.5	15	Yes	5	42	68	79	134	146	56	84	60	-----	-----		
33	441	21.5	15	Yes	5	46	81	12	132	135	51	128	87	-----	-----		
34	431	20.5	15	No	5	42	148	222	300	---	58	220	145	15	1-1/4		
35	428	20	15	Yes	5	40	70	91	114	154	48	98	64	-----	-----		
36	440	18	15	No	5	56	132	236	300	---	64	223	146	15	1		
37	430	18	15	No	5	54	120	136	140	244	59	149	101	17	4		
38	439	17.5	15	No	5	46	80	102	144	156	44	103	72	16	2-1/2		
39	438	16.5	15	Yes	5	54	74	79	131	127	44	91	61	-----	-----		
40	437	15	15	No	5	48	106	180	242	300	51	163	120	16	1		
41	439	14	15	Yes	5	51	60	52	48	48	39	53	43	-----	-----		
42	424	11	10	Yes	5	68	73	91	188	270	49	117	85	-----	-----		
43	425	28	10	No	5	52	101	176	290	300	54	177	118	15-1/2	1		
44	422	28	10	Yes	5	40	75	92	138	216	40	132	70	-----	-----		
45	421	27	10	Yes	5	30	44	44	58	74	25	32	38	-----	-----		
46	423	26.5	10	No	5	56	140	216	300	---	68	219	143	19	2-1/4		
47	426	24.5	10	No	5	48	74	96	155	200	42	108	76	15-1/2	1		
48	427	23.5	10	No	5	48	66	60	58	80	49	61	47	-----	-----		
49	418	20	10	No	5	32	74	90	148	148	37	104	70	17	1		
50	420	19	10	No	5	28	66	108	168	212	33	114	75	16-1/2	1-1/2		
Vehicle Test Weight 24,275 lb. Approximate Load 5,000 lb.																	
51	452	15	30	Yes	5	54	126	214	300	---	68	213	140	-----	-----	Sand dry on surface, moist below	
52	455	11	30	Yes	5	51	101	141	210	300	52	154	106	-----	-----		
53	457	11	30	Yes	5	56	134	200	266	300	65	200	142	-----	-----		
54	456	9.5	30	No	5	54	144	172	192	360	71	169	115	18	3-1/4		
55	459	9	30	Yes	5	55	86	110	168	216	49	121	85	-----	-----		
56	460	7	30	No	5	66	130	184	288	300	67	201	135	15	2		
57	468	6	30	No	5	34	112	188	292	300	70	197	138	18	3		
58	493	7	30	No	5	78	178	254	300	---	87	244	163	15	2		
59	491	7	30	Yes	5	44	104	196	166	198	51	140	94	-----	-----		
60	494	5	30	No	5	78	196	284	170	118	79	184	127	-----	-----		
61	499	4	20	Yes	5	86	132	130	124	179	74	129	95	-----	-----		
62	500	21.5	20	No	5	72	126	172	284	300	68	194	132	16-1/2	2		
63	503	21	20	Yes	5	84	136	180	292	300	75	189	131	-----	-----		
64	501	21.5	20	No	5	86	162	222	272	274	84	219	149	19	1-1/2		
65	498	21	20	No	5	80	158	212	296	300	81	229	154	16	1-1/2		
66	504	20	20	Yes	5	44	90	142	290	300	46	163	108	-----	-----		
67	497	17	20	Yes	5	43	84	134	194	140	46	110	77	-----	-----		
68	505	16	20	No	5	63	124	152	206	261	63	152	109	15	2		
69	500	15	20	Yes	5	58	98	91	104	140	54	98	71	-----	-----		
70	496	13.5	20	No	5	73	134	234	300	---	77	226	151	15-1/2	1-1/2		
71	495	10	20	No	5	48	84	106	180	180	66	104	73	16-1/2	1		
72	491	9	15	Yes	5	48	116	136	290	300	76	203	138	-----	-----		
73	493	6.5	15	Yes	5	80	140	171	136	194	75	196	110	-----	-----		
74	492	6	15	No	5	62	124	216	300	---	64	214	140	17	1-1/2		
75	499	5	15	Yes	5	58	98	142	290	300	51	153	103	-----	-----		
76	494	4	15	No	5	80	138	236	300	---	64	213	138	16-1/2	1-1/2		
77	498	4	15	No	5	62	94	144	290	300	53	156	105	17-1/2	2-1/2		
78	497	4	15	No	5	62	106	194	272	300	64	197	132	16-1/2	1		
79	496	3.5	15	No	5	62	84	148	272	300	64	197	132	16-1/2	1		
80																	

Table 7 (Continued)

Item No.	Test No.	Slope %	Fire Pressure psi	Femo-bilized	Cone Index at Depth of					Cone Index Averages by Soil Layers			Dist. Size, in.		Remarks	
					0 in. 1 in. 5 in. 9 in. 12 in. 15 in.					0- to 6-in. 6- to 12-in. 12- to 18-in.			Width Depth			
Vehicle Test Weight 20,175 lb. Approximate Load 10,000 lb																
85	278	24	10	No	5	81	76	85	105	158	54	89	70	24	5	
86	281	23.5	10	No	5	72	110	130	148	168	62	129	93	-----	-----	
87	282	23	10	Yes	5	53	63	70	83	116	40	75	56	-----	-----	
88	284	23	10	No	10	128	176	232	288	---	105	232	167	18	1-1/2	
89	283	22.5	10	No	10	54	85	122	150	210	49	119	84	23	4-1/4	
90	279	20	10	No	10	106	152	143	168	188	89	156	117	-----	-----	
91	243	16	30	Yes	5	107	160	212	264	292	91	212	150	-----	-----	Sand wet to 1 in., moist below
92	240	16	30	Yes	5	61	72	58	79	74	46	70	55	-----	-----	
93	236	12.5	30	Yes	5	64	112	138	246	264	60	179	121	19-1/2	3-1/2	
94	237	10.5	30	No	5	64	145	118	262	300+	71	210	140	-----	-----	
95	244	10.5	30	No	10	100	143	198	258	288	84	200	142	-----	-----	
96	242	10	30	Yes	5	86	160	208	256	292	84	208	143	-----	-----	
97	241	10	30	No	5	85	138	192	236	264	76	189	131	20-1/2	4-3/4	
98	239	9	30	Yes	5	53	79	113	154	206	45	111	81	-----	-----	
99	238	7	30	No	5	71	96	160	246	296	57	167	116	20-1/2	5	
100	249	22	20	Yes	5	62	121	178	288	268	63	176	119	-----	-----	
101	248	21	20	No	5	86	120	162	208	260	70	163	116	18-1/2	2	
102	251	20.5	20	Yes	5	75	82	71	61	58	54	71	59	-----	-----	
103	253	20	20	Yes	5	85	122	169	178	192	71	156	119	-----	-----	
104	252	19	20	No	10	133	182	254	288	---	108	241	174	16	1-1/4	
105	247	19	20	Yes	5	38	30	32	37	39	24	32	28	-----	-----	
106	246	18	20	Yes	5	30	35	41	47	44	23	41	32	-----	-----	
107	255	15.5	20	Yes	5	67	90	133	166	176	54	130	92	-----	-----	
108	250	15	20	No	10	97	122	184	234	276	73	180	127	18-1/2	2-1/2	
109	245	14	20	No	10	119	176	248	296	300+	102	240	170	16-1/2	1-1/2	
110	256	13	20	Yes	5	50	83	106	137	178	46	109	75	-----	-----	
111	254	11.5	20	No	5	93	134	171	212	248	77	172	123	22-1/2	5-1/4	
112	262	27	15	Yes	5	61	57	59	57	61	41	54	48	-----	-----	
113	258	25	15	Yes	10	77	120	180	216	228	69	172	121	-----	-----	
114	261	25	15	No	10	120	128	204	300+	---	177	259	181	18-1/2	1	
115	263	23.5	15	No	10	116	172	220	252	292	99	215	154	18	1-1/2	
116	260	23	15	No	10	82	130	164	212	252	74	169	120	19	2-1/2	
117	257	21.5	15	No	10	122	174	220	260	286	102	218	157	18	2	
118	264	20.5	15	Yes	10	50	68	88	158	188	43	105	75	-----	-----	
119	269	20	15	Yes	10	90	86	82	136	158	62	101	81	-----	-----	
120	259	19	15	No	10	95	140	188	252	292	82	193	137	19	2-1/2	
121	265	19	15	No	10	84	56	58	61	81	50	60	55	19	2-1/2	
122	266	19	15	Yes	10	72	75	125	168	204	59	129	94	-----	-----	
123	267	18	15	Yes	10	64	80	94	122	146	51	99	74	-----	-----	
124	268	18	15	No	10	120	164	236	277	288	98	226	161	24	4	
125	271	29	10	No	5	58	100	152	256	300+	54	169	114	21	2-1/2	
126	274	27	10	No	5	61	57	59	57	63	41	58	48	-----	-----	
127	272	25	10	Yes	5	39	65	100	134	152	36	100	79	-----	-----	
128	271	22	10	No	5	40	62	96	112	130	36	90	61	25	4-1/2	
129	275	22	10	No	10	46	106	156	208	258	54	157	105	26	5	
130	276	22	10	Yes	10	46	56	82	146	146	37	89	64	-----	-----	
131	277	22	10	No	5	73	112	156	228	268	63	165	115	25	4-1/2	
132	270	20	10	No	10	90	86	82	136	158	62	101	81	-----	-----	
Vehicle Test Weight 32,380 lb. Approximate Load 15,000 lb																
133	297	14	10	Yes	5	45	101	186	244	276	50	177	116	-----	-----	Sand wet to 1 in., moist below
134	293	11	10	Yes	5	64	129	157	203	283	63	160	116	-----	-----	
135	295	10.5	10	Yes	5	49	70	146	204	264	49	147	99	-----	-----	
136	294	10	10	No	5	75	158	272	300+	---	79	241	162	-----	-----	
137	292	10	10	No	5	59	120	204	209	274	61	178	119	-----	-----	
138	292	10	10	No	5	82	146	200	247	280	78	198	136	-----	-----	
139	291	9	10	Yes	5	80	109	152	288	240	65	176	123	-----	-----	
140	296	9	10	No	5	101	176	274	300+	---	34	247	164	-----	-----	
141	293	8	10	No	5	73	137	186	284	300+	72	202	137	-----	-----	
142	291	8	10	No	5	101	164	224	284	300+	50	221	156	-----	-----	
143	291	7	10	No	5	78	152	267	297	300+	78	239	160	-----	-----	
144	298	6.5	10	No	5	92	128	206	248	264	75	193	135	-----	-----	
145	299	6	10	Yes	5	51	72	104	140	174	36	105	75	-----	-----	
146	221	20	20	No	8	133	172	229	300+	---	104	234	168	-----	-----	
147	294	19	20	No	5	106	163	216	288	300+	91	222	159	-----	-----	
148	294	18	20	Yes	5	74	108	124	172	274	62	155	97	-----	-----	
149	293	17	20	No	5	108	152	212	272	300+	88	212	150	-----	-----	
150	293	16	20	Yes	5	48	106	210	220	244	54	181	119	-----	-----	
151	293	15	20	No	5	104	140	200	276	300+	81	205	145	-----	-----	
152	229	15	20	Yes	5	98	145	152	268	288	83	206	142	-----	-----	
153	222	14	20	Yes	5	85	97	46	69	32	62	77	64	-----	-----	
154	293	14	20	No	5	88	126	158	192	272	73	159	114	-----	-----	
155	295	12	20	Yes	5	36	68	94	126	156	36	96	66	-----	-----	
156	297	10	20	No	5	60	118	212	292+	---	61	207	137	-----	-----	
157	294	26.5	15	Yes	5	84	112	107	86	44	67	102	79	-----	-----	
158	290	24	15	Yes	5	35	48	51	54	36	29	51	39	-----	-----	
159	295	21	15	No	10	131	187	240	288	225	110	218	140	23	2-1/2	
160	291	21	15	Yes	5	40	46	92	51	57	30	50	39	-----	-----	
161	287	20.5	15	No	5	72	108	67	70	90	61	82	64	-----	-----	
162	292	18.5	15	Yes	5	36	70	108	86	99	43	85	63	-----	-----	
163	289	18	15	No	5	51	92	105	132	146	49	110	77	-----	-----	
164	228	16	15	No	7	88	74	95	156	224	54	108	82	-----	-----	

Table 8

Summary of Data and Test Results, Towing Tests

Tow Test Program

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Brusher Pull lb	Wheel Slip %	Brusher Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks		
Wheeled Vehicles											
1/4-ton M38A1, 4x4 Truck, Test Weight 2,975 lb											
1	Yuma Test Station	47	0	30	2800	----	9.4	14	Moist sand		
2		48	0	20	4500	----	15.2	14			
3		49	0	15	5500	----	18.5	14			
4		50	0	10	7000	----	26.6	14			
5		52A	10	15	0	----	----	24			
6	Dune area	52B	10	15	2000	----	6.7	24	Dry sand on surface, moist below		
7		54A	1	10	8000	----	26.9	89			
8		54B	1.5	10	8000	----	26.9	102			
9		54C	2	10	7000	----	23.5	132			
10		54D	2	10	7000	----	23.5	118			
1/4-ton M7, 4x4 Truck, Test Weight 7,085 lb											
11	Yuma Test Station	54	0	30	8000	----	11.3	19	Moist sand		
12		55	0	20	1,3000	----	18.4	19			
13		56	0	15	1,6000	----	22.6	19			
14		57	0	10	1,4000	----	19.7	19			
15		58	10	10	1,2000	----	14.1	27			
16	Dune area	91B	1	15	1,7000	----	26.8	120	Dry sand on surface, moist below		
17		91A	4	15	1,4000	----	19.8	92			
18		88	6.5	15	1,2000	----	16.9	108			
19		90A	6.5	15	1,2000	----	16.9	113			
20		89	10	15	1,0000	----	14.1	112			
21		90B	10	15	1,1000	----	15.5	122			
22		92B	0	10	1,3000	----	26.8	112			
23		92A	2	10	1,8000	----	25.4	108			
24		92C	2.5	10	1,5000	----	21.2	96			
25	91	5	10	1,0000	----	14.1	78				
2-1/2-ton M35, 6x6 Truck, Test Weight 12,550 lb											
26	Yuma Test Station	42A	0	30	2,3000	14.5	16.1	29	Moist sand		
27		42B	0	30	1,800	17.5	14.5	29			
28		42C	0	30	1,500	8.5	14.5	29			
29		42D	0	30	1,200	5.0	9.6	29			
30		42E	0	30	800	1.0	6.4	29			
31		43A	0	20	1,600	4.0	12.9	44			
32		43B	0	20	2,7000	16.5	21.7	44			
33		43C	0	20	2,500	11.5	20.1	44			
34		43D	0	20	2,000	8.5	16.1	44			
35		43E	0	20	2,500	28.5	20.1	44			
36		43F	0	20	2,400	28.0	19.3	44			
37		44A	0	15	1,200	1.5	9.6	19			
38		44B	0	15	2,100	5.0	6.9	19			
39		44C	0	15	2,400	7.0	19.3	19			
40		44D	0	15	2,300	13.5	27.3	19			
41		44E	0	15	3,4000	19.5	27.3	19			
42		44F	0	15	2,800	22.0	22.5	19			
43		45A	0	10	2,400	5.5	18.5	26			
44		45B	0	10	1,000	0	8.0	26			
45		45C	0	10	1,700	12.0	29.7	26			
46		45D	0	10	4,100	16.0	32.9	26			
47		45E	0	10	4,5000	23.0	36.0	26			
48		45F	0	10	4,100	40.0	32.9	26			
49		46	12	30	0	----	----	31			
50		46B	10	30	0	----	----	25			
51		46C	10	20	0	----	----	25			
52		47	10	15	2,0000	----	16.0	25			
53		48	10	10	3,2000	----	25.7	25			
54		41A	12	10	2,3000	----	23.3	31			
55		41B	15	10	2,4000	----	19.2	31			
2-1/2-ton M35, 6x6 Truck, Test Weight 17,110 lb											
56		Yuma Test Station	23A	0	30	2,2000	15.0	12.7		29	Moist sand
57			23B	0	30	1,600	41.5	9.2		29	
58			23C	0	30	1,500	23.0	8.7		29	
59			23D	0	30	2,000	11.5	11.5		29	
60	24A		0	20	1,000	1.0	5.8	24			
61	24B		0	20	2,100	10.5	14.6	24			
62	24C		0	20	2,300	45.0	11.3	24			
63	24D		0	20	2,200	39.0	12.7	24			
64	24E		0	20	1,000	12.0	17.3	24			
65	24F		0	20	2,600	9.0	19.0	24			
66	24G		0	20	3,2000	18.5	18.5	24			
67	25A		0	15	4,5000	21.0	24.8	19			
68	25B		0	15	3,700	47.5	21.1	19			
69	25C		0	15	3,300	8.0	19.0	19			
70	25D		0	10	3,200	53.5	21.9	19			
71	25E		0	10	3,500	76.0	20.2	19			
72	25F		0	10	5,2000	24.0	30.0	19			
73	18		10	20	1,3000	----	7.5	13			

(Continued)

