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CORPS OF ENGINEERS, U. S. ARMY

TRAFFICABILITY OF SOILS

A SUMMARY OF TRAFFICABILITY STUDIES THROUGH 1955

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FOURTEENTH SUPPLEMENT

A
CORPS OF ENGINEERS
RESEARCH AND DEVELOPMENT REPORT

PREPARED BY THE

WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

DECEMBER 1956

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ARMY-MRC VICKSBURG, MISS.

DECEMBER 1956

This report supersedes TB 5-550-1, Soils Trafficability,
dated 20 August 1951

PREFACE

This report presents a summary of trafficability studies conducted by the Waterways Experiment Station through calendar year 1955. These studies were a part of Corps of Engineers Subproject 8-70-05-101, "Trafficability of Soils as Related to the Mobility of Military Vehicles," under Project 8-70-05-100, "Mobility of the Army." The subproject is divided into the following three phases:

Phase I, soils classification and trafficability data, includes the development of techniques and the necessary equipment for the determination of ground conditions by reconnaissance parties, and a graphic means of presentation of soil conditions to field commanders showing the relationship between vehicle mobility, soil type, soil condition, and slope.

Phase II, soils trafficability predictions, includes the development of methods to correlate soil trafficability with weather data or with aerial photographs that will be sufficiently accurate to enable military planners to predict the trafficability of soils in areas without physical tests.

Phase III, crossing areas of mud, sand, or other unstable terrain, includes the development of portable roadways and construction of roadways from local and other materials for crossing sand areas, canals, dikes, streams, and areas subject to inundation.

Investigation of the first two phases has been assigned to the Waterways Experiment Station; phase I is the principal subject of this report.

Authority for this report is contained in the Plan of Tests, Trafficability Studies, Fiscal Year 1954, approved by the Office, Chief of Engineers.

The studies and field tests which form the background of this report were conducted by the Trafficability of Soils Section of the Flexible Pavement Branch, Soils Division, Waterways Experiment