Table 8

Summary of Data and Test Results, Towing Tests

Tow Test Program

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Breaker Pull lb	Wheel Slip %	Breaker Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks
Wheeled Vehicles									
1/4-ton M38A1, 4x4 Truck, Test Weight 2,975 lb									
1	Yam Test Station	47	0	30	2800	----	9.4	14	Moist sand
2		48	0	20	4500	----	15.2	14	
3		49	0	15	5500	----	18.5	14	
4		50	0	10	7900	----	26.6	14	
5		52A	10	15	0	----	----	24	
6	Dune area	52B	10	15	2000	----	6.7	24	Dry sand on surface, moist below
7		94A	1	10	8000	----	26.9	89	
8		94B	1.5	10	8000	----	26.9	102	
9		94C	2	10	7000	----	23.5	142	
10		94D	2	10	7000	----	23.5	148	
1/4-ton M7, 4x4 Truck, Test Weight 7,085 lb									
11	Yam Test Station	54	0	30	8000	----	11.3	19	Moist sand
12		55	0	20	1,3000	----	18.4	19	
13		56	0	15	1,6000	----	22.6	19	
14		57	0	10	1,4000	----	19.7	19	
15		58	10	15	1,2000	----	14.1	27	
16	Dune area	91B	1	15	1,2000	----	26.8	120	Dry sand on surface, moist below
17		91A	4	15	1,4000	----	19.8	82	
18		88	6.5	15	1,2000	----	16.9	108	
19		90A	6.5	15	1,2000	----	16.9	113	
20		89	10	15	1,0000	----	14.1	112	
21		90B	10	15	1,1000	----	15.5	122	
22		92B	0	10	1,9000	----	26.8	112	
23		92A	2	15	1,8000	----	25.4	108	
24		92C	2.5	10	1,5000	----	21.2	96	
25		91	5	10	1,0000	----	14.1	78	
2-1/2-ton M15, 6x6 Truck, Test Weight 12,450 lb									
26	Yam Test Station	42A	0	30	2,0000	14.5	15.1	29	Moist sand
27		42B	0	30	1,8000	17.5	14.5	29	
28		42C	0	30	1,9000	8.5	14.5	29	
29		42D	0	30	1,2000	3.0	9.6	29	
30		42E	0	30	8000	1.0	6.4	29	
31		43A	0	20	1,6000	4.0	12.9	44	
32		43B	0	20	2,7000	16.5	21.7	44	
33		43C	0	20	2,5000	11.5	20.1	44	
34		43D	0	20	2,0000	8.5	16.1	44	
35		43E	0	20	1,5000	28.5	20.1	44	
36		43F	0	20	2,4000	28.0	19.3	44	
37		44A	0	15	1,2000	1.5	9.6	19	
38		44B	0	15	2,1000	5.0	6.9	19	
39		44C	0	15	2,4000	7.0	17.3	19	
40		44D	0	15	2,7000	13.5	21.3	19	
41		44E	0	15	3,4000	19.5	27.3	19	
42		44F	0	15	2,8000	17.0	22.5	19	
43		45A	0	10	2,3000	5.5	18.5	26	
44		45B	0	10	1,0000	0	8.0	26	
45		45C	0	10	1,7000	12.0	29.7	26	
46		45D	0	10	4,1000	16.0	32.9	26	
47		45E	0	10	4,5000	23.0	36.0	26	
48		45F	0	10	4,1000	40.0	32.9	26	
49		47	12	40	0	----	----	31	
50		48A	10	30	0	----	----	25	
51		48B	10	20	0	----	----	25	
52		49	10	15	2,0000	----	16.0	27	
53		40	10	10	3,2000	----	25.7	25	
54		41A	12	10	2,9000	----	21.3	31	
55		41B	15	10	2,4000	----	19.2	31	
2-1/2-ton M15, 6x6 Truck, Test Weight 17,130 lb									
56	Yam Test Station	23A	0	30	2,2000	15.0	12.7	29	Moist sand
57		23B	0	30	1,6000	41.5	9.2	29	
58		23C	0	30	1,5000	23.0	8.7	29	
59		23D	0	30	2,0000	11.5	14.5	29	
60		24A	0	20	1,0000	1.0	5.8	24	
61		24B	0	20	2,1000	10.5	14.4	24	
62		24C	0	20	2,3000	45.0	13.3	24	
63		24D	0	20	2,2000	59.0	12.7	24	
64		24E	0	20	3,0000	12.0	17.3	24	
65		24F	0	20	2,6000	9.0	15.0	24	
66		24G	0	20	3,8000	18.5	18.1	24	
67		25A	0	15	4,5000	21.0	24.4	19	
68		25B	0	15	3,7000	47.5	21.1	19	
69		25C	0	15	3,3000	8.0	19.0	19	
70		26A	0	10	3,8000	53.5	21.9	19	
71		26B	0	10	3,9000	76.0	20.2	19	
72		26C	0	10	3,2000	26.0	30.0	19	
73		26	10	20	1,3000	----	7.5	13	

(Continued)

Table 8 (Cont. sand)

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Brake Pull lb	Wheel Slip %	Brake Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks
Wheeled Vehicles (Continued)									
2-1/2-ton M135, 6x6 Truck, Test Weight 17,540 lb (Continued)									
74	Yuma Test Station (Continued)	19	10	15	2,000*	----	11.5	13	Moist sand
75		21	14	15	2,000*	----	11.5	14	
76		20	10	10	3,800*	----	21.9	13	
77		22	13	10	2,800*	----	16.2	14	
78		Dune area	183	9	15	2,000*	----	11.5	
79	184	9	10	2,400*	----	13.8	71		
2-1/2-ton M135, 6x6 Truck, Test Weight 22,105 lb									
80	Yuma Test Station	27A	0	30	2,000	10.5	8.8	20	Moist sand
81		27B	0	30	2,300	12.5	10.1	20	
82		27C	0	30	2,500*	17.5	11.2	20	
83		27D	0	30	2,000	36.0	9.7	20	
84		27E	0	30	2,000	46.0	8.8	20	
85		28A	0	20	1,400	9.0	13.2	14	
86		28B	0	20	4,100	15.0	18.1	14	
87		28C	0	20	4,200*	20.5	18.5	14	
88		28D	0	20	2,300	6.5	8.8	14	
89		28E	0	20	2,300	62.0	10.1	14	
90		29A	0	15	5,000*	25.0	22.0	20	
91		29B	0	15	4,000	34.0	17.6	20	
92		29C	0	15	4,500	40.0	19.8	20	
93		29D	0	15	2,300	5.1	10.1	20	
94		29E	0	15	3,700	8.0	16.3	20	
95		29F	0	15	4,500	14.5	20.3	20	
96		29G	0	15	4,800	17.5	21.1	20	
97		30A	0	10	1,300	5.0	13.2	14	
98		30B	0	10	1,800	5.1	16.7	14	
99		30C	0	10	4,100	3.0	20.7	14	
100		30D	0	10	6,000*	25.5	26.4	14	
101		30E	0	10	5,000	69.0	22.0	14	
102		31	10	20	2,000*	----	8.8	25	
103		32	10	15	1,000*	----	14.2	25	
104		33A	12	15	2,000*	----	8.8	14	
105		33B	15	15	1,400*	----	7.0	14	
106		33A	12	10	1,400*	----	14.5	14	
107		33B	15	10	2,600*	----	11.5	14	
108		36	10	10	1,800*	----	10.1	25	
3-ton M41, 6x6 Truck, Test Weight 28,175 lb									
109	Yuma Test Station	59	0	30	3,400*	----	12.1	14	Moist sand
110		60	0	20	5,400*	----	19.2	14	
111		61	0	15	1,500*	----	23.1	14	
112		62	0	10	2,000*	----	11.9	14	
113		95A	8	30	1,200*	----	4.3	29	
114		95B	10	30	1,000*	----	2.1	29	
115		95A	8	20	2,700*	----	9.6	29	
116		95B	10	20	2,500*	----	8.9	29	
117		96	10	15	4,000*	----	14.2	22	
118		97	15	15	2,000*	----	7.1	21	
119		98	15	15	2,200*	----	7.8	21	
120		100	10	10	2,200*	----	11.8	22	
121		101A	13	10	4,200*	----	14.9	20	
122		101B	15	10	4,000*	----	14.2	20	
123		102	20	10	2,800*	----	9.9	42	
3-ton M41, 6x6 Truck, Test Weight 30,645 lb									
124	Yuma Test Station	105	0	30	3,000*	----	9.8	14	Moist sand
125		106	0	20	3,000*	----	12.7	14	
126		107	0	10	5,400*	----	18.1	14	
127		108	0	10	4,400*	----	22.2	14	
128		112	10	15	2,300*	----	11.5	14	
129		111	8	10	1,000*	----	7.8	14	
130		110	12	10	1,000*	----	9.8	22	
Tracked Vehicles									
1/2-ton M50C (M50), Test Weight 3,275 lb									
131	Yuma Test Station	28	0	--	2,200	12.0	8.9	157*	Moist sand
132		29	0	--	2,400	11.5	8.5	157*	
133		30	0	--	2,800	11.5	8.5	157*	
134		31	0	--	2,800	12.5	8.5	157*	
135		32	0	--	1,500*	44.0	18.5	17*	
136		33	0	--	2,500	12.0	8.5	157*	
137		34	0	--	3,400	9.0	37.0	157*	
138		35	0	--	2,200	10.0	9.9	15	
139		36	0	--	1,200	25.0	9.9	15	
140		37	0	--	2,200	10.5	9.9	14	
141		38	0	--	2,400	10.5	9.9	14	
142		39	0	--	1,200	19.5	9.9	14	
143		40	0	--	1,200	26.5	9.9	14	
144		41	0	--	1,400*	41.5	27.0	14	
145		42	0	--	1,400*	41.5	27.0	14	

(Continued)

- * Station brake pull.
 ** Tests 111-117 conducted on test lane before harrowing.
 † Tests 118-146 conducted on test lane after one pass of the harrow.

Table 6 (Continued)

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Brusher Pull lb	Wheel Slip %	Brusher Pull % of Test Weight	Cone Index 6- to 6-in. Depth before Traffic	Remarks		
Tracked Vehicles (Continued)											
1 1/4-ton M42C Weasel, Test Weight 5,970 lb (Continued)											
1459	Yuma Test Station (Continued)	5H	0	--	3,000	25.0	50.3	14	Moist sand		
1460		5I	0	--	3,250*	55.0	54.4	14			
1479		5J	0	--	3,250*	62.0	54.4	14			
1480		5K	0	--	3,250*	79.0	54.4	14			
149		6A	0	--	3,600	40.0	60.3	5			
150		6B	0	--	3,600	50.0	60.3	5			
151		6C	0	--	1,300	5.0	21.8	5			
152		6D	0	--	3,400	24.0	57.0	5			
153		6E	0	--	700	2.0	11.7	5			
154		6F	0	--	3,500	26.0	58.6	5			
155		6G	0	--	3,700*	37.0	62.0	5			
156	Dune area	3	20	--	2,000*	----	33.5	44	Dry sand on surface, moist below		
157		4	15	--	2,300*	----	38.5	40			
158		387	8	--	2,800*	----	46.9	54			
159		389	10	--	2,300*	----	38.5	36			
160		388	14	--	2,600*	----	43.6	90			
1 1/4-ton M59C Weasel, Test Weight 6,970 lb											
161	Yuma Test Station	7A	0	--	1,600	7.5	23.0	9	Moist sand		
162		7B	0	--	1,500	5.0	21.5	9			
163		7C	0	--	2,400	10.0	34.4	9			
164		7D	0	--	3,800	47.0	54.5	9			
165		7E	0	--	4,400*	40.0	63.1	9			
166		7F	0	--	4,400*	38.0	63.1	9			
167		7G	0	--	2,600	10.0	37.3	9			
168		8A	0	--	1,600	7.0	23.0	10			
169		8B	0	--	3,600	12.0	51.6	10			
170		8C	0	--	1,500	5.0	21.5	10			
171		8D	0	--	3,000	9.0	41.0	10			
172		8E	0	--	3,400	10.0	48.8	10			
173		8F	0	--	4,200	27.0	60.3	10			
174		8G	0	--	4,200	25.0	60.3	10			
175		8H	0	--	4,500*	17.0	64.6	10			
176		8I	0	--	1,600	13.0	51.6	10			
177		10	15	--	2,600*	----	37.3	29			
178		11	15	--	1,000*	----	43.0	31			
18-ton M42, Hi-speed Tractor, Test Weight 20,300 lb											
179	Yuma Test Station	374	0	--	20,000*	----	54.1	41	Dry sand to 6 in., moist below		
180		376A	8	--	15,000*	----	40.0	16			
181		376B	12.5	--	15,000*	----	40.6	12			
182		376C	15	--	17,000*	----	32.5	12			
183		Dune area	384	9	--	11,000*	----	29.8		11	Dry sand on surface, moist below
184			386	11	--	10,500*	----	27.1		27	
185			382	15	--	8,000*	----	21.7		70	
186			385	15	--	9,500*	----	25.7		50	
187	383	16	--	7,500*	----	20.1	51				
38-ton M1, Hi-speed Tractor, Test Weight 36,000 lb											
188	Yuma Test Station	378	0	--	38,000*	----	50.0	41	Dry sand to 6 in., moist below		
189		377A	8	--	29,000*	----	38.1	16			
190		378	12.5	--	28,000*	----	36.8	12			

Table 9
Summary of Data and Test Results, Towed-vehicle Tests:
Onslow Beach, Camp Lejeune

Item No.	Type of Test Surface*	Test No.	Tire Pressure psi	Towing Force Required lb	Towing Force as % of Test Weight	Comp Index 0- to 5-in. Depth		Pen. Depth One Pass in.	Average Moisture Content 0- to 6-in. Depth	Sand Condition
						Before Traffic	After One Pass			
<u>1/4-ton M100 Trailer, Test Weight 569 lb</u>										
1	Asphalt pavement	9	25	12	2.1	---	---	-----		
2	Asphalt pavement	10	20	12	2.1	---	---	-----		
3	Asphalt pavement	11	15	15	2.6	---	---	-----		
4	Asphalt pavement	12	10	18	3.2	---	---	-----		
5	Disturbed sand	5	25	30	5.3	156	155	1/2		Wet
6	Disturbed sand	6	20	30	5.3	155	153	0		Wet
7	Disturbed sand	7	15	30	5.3	154	153	0		Wet
8	Disturbed sand	8	10	30	5.3	153	153	0		Wet
9	Undisturbed sand	1	25	22	3.9	176	174	0		Wet
10	Undisturbed sand	2	20	22	3.9	173	174	0		Wet
11	Undisturbed sand	3	15	20	3.5	174	174	0		Wet
12	Undisturbed sand	4	10	18	3.2	174	173	0		Wet
<u>1/4-ton M100 Trailer, Test Weight 782 lb</u>										
13	Asphalt pavement	63	25	24	2.7	---	---	-----		
14	Asphalt pavement	64	20	17	2.2	---	---	-----		
15	Asphalt pavement	65	15	17	2.2	---	---	-----		
16	Asphalt pavement	66	10	17	2.2	---	---	-----		
17	Disturbed sand	18	25	51	6.5	152	152	1/16	4.0	Wet
18	Disturbed sand	19	20	38	4.9	156	156	1/16	4.0	Wet
19	Disturbed sand	20	15	38	4.9	155	155	1/16	4.0	Wet
20	Disturbed sand	21	10	46	5.9	126	123	1/16	4.0	Wet
21	Undisturbed sand	13	25	53	6.8	151	151	1/8	4.0	Wet
22	Undisturbed sand	14	20	60	7.6	147	147	1/8	4.0	Wet
23	Undisturbed sand	15	15	47	6.0	148	148	1/8	4.0	Wet
24	Undisturbed sand	17	10	50	6.4	123	124	1/8	4.0	Wet
<u>1/4-ton M100 Trailer, Test Weight 1,127 lb</u>										
25	Asphalt pavement	59	25	22	2.0	---	---	-----		
26	Asphalt pavement	60	20	22	2.0	---	---	-----		
27	Asphalt pavement	61	15	22	2.0	---	---	-----		
28	Asphalt pavement	62	10	25	2.2	---	---	-----		
29	Disturbed sand	43	25	65	5.8	149	152	1	11.1	Wet
30	Disturbed sand	44	20	56	5.0	110	114	1	11.1	Wet
31	Disturbed sand	45	15	56	5.0	151	152	5/8	11.1	Wet
32	Disturbed sand	46	10	40	3.6	152	153	1/2	11.1	Wet
33	Undisturbed sand	39	25	75	6.7	151	156	1/4	11.1	Wet
34	Undisturbed sand	40	20	87	7.7	151	152	1/4	11.1	Wet
35	Undisturbed sand	41	15	82	7.3	149	151	1/4	11.1	Wet
36	Undisturbed sand	42	10	60	5.3	150	151	1/4	11.1	Wet
<u>1/4-ton M100 Trailer, Test Weight 1,211 lb</u>										
37	Asphalt pavement	55	25	23	1.9	---	---	-----		
38	Asphalt pavement	56	20	23	1.9	---	---	-----		
39	Asphalt pavement	57	15	32	2.6	---	---	-----		
40	Asphalt pavement	58	10	43	3.6	---	---	-----		
41	Disturbed sand	47	25	72	5.9	153	152	3/4	6.2	Wet
42	Disturbed sand	48	20	72	5.9	146	148	1	6.2	Wet
43	Disturbed sand	49	15	60	5.0	150	150	3/4	6.2	Wet
44	Disturbed sand	50	10	54	4.5	150	151	5/8	6.2	Wet
45	Undisturbed sand	51	25	118	9.7	145	147	3/4	6.2	Wet
46	Undisturbed sand	52	20	32	7.6	146	148	1/2	6.2	Wet
47	Undisturbed sand	53	15	75	6.2	151	154	1/4	6.2	Wet
48	Undisturbed sand	54	10	63	5.2	156	157	1/4	6.2	Wet
<u>3/4-ton M101 Trailer, Test Weight 2,089 lb</u>										
49	Asphalt pavement	132	45	27	1.3	---	---	-----		
50	Asphalt pavement	133	30	29	1.4	---	---	-----		
51	Asphalt pavement	134	20	32	1.5	---	---	-----		
52	Asphalt pavement	135	10	35	1.7	---	---	-----		
53	Disturbed sand	91	45	196	9.4	153	154	1-1/2	6.1	Wet
54	Disturbed sand	92	30	149	7.1	153	154	1-1/2	6.1	Wet
55	Disturbed sand	93	20	112	5.4	153	155	1-1/4	6.1	Wet
56	Disturbed sand	94	10	90	4.3	157	157	1	6.1	Wet
57	Undisturbed sand	95	45	150	7.2	167	168	1/8	13.3	Wet
58	Undisturbed sand	96	30	121	5.8	166	167	1/8	13.3	Wet
59	Undisturbed sand	97	20	110	5.3	169	170	1/4	13.3	Wet
60	Undisturbed sand	98	10	100	4.8	172	173	1/16	13.3	Wet

(Continued)

Table 7 (Continued)

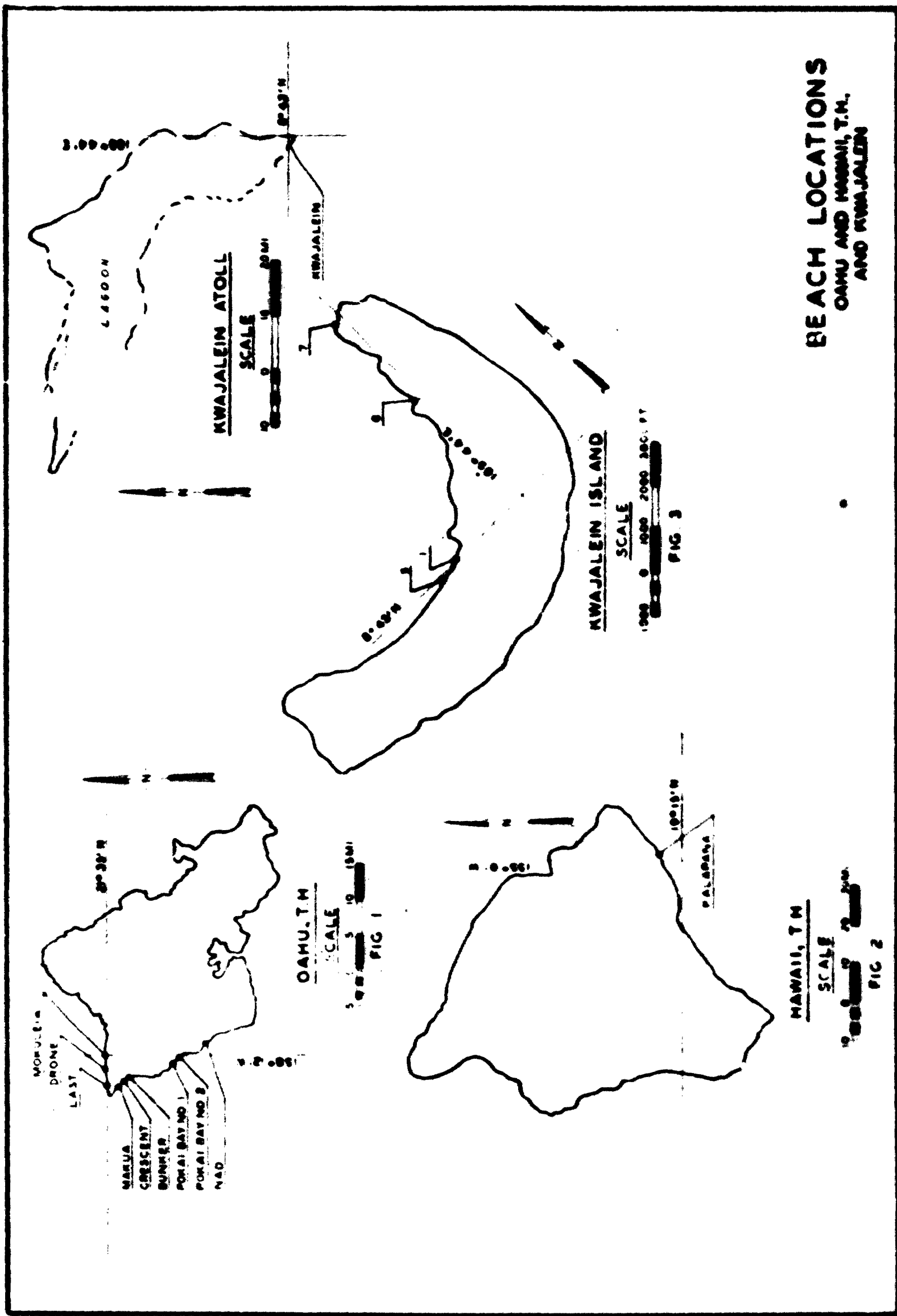
Item No.	Type of Test Surface	Test No.	Tire Pressure psi	Towing Force Required lb	Towing Force, as % of Test Weight	Cone Index - 0- to 6-in. Depth		Pen Depth One Pass in.	Average Moisture Content 0- to 6-in. Depth	Sand Condition
						Before Traffic	After One Pass			
<u>1/4-ton M101 Trailer, Test Weight 2,560 lb</u>										
61	Asphalt pavement	123	45	29	1.0	---	---	-----		
62	Asphalt pavement	124	30	32	1.1	---	---	-----		
63	Asphalt pavement	125	20	40	1.4	---	---	-----		
64	Asphalt pavement	126	10	50	1.7	---	---	-----		
65	Disturbed sand	103	45	350	11.8	145	149	1-3/4	4.2	Wet
66	Disturbed sand	104	30	278	9.4	145	147	1-3/8	4.2	Wet
67	Disturbed sand	105	20	220	7.4	145	147	1-1/4	4.2	Wet
68	Disturbed sand	106	10	185	6.2	145	147	3/4	4.2	Wet
69	Undisturbed sand	99	45	210	7.1	160	161	0	19.3	Wet
70	Undisturbed sand	100	30	170	5.7	161	161	1/8	19.3	Wet
71	Undisturbed sand	101	20	195	6.6	152	153	1/4	19.3	Gr*
72	Undisturbed sand	102	10	170	5.7	150	151	1/4	19.3	Wet
<u>1/4-ton M101 Trailer, Test Weight 2,579 lb</u>										
73	Asphalt pavement	119	45	30	0.8	---	---	-----		
74	Asphalt pavement	120	30	36	1.0	---	---	-----		
75	Asphalt pavement	121	20	42	1.1	---	---	-----		
76	Asphalt pavement	122	10	56	1.5	---	---	-----		
77	Disturbed sand	107	45	404	11.6	142	144	1	11.0	Wet
78	Disturbed sand	108	30	350	9.6	126	115	1-1/2	11.0	Wet
79	Disturbed sand	109	20	304	8.1	117	111	1	11.0	Wet
80	Disturbed sand	110	10	219	6.9	121	124	1/2	11.0	Wet
81	Undisturbed sand	115	45	312	8.5	151	151	3/4	17.1	Wet
82	Undisturbed sand	116	30	230	6.3	160	161	1/4	17.1	Wet
83	Undisturbed sand	117	20	177	4.8	166	167	1/16	17.1	Wet
84	Undisturbed sand	118	10	150	4.1	171	172	1/2	17.1	Wet
<u>1-1/2-ton M105 Trailer, Test Weight 4,110 lb</u>										
85	Asphalt pavement	144	45	40	1.5	---	---	-----		
86	Asphalt pavement	145	30	62	1.5	---	---	-----		
87	Asphalt pavement	146	20	62	1.5	---	---	-----		
88	Asphalt pavement	147	10	62	1.5	---	---	-----		
89	Disturbed sand	140	45	488	11.9	124	108	1-1/2	9.0	Wet
90	Disturbed sand	141	30	412	10.0	118	105	1-3/4	9.0	Wet
91	Disturbed sand	142	20	550	13.4	95	91	1	9.0	Wet
92	Disturbed sand	143	10	350	8.5	70	70	1-1/4	9.0	Wet
93	Undisturbed sand	136	45	510	11.4	100	100	1	18.6	Wet
94	Undisturbed sand	137	30	420	10.2	106	106	1	18.6	Wet
95	Undisturbed sand	138	20	350	8.5	112	112	5/8	18.6	Wet
96	Undisturbed sand	139	10	280	6.8	101	112	1/4	18.6	Wet
<u>1-1/2-ton M105 Trailer, Test Weight 5,648 lb</u>										
97	Asphalt pavement	148	45	65	1.2	---	---	-----		
98	Asphalt pavement	149	30	76	1.3	---	---	-----		
99	Asphalt pavement	150	20	76	1.3	---	---	-----		
100	Asphalt pavement	151	10	76	1.3	---	---	-----		
101	Disturbed sand	152	45	1,017	18.9	105	87	1	2.6	Moist
102	Disturbed sand	153	30	815	14.4	77	59	1	2.6	Moist
103	Disturbed sand	154	20	548	9.7	87	85	1-1/4	2.6	Moist
104	Disturbed sand	155	10	508	9.0	77	71	1-1/4	2.6	Moist
105	Undisturbed sand	156	45	745	16.4	94	90	1	3.4	Moist
106	Undisturbed sand	157	30	750	14.3	87	88	1-1/4	3.4	Moist
107	Undisturbed sand	158	20	650	11.5	77	76	1	3.4	Moist
108	Undisturbed sand	159	10	600	10.4	77	76	1/4	3.4	Moist
<u>1-1/2-ton M105 Trailer, Test Weight 7,482 lb</u>										
109	Asphalt pavement	168	45	62	0.8	---	---	-----		
110	Asphalt pavement	169	30	88	1.2	---	---	-----		
111	Asphalt pavement	170	20	88	1.2	---	---	-----		
112	Asphalt pavement	171	10	88	1.2	---	---	-----		
113	Disturbed sand	160	45	1,270	17.0	70	70	2-1/4	2.6	Moist
114	Disturbed sand	161	30	1,360	14.2	77	74	2-1/2	2.6	Moist
115	Disturbed sand	162	20	87	11.9	87	77	1-3/4	2.6	Moist
116	Disturbed sand	163	10	757	10.4	87	88	1-1/4	2.6	Moist
117	Undisturbed sand	164	45	1,175	15.0	98	98	1-1/2	2.9	Moist
118	Undisturbed sand	165	30	745	12.4	97	97	1-1/4	2.9	Moist
119	Undisturbed sand	166	20	750	10.0	109	108	3/4	2.9	Moist
120	Undisturbed sand	167	10	675	9.0	125	125	1/2	2.9	Moist

(Continued)

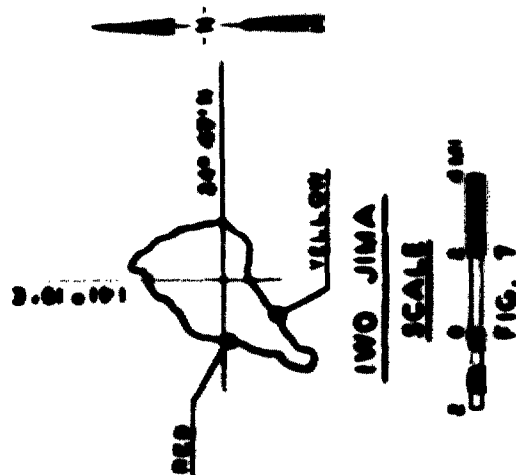
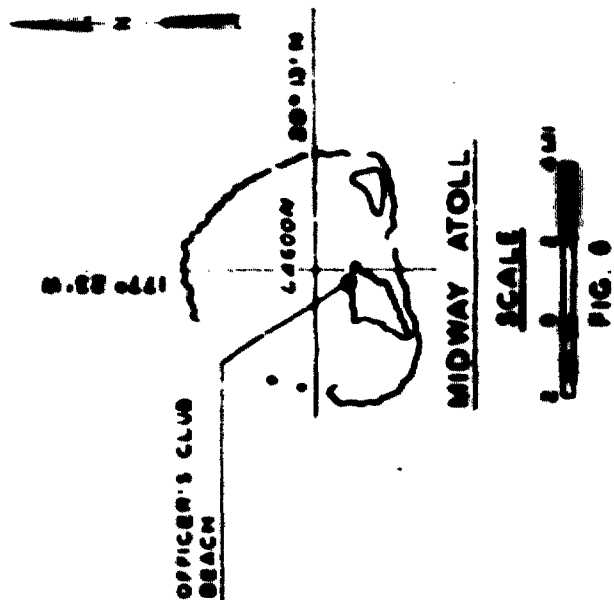
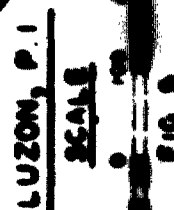
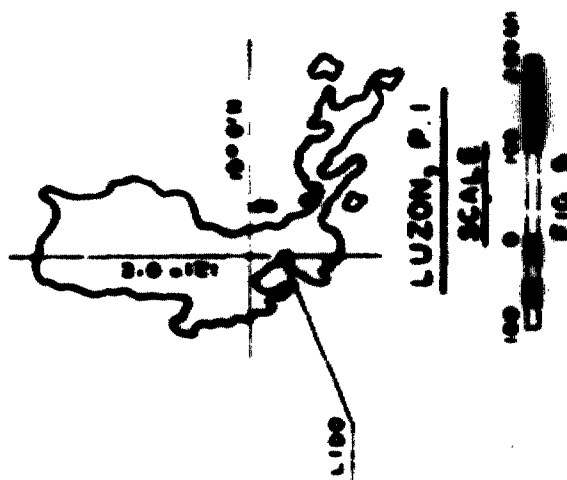
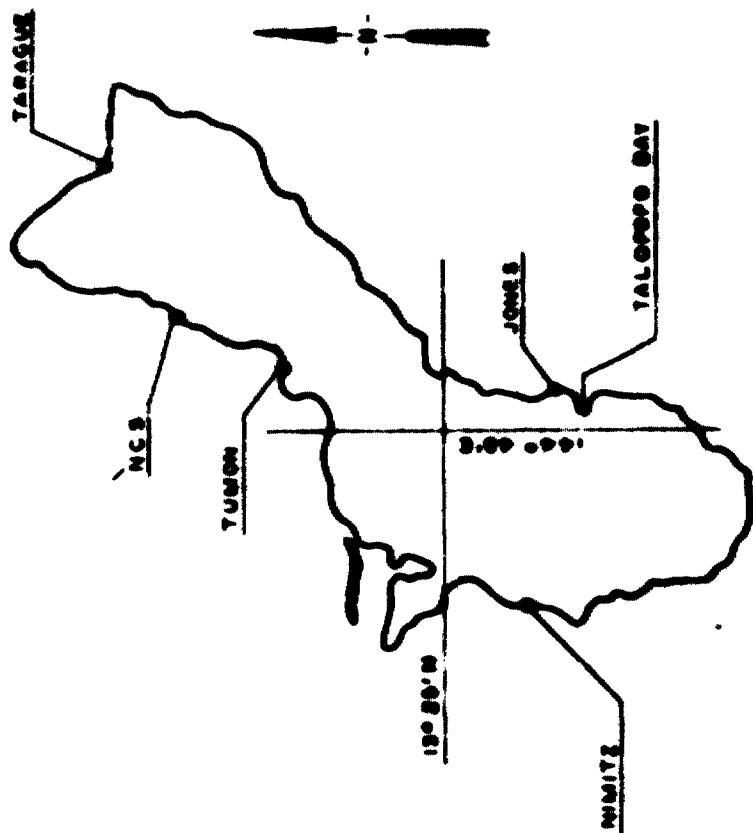
Sheet 7 of 3 sheets

Table 9 (Continued)

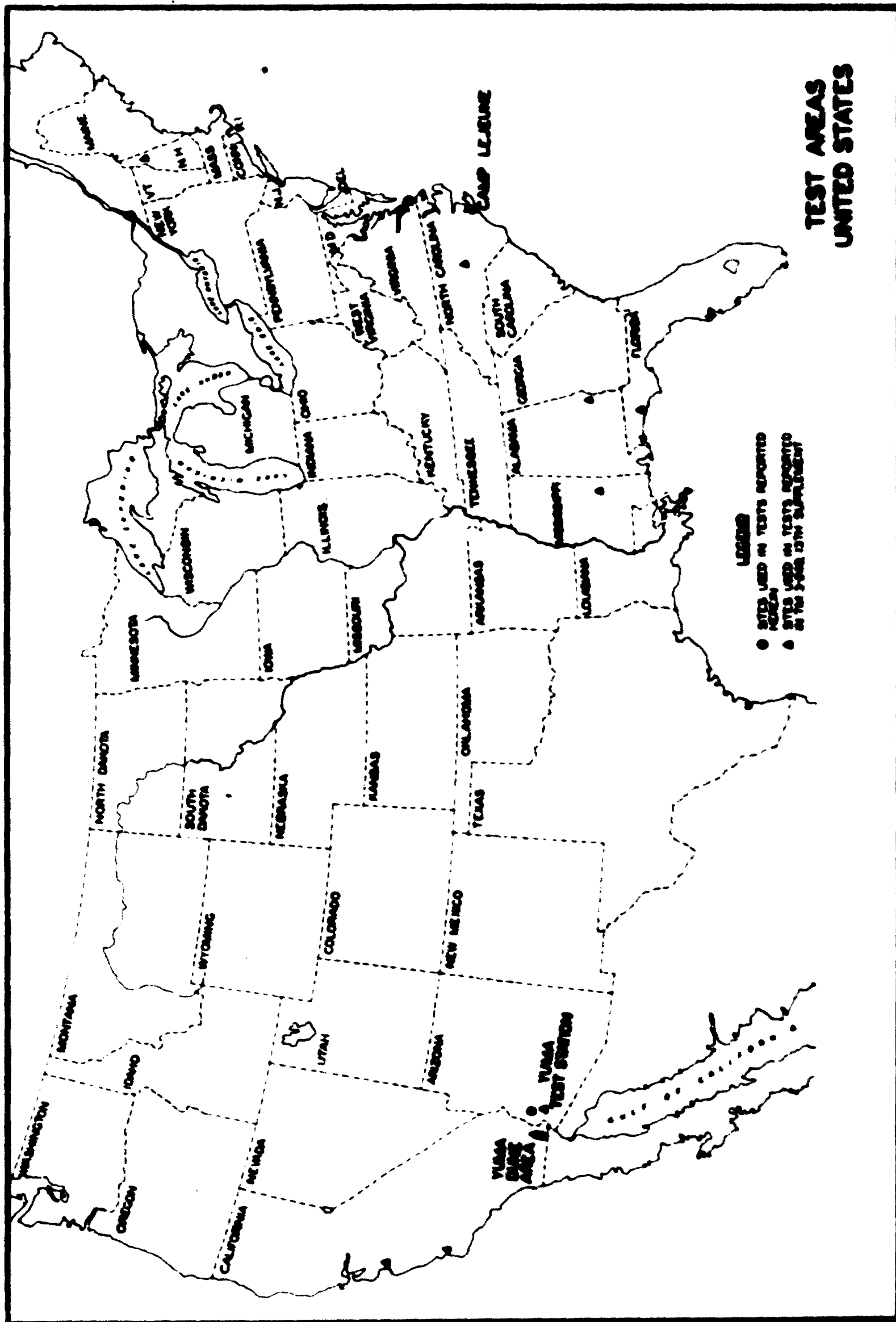
Item No.	Type of Test Surface	Test No.	Tire Pressure psi	Towing Force Required lb	Towing Force as % of Test Weight	Cone Index G. to 6-in. Depth		Pen. Depth One Pass in.	Average Moisture Content 0- to 6-in. Depth	Sand Condition
						Before Traffic	After One Pass			
<u>17.5-ton Generator Trailer, Test Weight 7,151 lb</u>										
121	Asphalt pavement	216	60	97	1.4	---	---	-----		
122	Asphalt pavement	217	45	116	1.6	---	---	-----		
123	Asphalt pavement	218	30	126	1.8	---	---	-----		
124	Asphalt pavement	219	15	203	2.8	---	---	-----		
125	Disturbed sand	208	60	1,310	18.3	116	131	-----	9.6	Wet
126	Disturbed sand	209	45	1,212	15.9	114	119	-----	9.6	Wet
127	Disturbed sand	210	30	1,019	14.2	98	101	-----	9.6	Wet
128	Disturbed sand	211	15	700	9.8	95	94	-----	9.6	Wet
129	Undisturbed sand	212	60	680	6.7	172	171	-----	21.7	Wet
130	Undisturbed sand	213	45	380	5.3	174	174	-----	21.7	Wet
131	Undisturbed sand	214	30	280	3.9	194	197	-----	21.7	Wet
132	Undisturbed sand	215	15	240	3.4	198	200	-----	21.7	Wet
<u>6-ton Trailer, Test weight 10,960 lb</u>										
133	Asphalt pavement	196	60	100	0.9	---	---	-----		
134	Asphalt pavement	197	45	100	0.9	---	---	-----		
135	Asphalt pavement	198	30	130	1.2	---	---	-----		
136	Asphalt pavement	199	15	200	1.8	---	---	-----		
137	Disturbed sand	204	60	1,090	9.9	162	162	1	14.5	Wet
138	Disturbed sand	205	45	690	6.3	176	173	1/2	14.5	Wet
139	Disturbed sand	206	30	450	4.1	174	174	3/8	14.5	Wet
140	Disturbed sand	207	15	320	2.9	184	178	-----	14.5	Wet
141	Undisturbed sand	200	60	1,380	12.5	112	114	1-1/4	1.0	Moist
142	Undisturbed sand	201	45	1,000	9.1	104	112	1-1/8	1.0	Moist
143	Undisturbed sand	202	30	1,040	9.5	129	127	1/2	1.0	Moist
144	Undisturbed sand	203	15	720	6.6	146	138	1/4	1.0	Moist
<u>6-ton Trailer, Test Weight 17,160 lb</u>										
145	Asphalt pavement	192	60	220	1.3	---	---	-----		
146	Asphalt pavement	193	45	220	1.3	---	---	-----		
147	Asphalt pavement	194	30	230	1.3	---	---	-----		
148	Asphalt pavement	195	15	340	2.0	---	---	-----		
149	Disturbed sand	184	60	1,600	9.3	169	159	1-3/8	5.5	Wet
150	Disturbed sand	185	45	2,800	16.1	115	113	2	5.5	Wet
151	Disturbed sand	186	30	2,200	12.8	102	94	2-3/4	5.5	Wet
152	Disturbed sand	187	15	1,900	11.1	87	85	1-1/2	5.5	Wet
153	Undisturbed sand	188	60	2,500	14.6	128	118	1-1/8	6.7	Wet
154	Undisturbed sand	189	45	2,000	11.7	121	112	1-1/2	6.7	Wet
155	Undisturbed sand	190	30	1,600	9.3	127	120	1-1/4	6.7	Wet
156	Undisturbed sand	191	15	900	5.2	159	161	1-1/4	6.7	Wet
<u>6-ton Trailer, Test Weight 25,520 lb</u>										
157	Asphalt pavement	180	60	440	1.7	---	---	-----		
158	Asphalt pavement	181	45	450	1.8	---	---	-----		
159	Asphalt pavement	182	30	500	2.0	---	---	-----		
160	Asphalt pavement	183	15	700	2.7	---	---	-----		
161	Disturbed sand	172	60	4,200	16.5	94	---	1-3/8	4.7	Moist
162	Disturbed sand	173	45	4,400	18.0	87	89	2-3/4	4.7	Moist
163	Disturbed sand	174	30	3,600	14.1	97	97	2-1/8	4.7	Moist
164	Disturbed sand	175	15	2,140	8.2	110	97	1	4.7	Moist
165	Undisturbed sand	176	60	5,700	23.1	72	81	5	6.8	Wet
166	Undisturbed sand	177	45	4,900	19.2	82	---	-----	6.8	Wet
167	Undisturbed sand	178	30	4,400	17.2	78	75	2	6.8	Wet
168	Undisturbed sand	179	15	4,800	19.8	78	84	-----	6.8	Wet

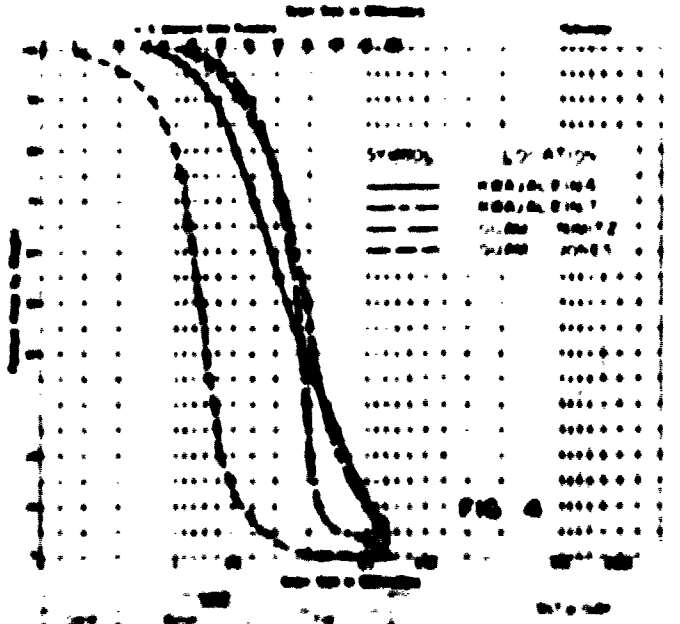
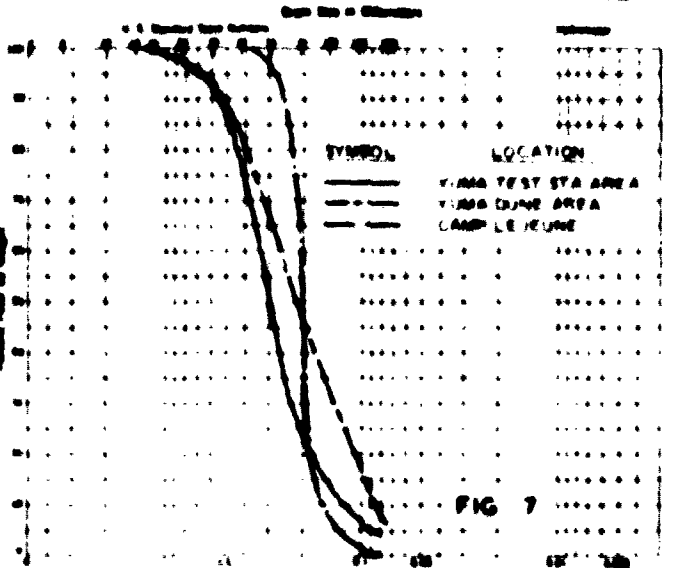
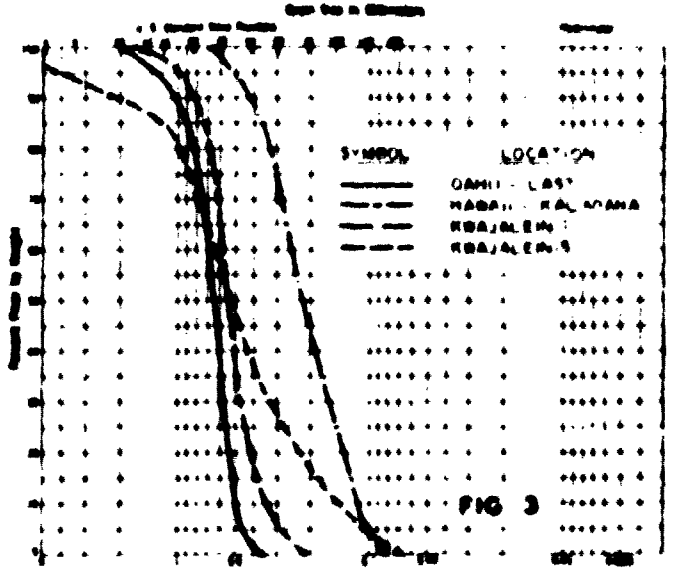
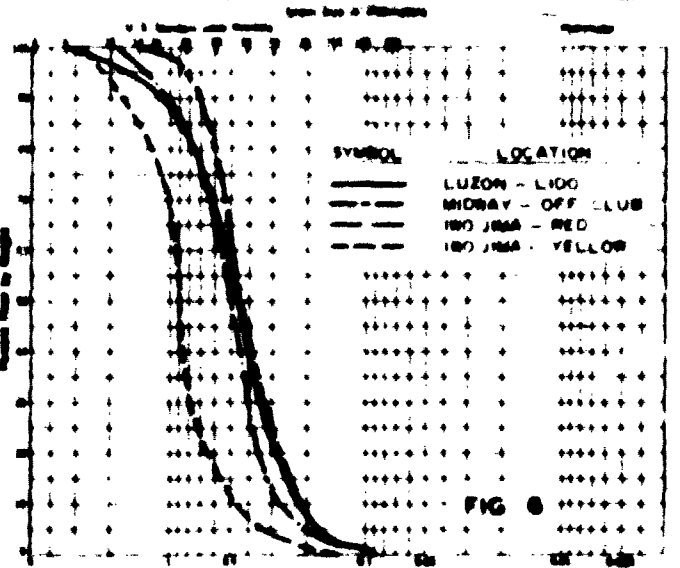
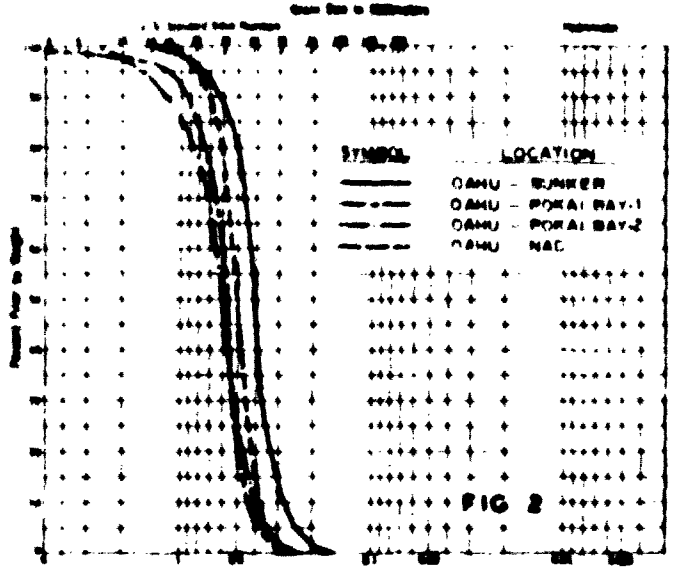
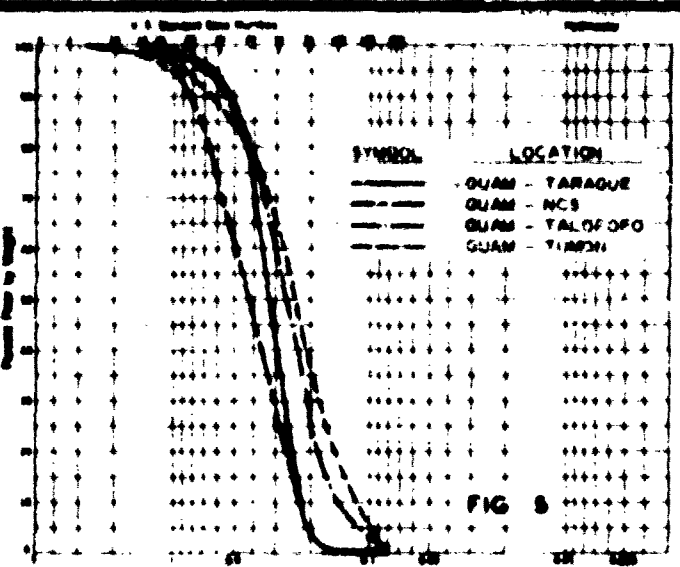
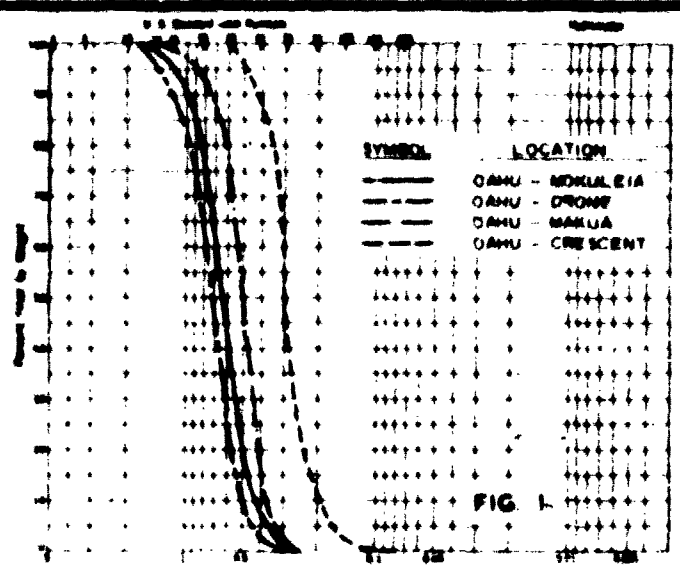


BEACH LOCATIONS OAHU AND HAWAII, T.H., AND KWAJALEIN



BEACH LOCATIONS
GUAM, LUZON, P.I., MIDWAY,
AND IWO JIMA



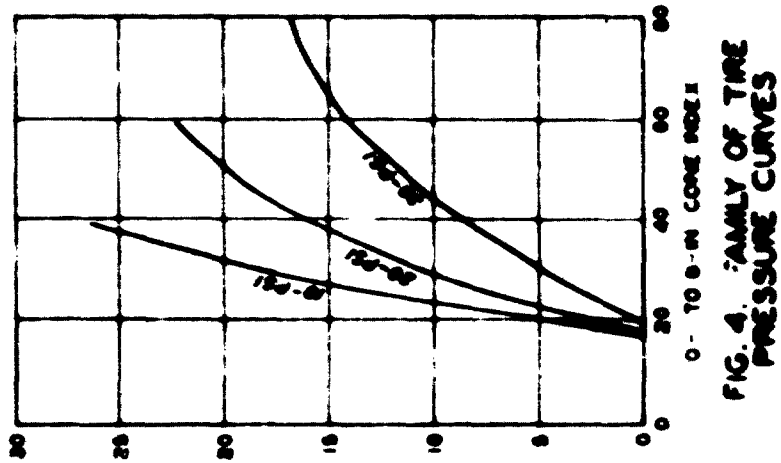
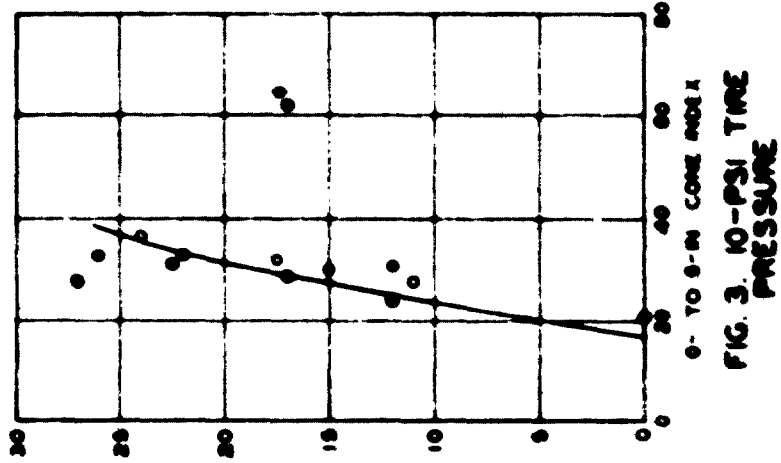
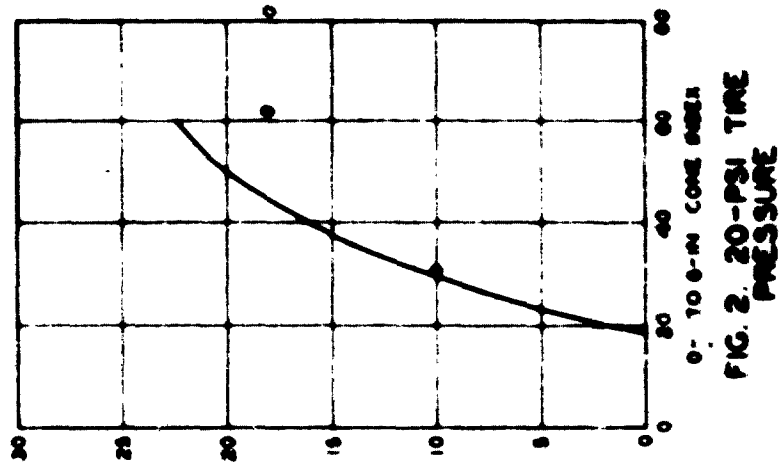
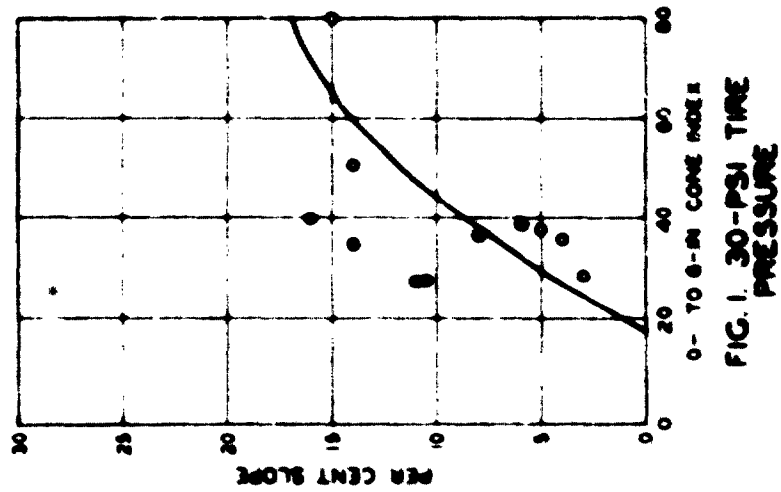


NOTE REFER TO TABLE 1 FOR SUPPLEMENTARY DATA

GRADATION CURVES

VEHICLE PERFORMANCE SINGLE SELF-PROPELLED VEHICLE TESTS WET TO UNDATED SAND PER CENT SLOPE VS CONE INDEX 1/2-TON M38A1 4X4 TRUCK, 7.00X16 GPR TIRES GROSS WT 2975-3125 LB

NOTE PLOTTED POINTS ARE FROM TABLE 3
OPEN SYMBOLS ARE NON-REMOVALIZATIONS
CLOSED SYMBOLS ARE REMOVALIZATIONS
O BY SYMBOL INDICATES TEST ON
A QUICK CONDITION



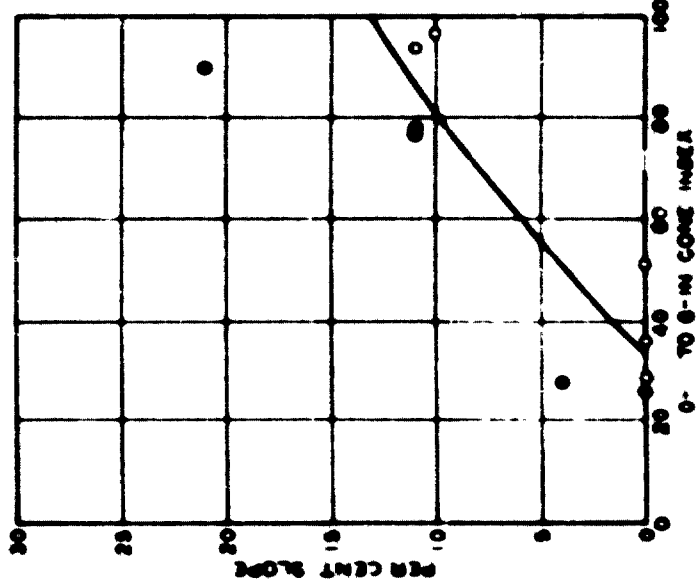


FIG. 1 30-PSI TIRE PRESSURE

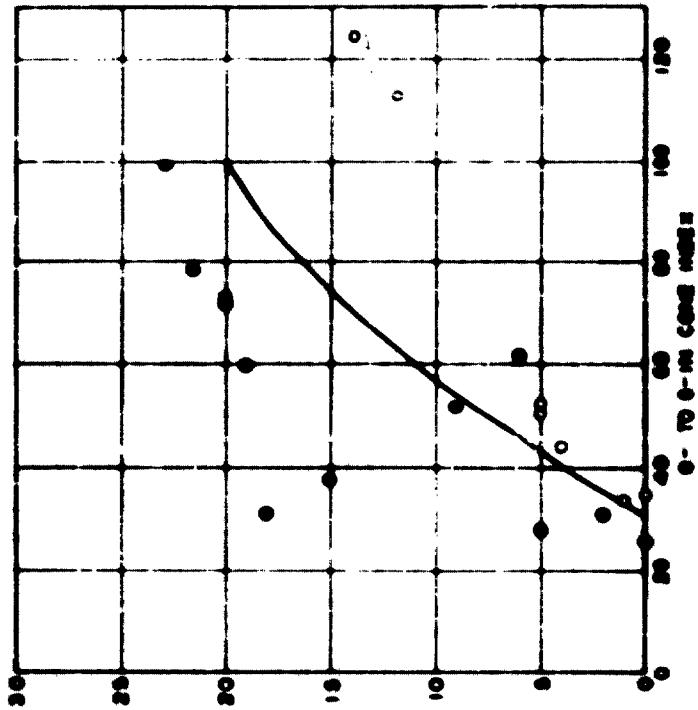


FIG. 2 20-PSI TIRE PRESSURE

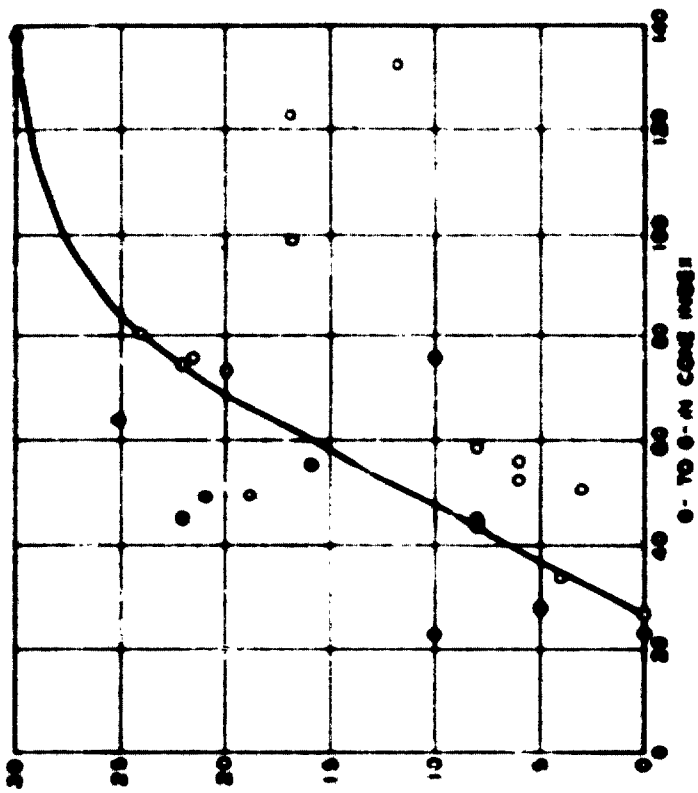


FIG. 3 15-PSI TIRE PRESSURE

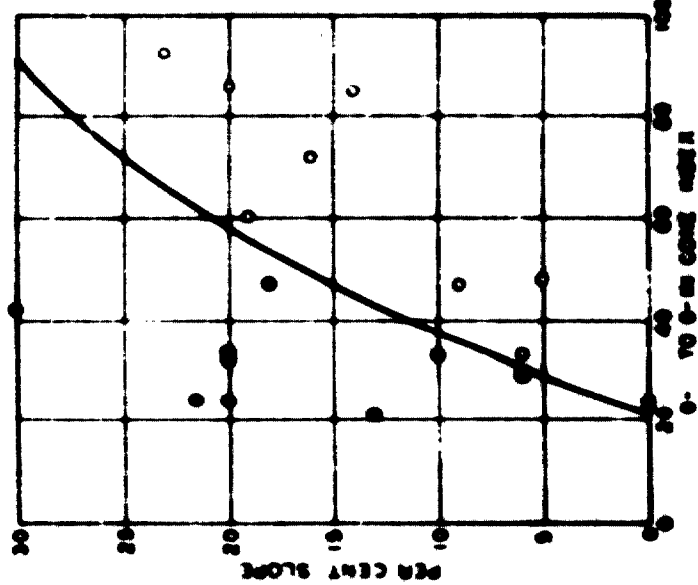


FIG. 4 10-PSI TIRE PRESSURE

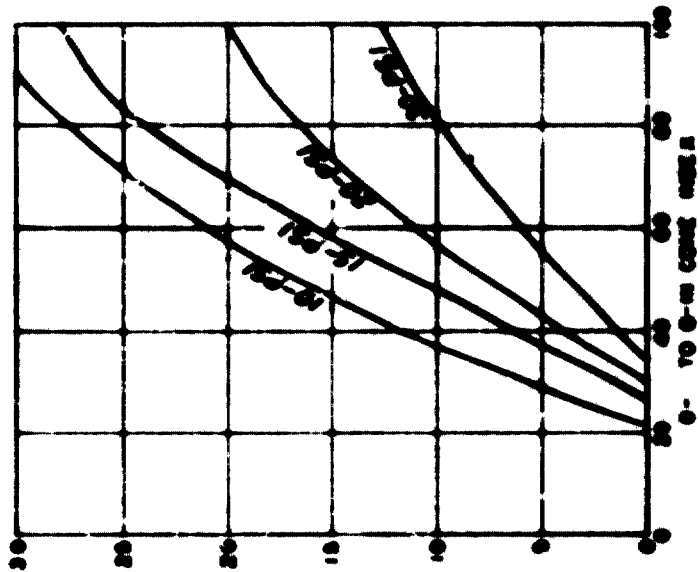


FIG. 5 FAMILY OF TIRE PRESSURE CURVES

NOTE PLOTTED POINTS ARE FROM TABLE 2
OPEN SYMBOLS ARE REMOBILIZATIONS
CLOSED SYMBOLS ARE UNMOBILIZATIONS

VEHICLE PERFORMANCE SINGLE SELF-PROPELLED VEHICLE TESTS

DRY TO MOIST SAND
PER CENT SLOPE VS CONE INDEX
1/2-TON M38A1 4X4 TRUCK.
7.00X16 GPR TIRES
GROSS WT 2975-3125 LB

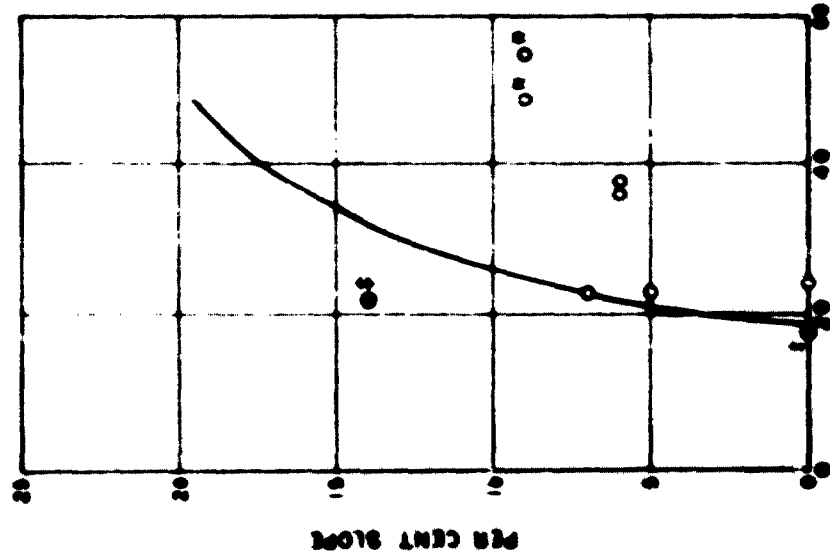


FIG. 1. 20-PSI TIME PRESSURE

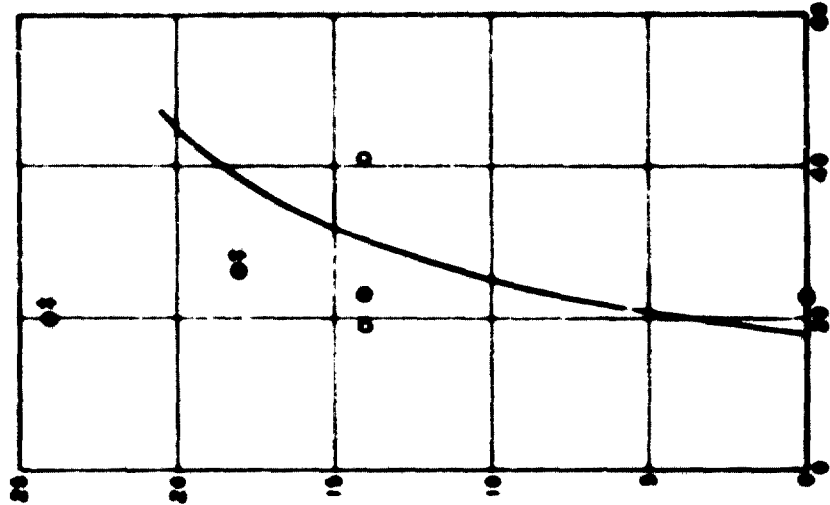


FIG. 2. 15-PSI TIME PRESSURE

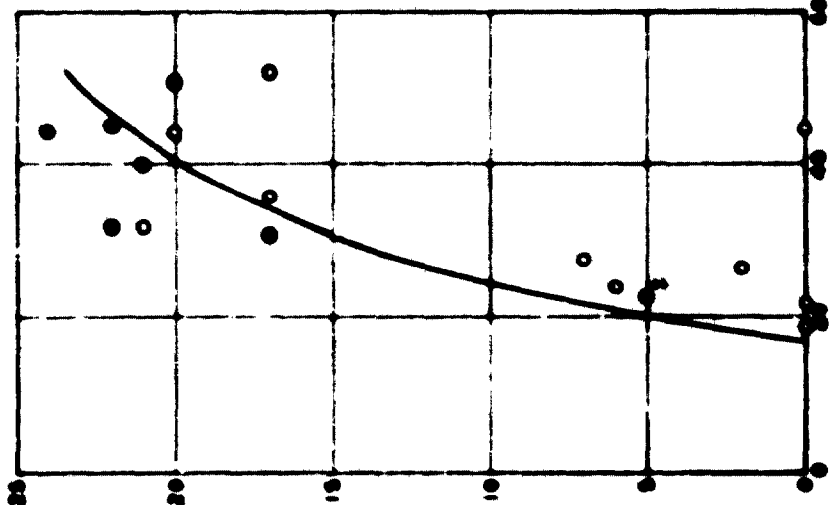


FIG. 3. 10-PSI TIME PRESSURE

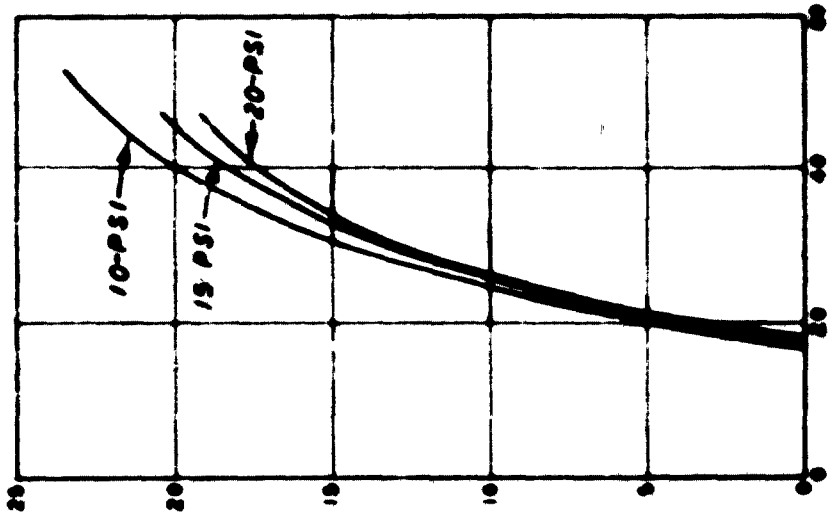


FIG. 4. FAMILY OF TIRE PRESSURE CURVES

NOTE: 1. BY SYMBOL INDICATES 15TH SUPPLEMENT DATA
2. BY SYMBOL INDICATES TEST ON A QUICK CONDITION
OTHER SYMBOLS ARE ITEMS FROM TABLE 4
OPEN SYMBOLS ARE NONMOBILIZATIONS
CLOSED SYMBOLS ARE MOBILIZATIONS

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS
WET TO UNDATED SAND
PER CENT SLOPE VS CONE INDEX
2-TON M37 4X4 TRUCK, 900X16 6PR TIRES
GROSS WT 7417 LB

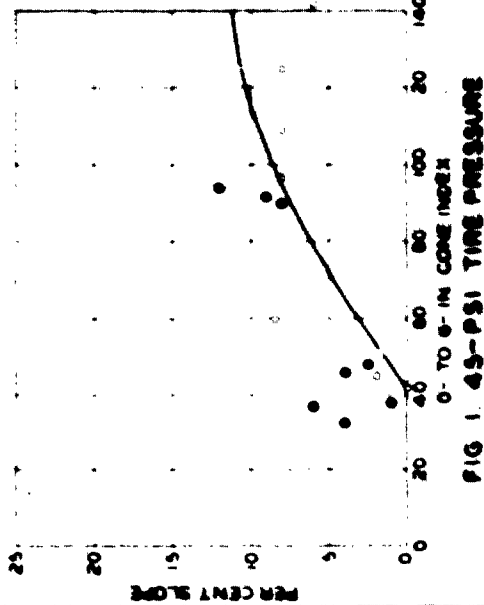


FIG 1 45-PSI TIME PRESSURE

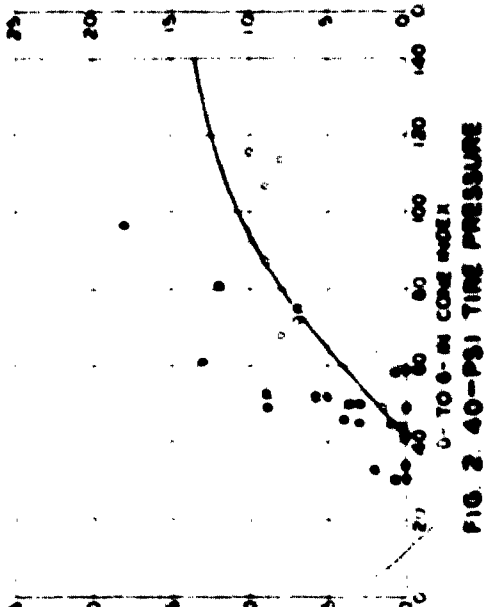


FIG 2 40-PSI TIME PRESSURE

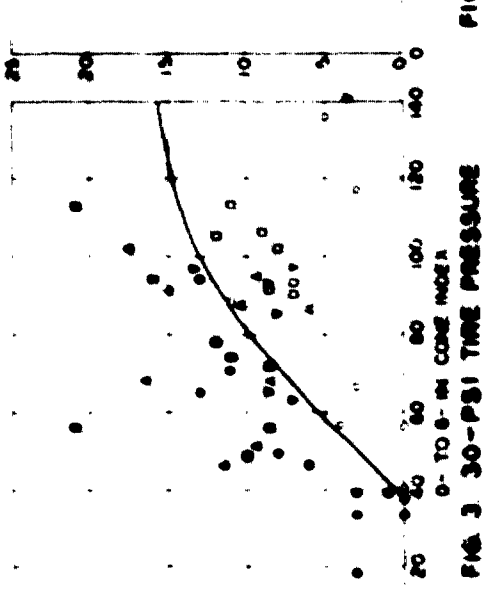


FIG 3 30-PSI TIME PRESSURE

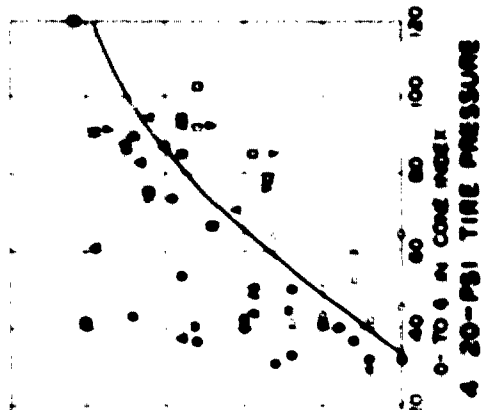


FIG 4 20-PSI TIME PRESSURE

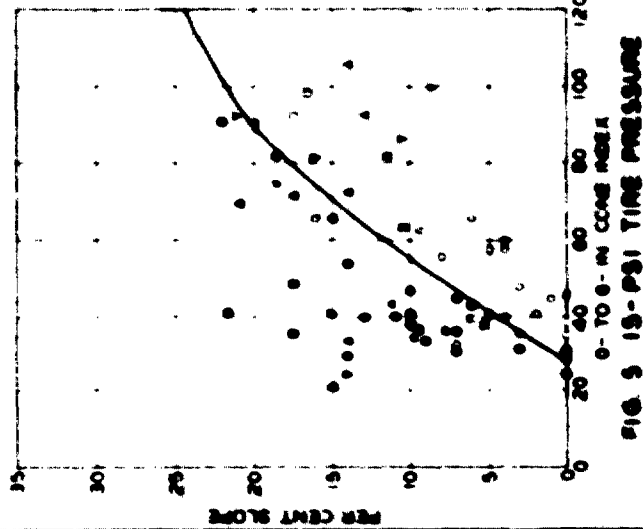


FIG 5 15-PSI TIME PRESSURE

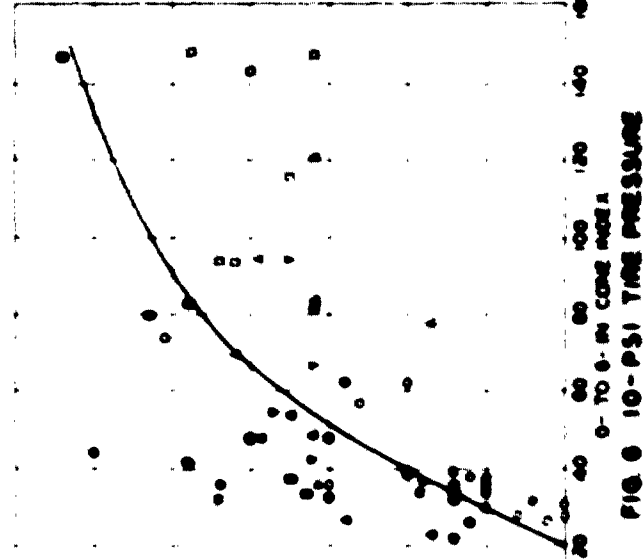


FIG 6 10-PSI TIME PRESSURE

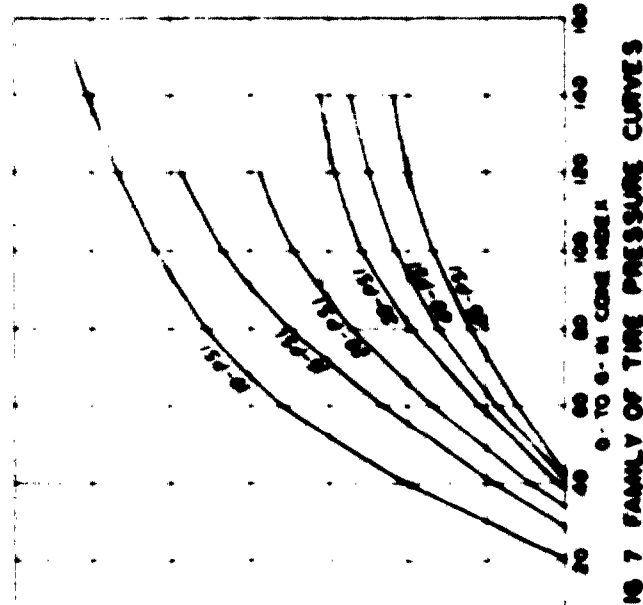


FIG 7 FAMILY OF TIME PRESSURE CURVES

LEGEND

GROSS WT-LB	RECON- LIZATION	RECON- LIZATION
5645	●	●
6067 - 6275	○	○
7085 - 7417	○	○
7805	○	○

● BY STUDIOS INDICATES 15TH SUPPLEMENT DATA
OTHER PLOTTED PRINTS ARE FROM TABLE 4

**VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS**
 DRY TO MOIST SAND
 PER CENT SLOPE VS CONE INDEX
 $\frac{1}{2}$ - TON M37 4 X 4 TRUCK
 900 X 16 8PR TIRES

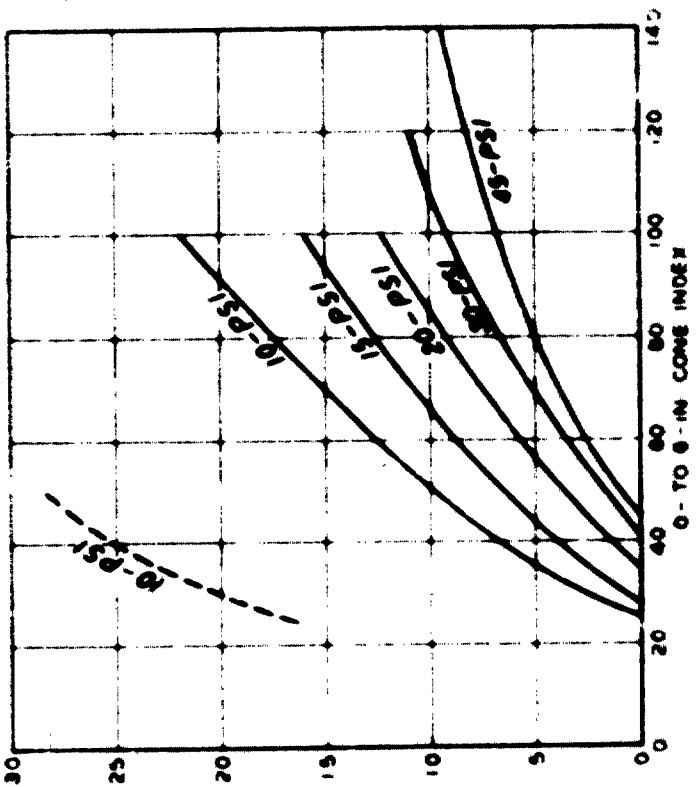
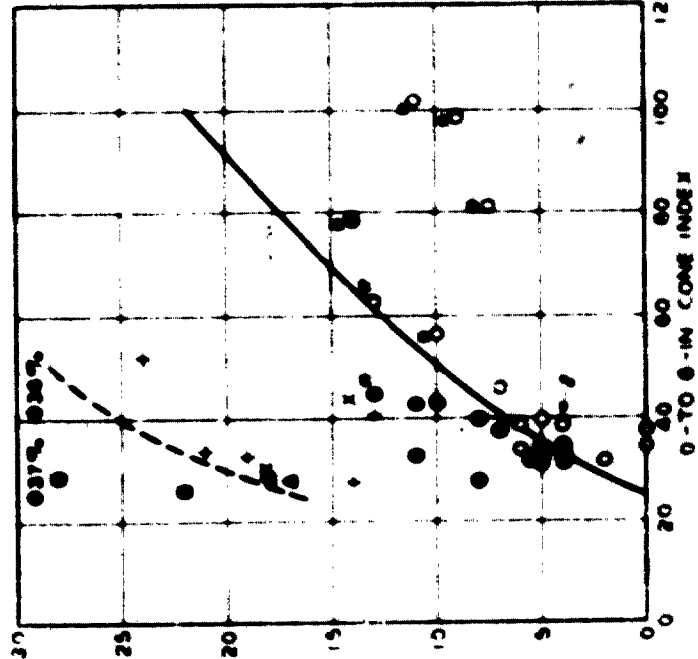
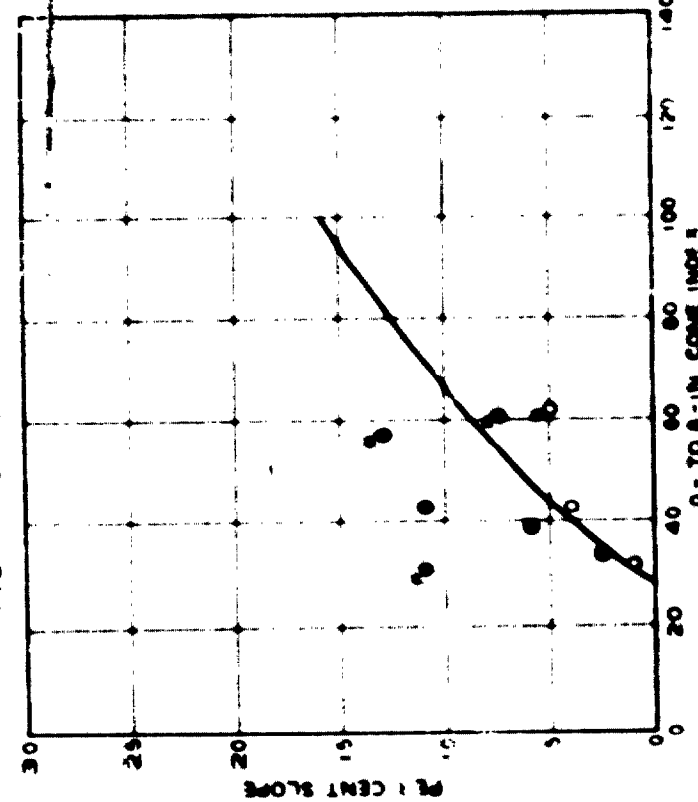
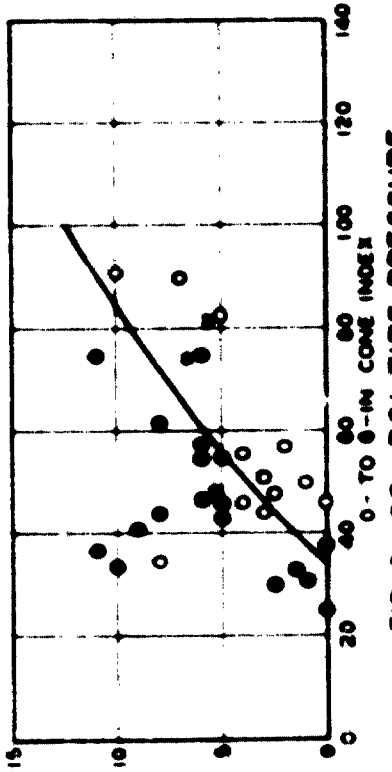
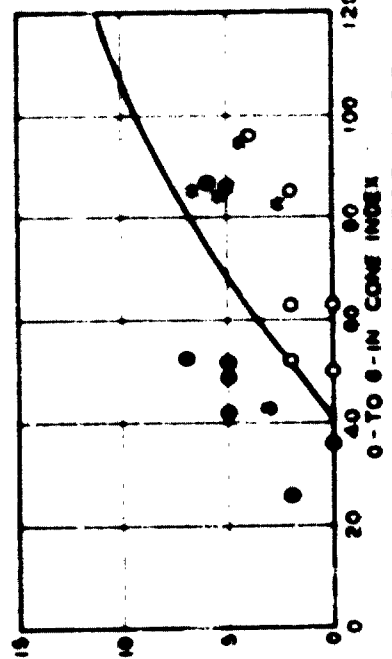
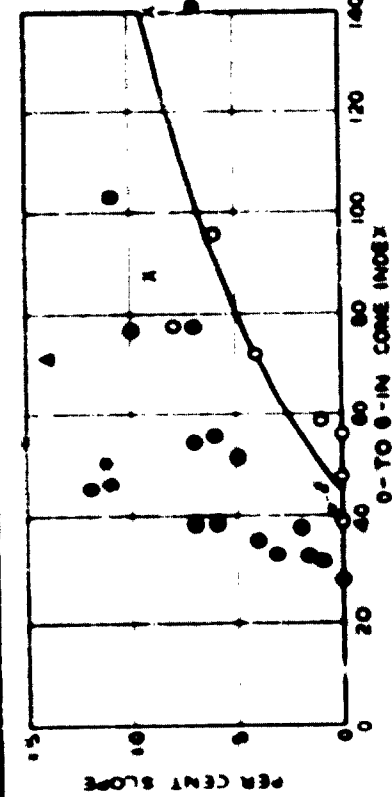


FIG. 4 15 - PSI TIME PRESSURE

FIG. 5 10- PSI TIME PRESSURE

FIG. 6. FAMILY OF TIRE PRESSURE CURVES

LEGEND

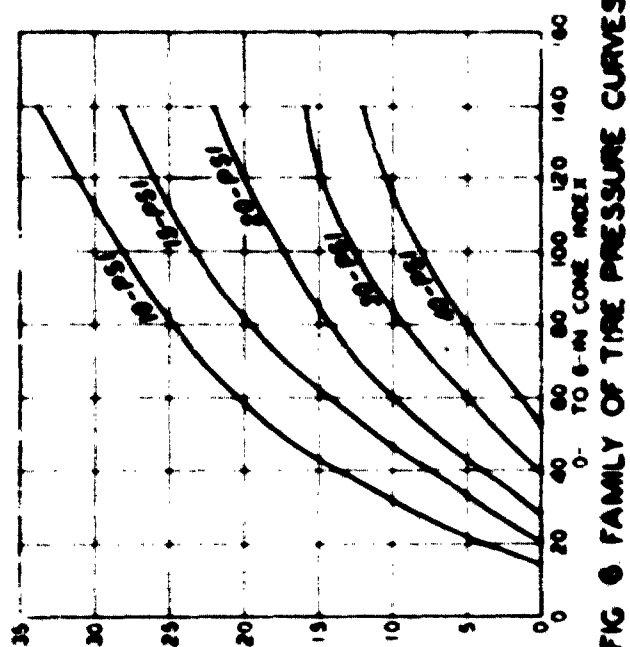
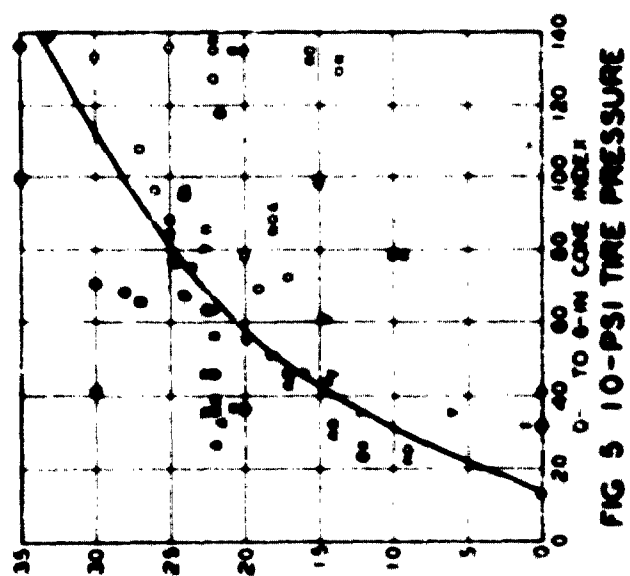
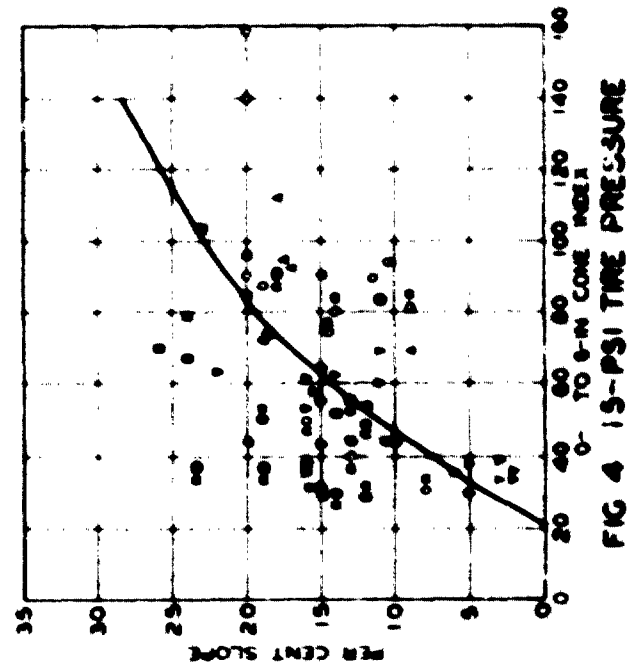
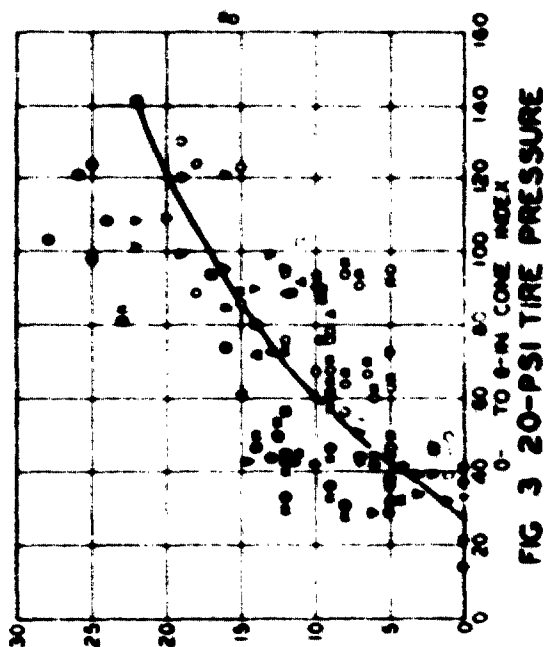
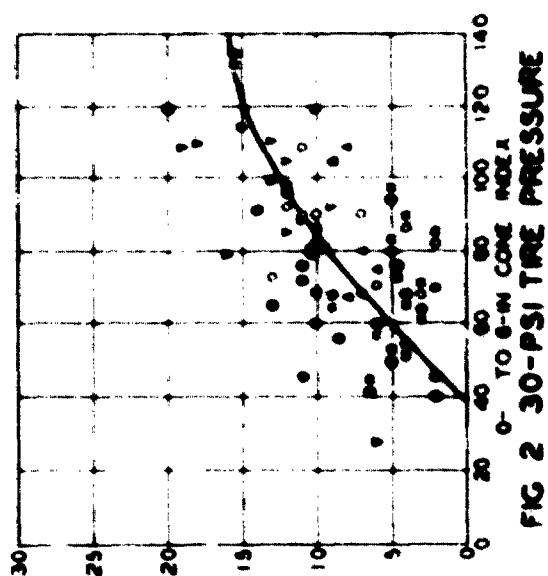
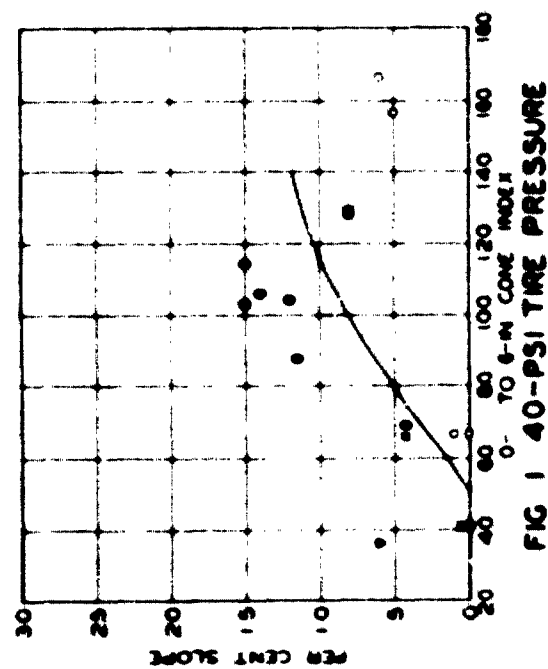
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NET TO RECORDED	0.00	0	0	---
NET TO RECORDED	13.00	0	0	---
NET TO RECORDED	13.00	0	0	---

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED DATE 01/10/2001 BY 60321 UCBAW

1. The first step is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the problem.

BY ORDER OF THE BOARD OF DIRECTORS

OWN A QUOTE **CONVERT YOUR**



**VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED
VEHICLE TESTS**

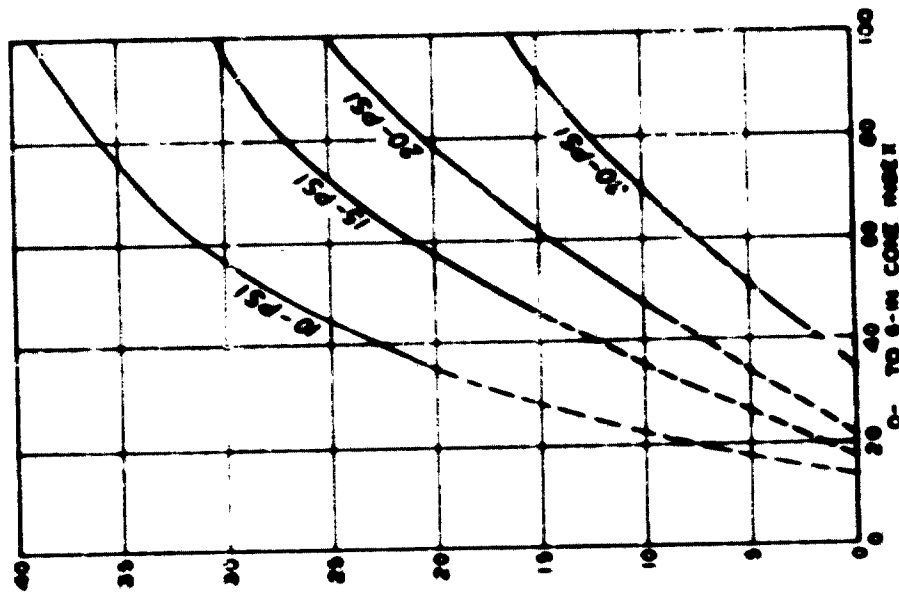
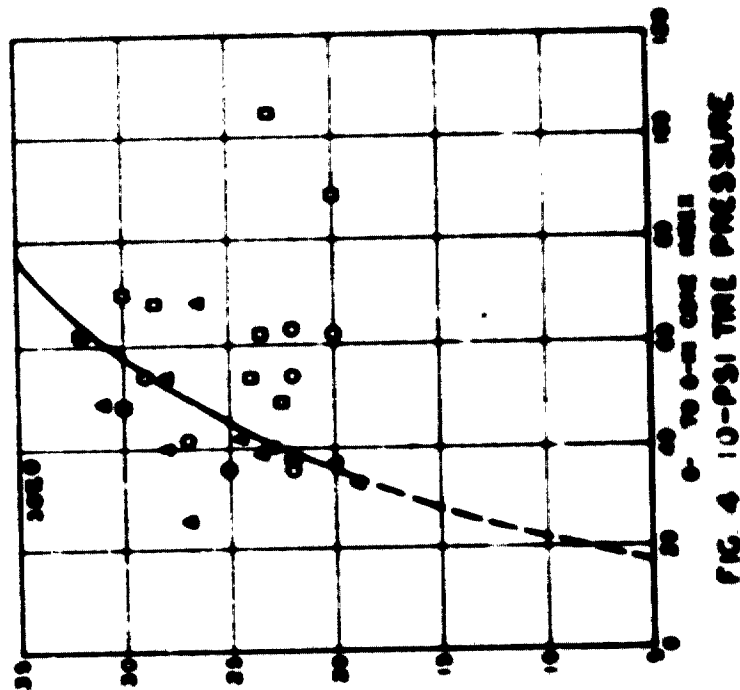
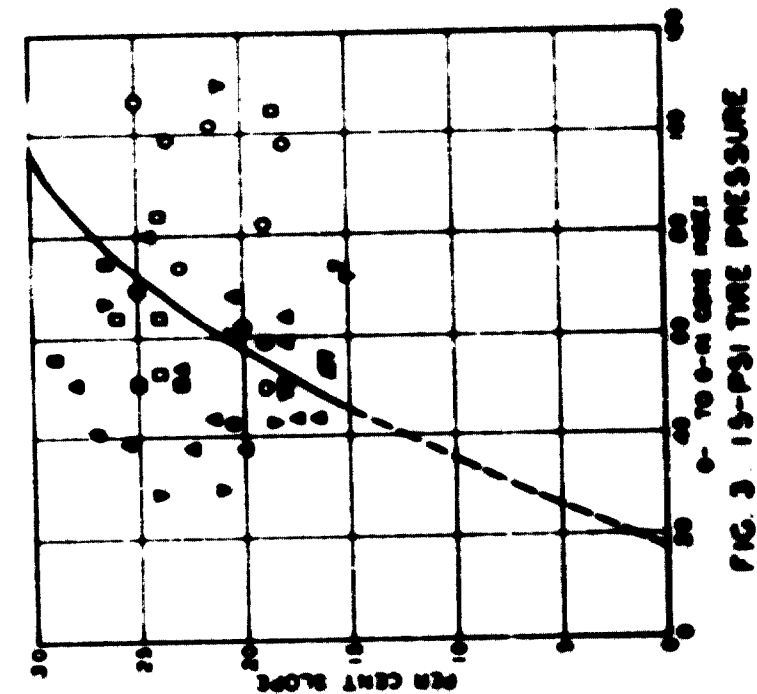
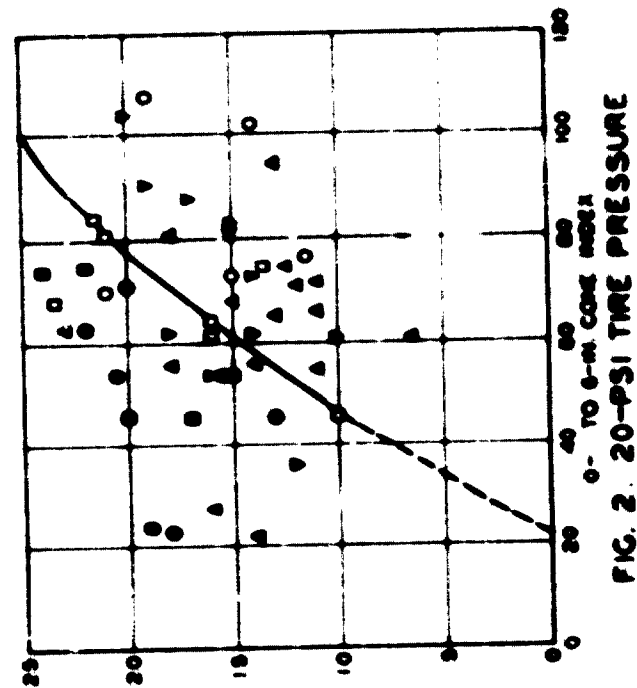
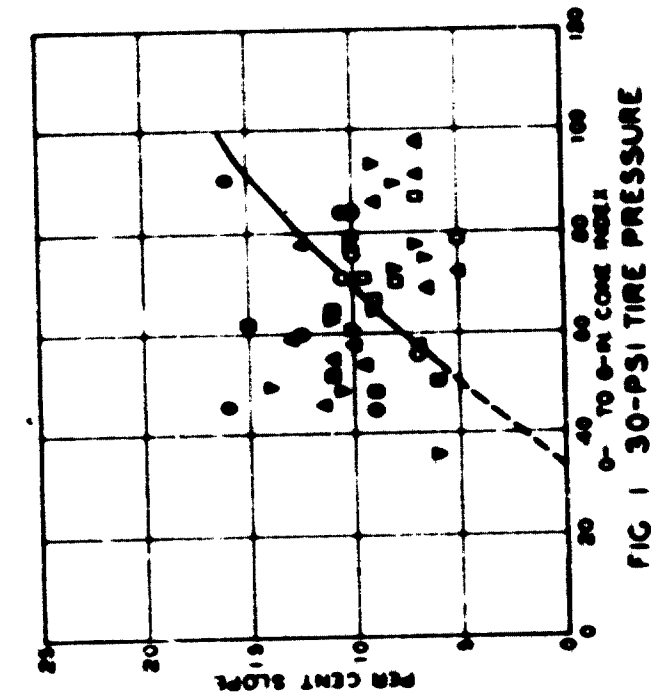
PER CENT SLOPE VS CONE INDEX

2½-TON 6X6 TRUCKS.

11.00X20 12PR TIRES (SINGLE)

SAND CLASS	GROSS WT. - LB	LOCATION		NUMBER OF CORES	VALUATION
		WET TO NEAREST	WET TO NEAREST		
WET TO NEAREST	19,820	0	0	1	0
DRY TO MOIST	12,480	0	0	1	0
DRY TO MOIST	14,950 - 19,000	0	0	0	0
DRY TO MOIST	17,320 - 17,480	0	0	0	0
DRY TO MOIST	19,620 - 20,500	0	0	1	0

A BY SYMBOLS INDICATES WITH SUPPLEMENT DATA
 OTHER PLOTTED POINTS ARE FROM TABLE
 S BY SYMBOL INDICATES TEST ON A QUICK CONDITION



LEGEND

CROSS SECTION	WHEEL	WHEEL	WHEEL
10,115	10,115	10,115	10,115
20,275	20,275	20,275	20,275
20,175	20,175	20,175	20,175
32,300	32,300	32,300	32,300

NOTES: PLOTTED POINTS ARE FROM TABLE 1

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED
VEHICLE TESTS
 DRY TO MOIST SAND
 PER CENT SLOPE VS CONE INDEX
 9-TON M41 G10 TRUCK,
 14,000-12 PSI TIRES (SINGLE)

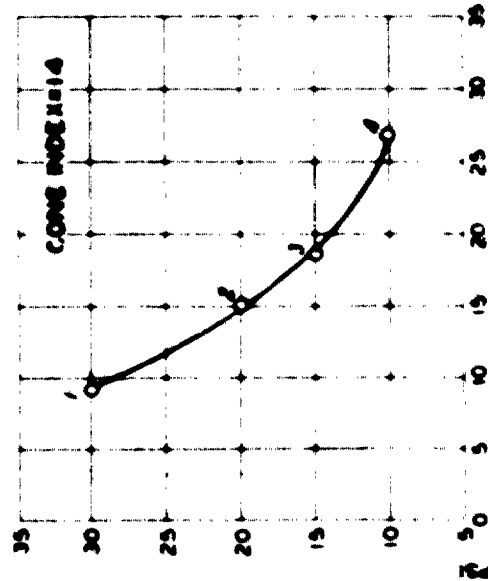


FIG 1 1/4-TON M38A1 4 X 4 TRUCK
TEST WEIGHT 2075 LB

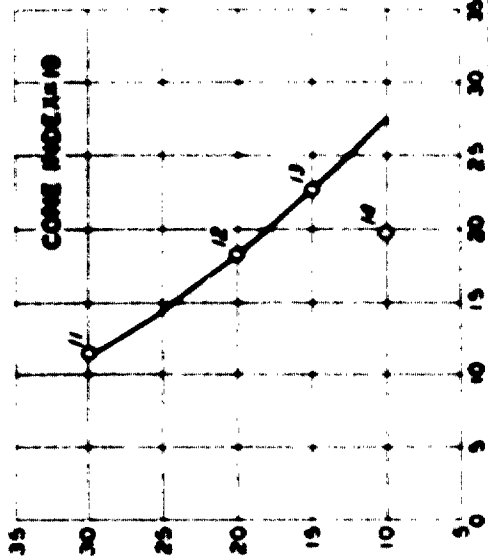


FIG 2 3/4-TON M37 4 X 4 TRUCK
TEST WEIGHT 7085 LB

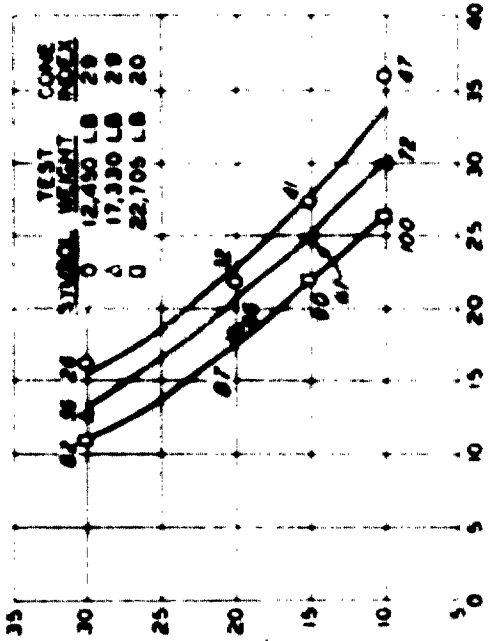


FIG 3 2 1/2-TON M135 6 X 6 TRUCK

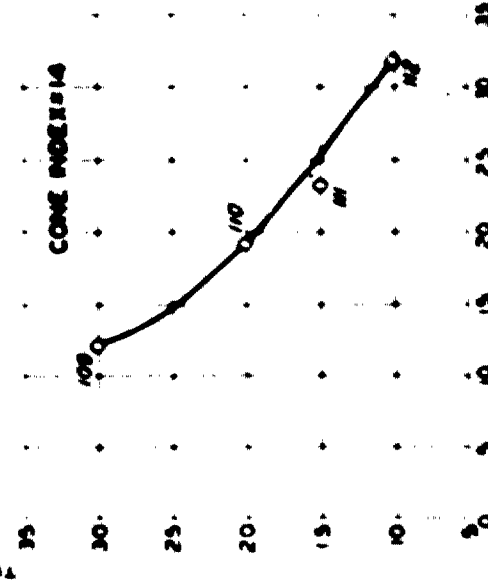


FIG 4 5-TON M41 6 X 6 TRUCK
TEST WEIGHT 28,175 LB

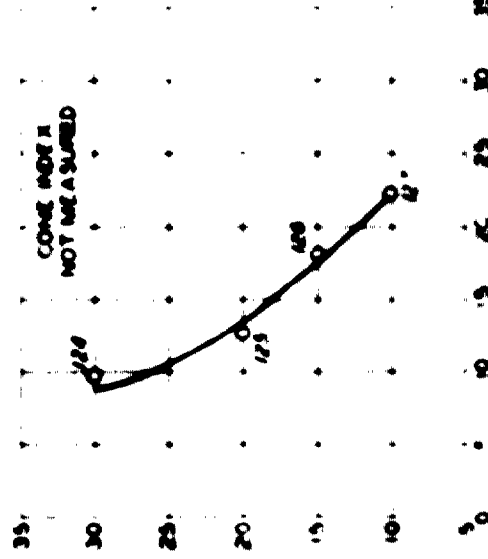


FIG 5 5-TON M54 6 X 6 TRUCK
TEST WEIGHT 30,635 LB

NOTE NUMBERS NEAR PLOTTED POINTS REFER TO ITEMS IN TABLE 8

VEHICLE PERFORMANCE
TOWING TESTS WITH
SELF-PROPELLED WHEELED VEHICLES
HARROWED SAND
MAXIMUM DRAWBAR PULL
VS TIRE PRESSURE

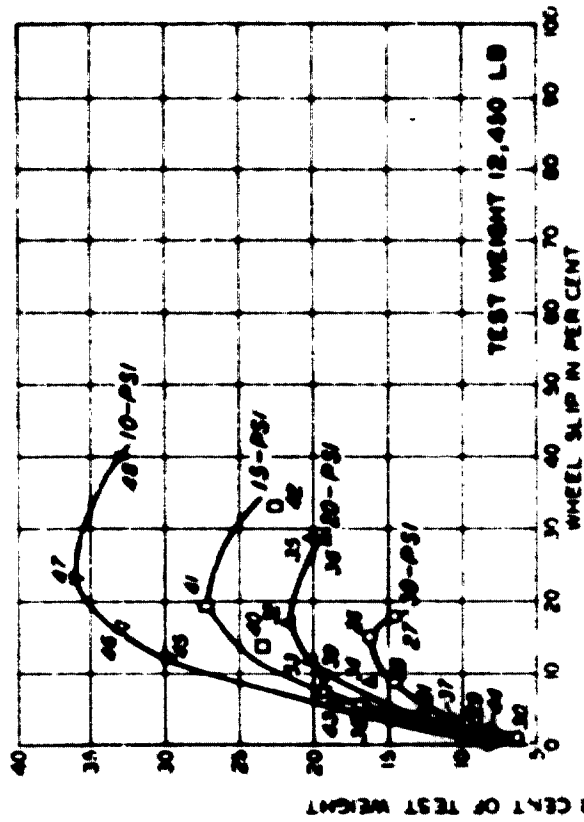


FIG. 1. 2 1/2-TON M135 6 X 6 TRUCK

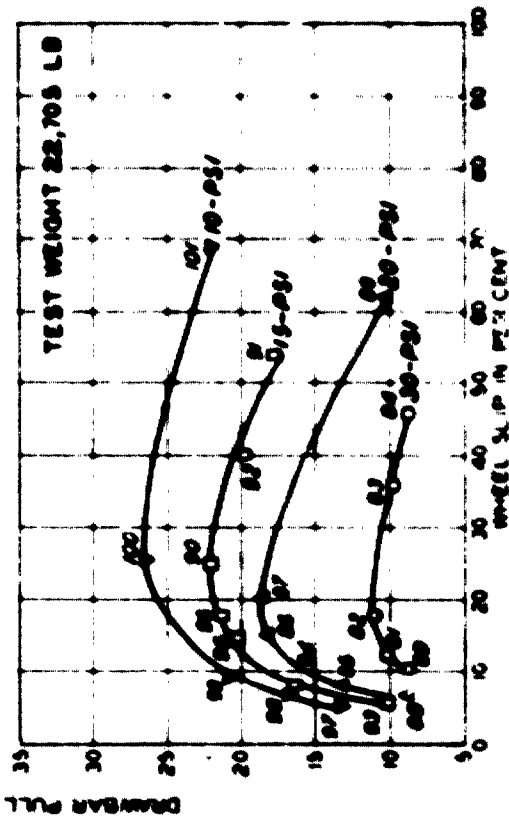


FIG. 3. 2 1/2-TON M135 6 X 6 TRUCK

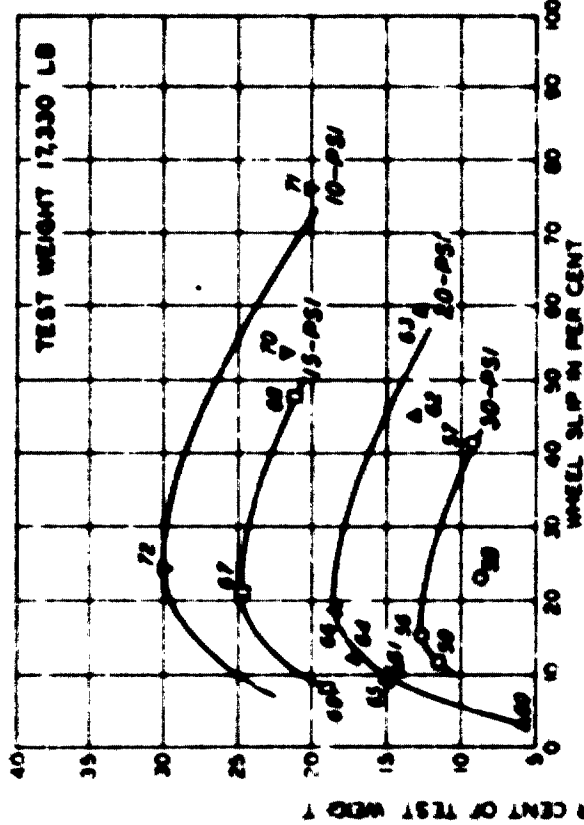


FIG. 2. 2 1/2-TON M135 6 X 6 TRUCK

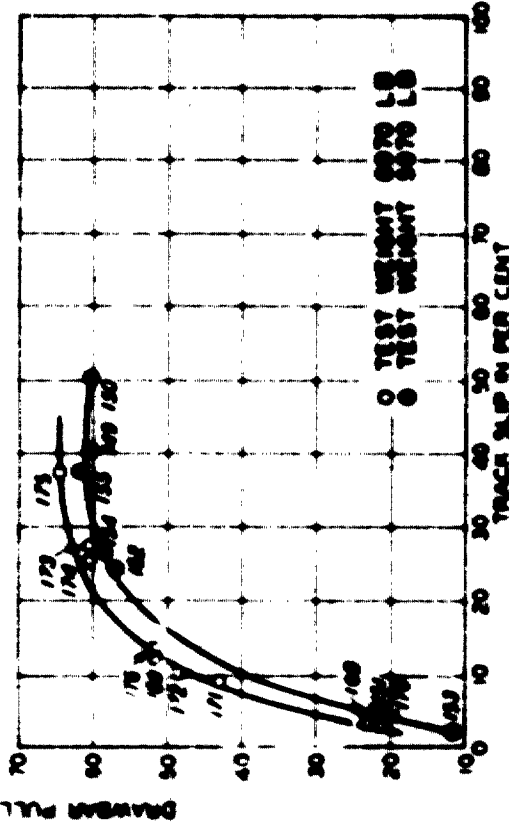


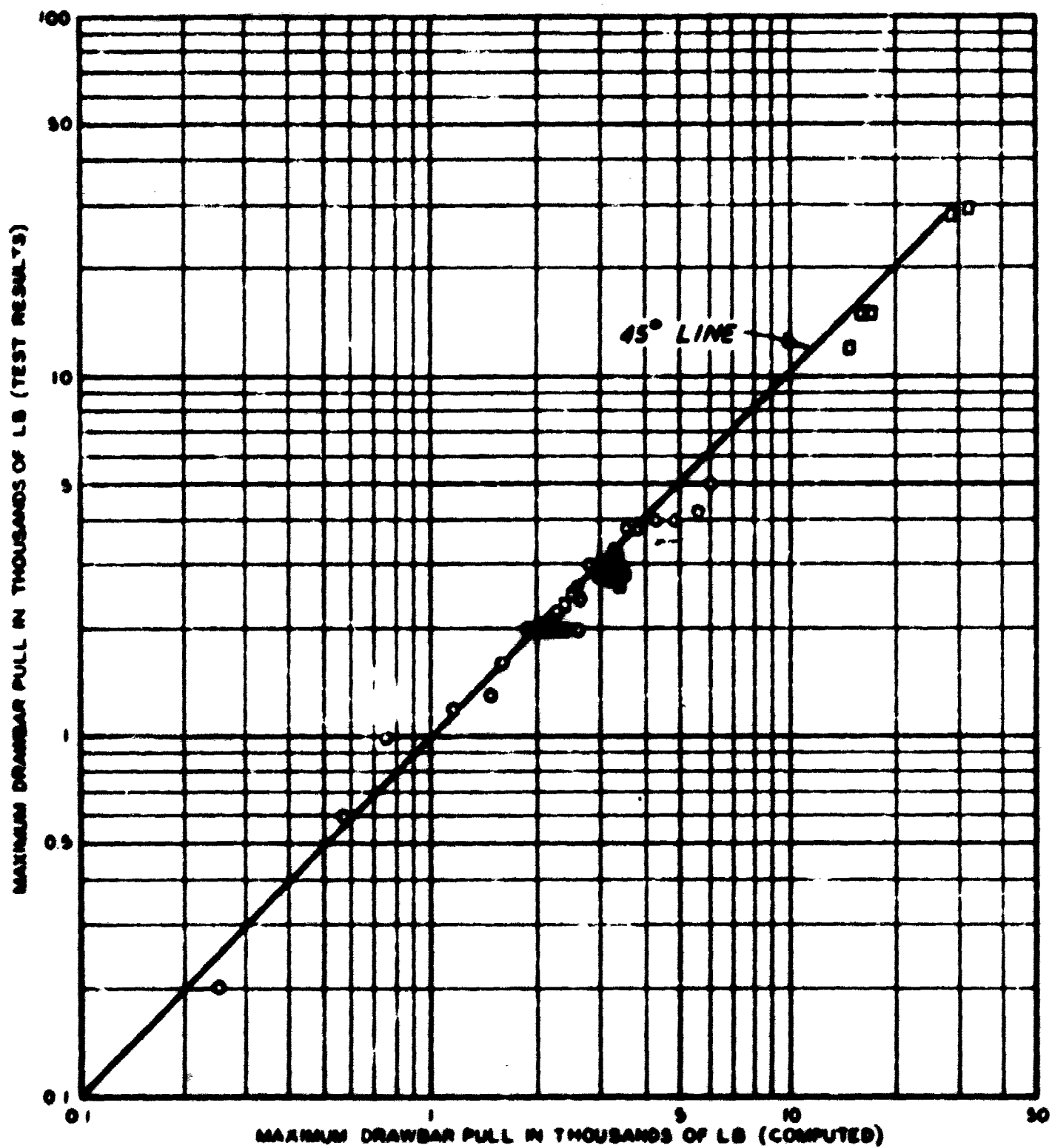
FIG. 4. 1-TON M28C WEASEL

LEGEND

SYMBOL	TEST PRESSURE
○	10 PSI
△	15 PSI
□	20 PSI
×	25 PSI
•	30 PSI

NOTE: REFER TO TABLE 6 FOR SUPPLEMENTARY DATA.
NUMBERS NEAR PLOTTED POINTS REFER TO ITEM NUMBERS.

VEHICLE PERFORMANCE TOWING TESTS WITH SELF-PROPELLED VEHICLES NARROWED SAND DRAWBAR PULL VS SLIP

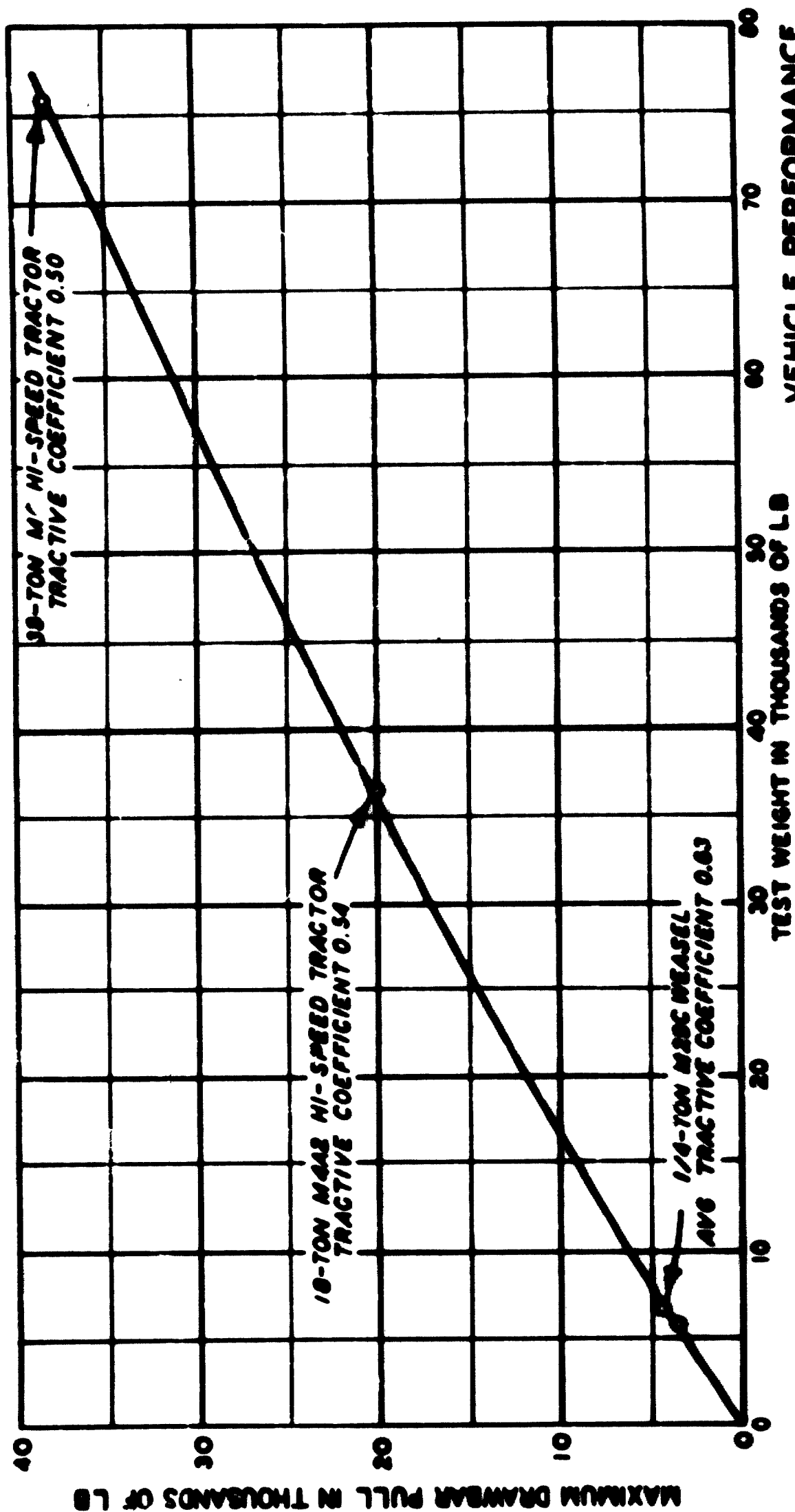


LEGEND

- WHEELED VEHICLES
- TRACKED VEHICLES

NOTE REFER TO TABLE 8 AND
TOWING TEST SECTION IN
TEXT FOR SUPPLEMENTARY
DATA.

**TEST RESULTS
VS COMPUTED MAXIMUM
DRAWBAR PULLS
WHEELED AND TRACKED
VEHICLES
HARROWED SAND**



NOTE: REFER TO TABLE 8 FOR
SUPPLEMENTARY DATA.

VEHICLE PERFORMANCE TOWING TESTS WITH SELF-PROPELLED TRACKED VEHICLES

HARROWED SAND
MAXIMUM DRAWBAR PULL
VS TEST WEIGHT

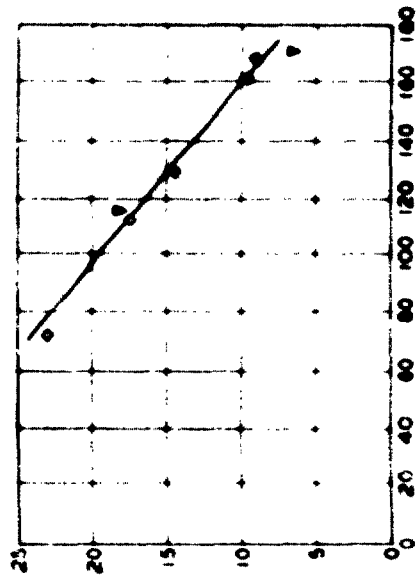


FIG. 1 60-PSI TIRE PRESSURE

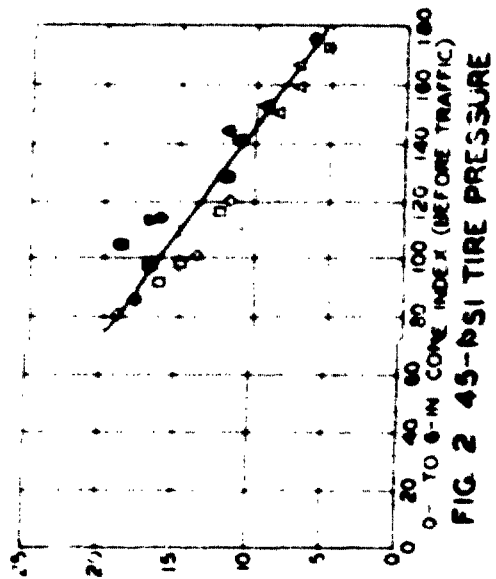


FIG. 2 45-PSI TIRE PRESSURE

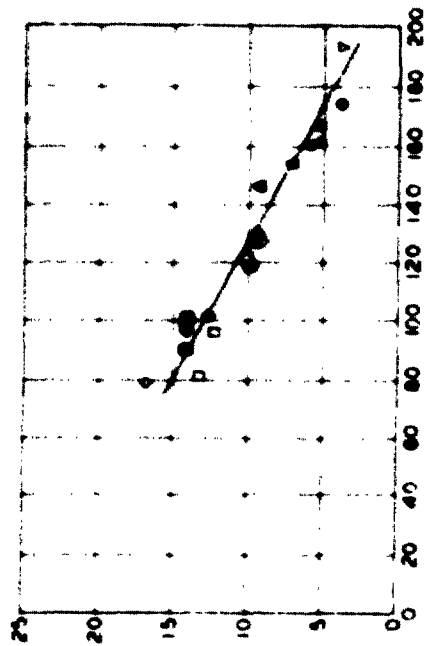


FIG. 3 30-PSI TIRE PRESSURE

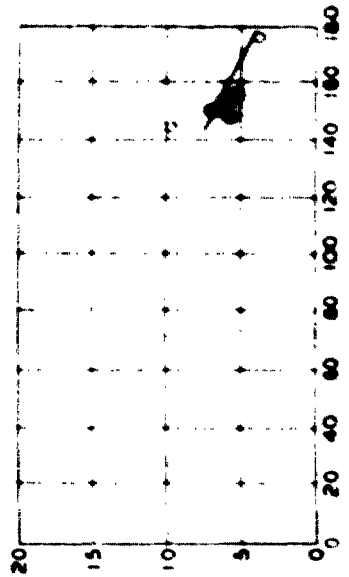


FIG. 4 25-PSI TIRE PRESSURE

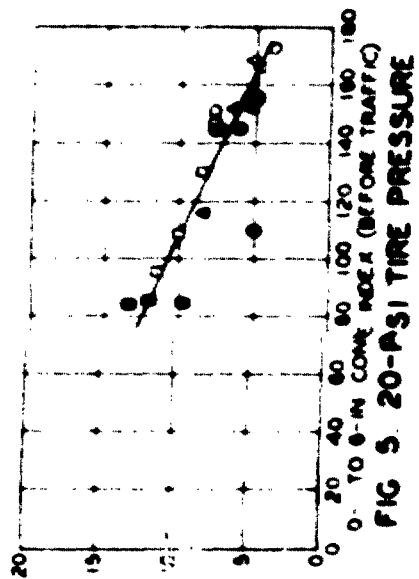


FIG. 5 20-PSI TIRE PRESSURE

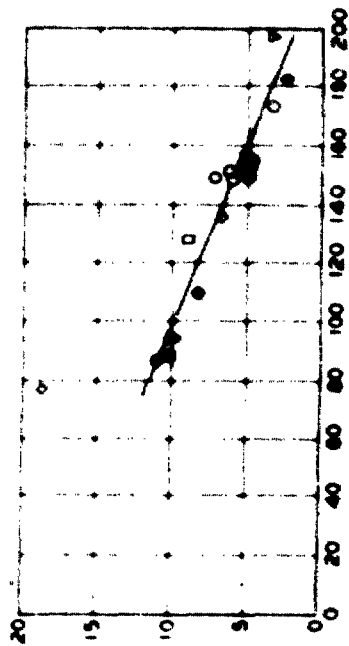


FIG. 6 15-PSI TIRE PRESSURE

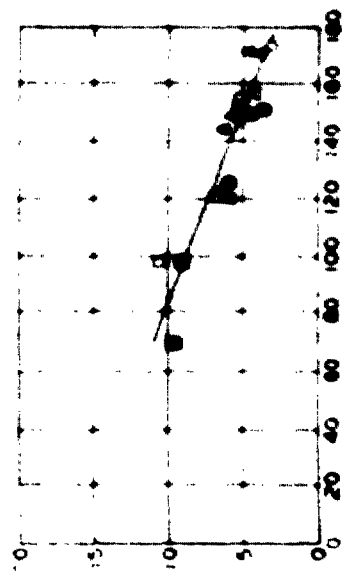


FIG. 7 10-PSI TIRE PRESSURE

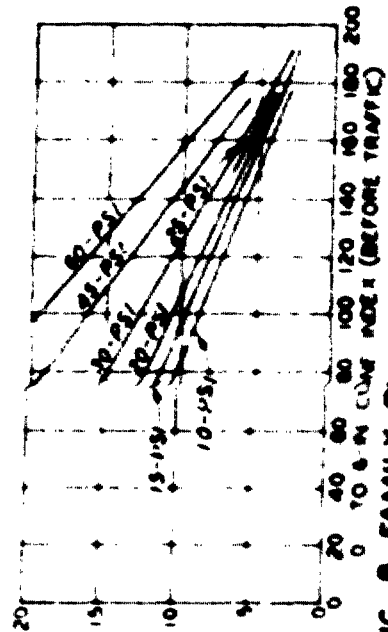


FIG. 8 FAMILY OF TIRE PRESSURE CURVES

LEGEND

SYMBOL	VEHICLE	SYMBOL	VEHICLE
○	1-TON M100 TRAILER	▽	375 KW GEN TRAILER
△	2-TON M100 TRAILER	●	8-TON TRAILER
□	1 1/2-TON M100 TRAILER		

NOTE: OPEN SYMBOLS DENOTE UNDISTURBED SAND TESTS
CLOSED SYMBOLS DENOTE DISTURBED SAND TESTS
FOR SUPPLEMENTARY DATA REFER TO TABLE 9

VEHICLE PERFORMANCE TOWED WHEELED VEHICLE TESTS TOWING FORCE REQUIREMENTS VS CONE INDEX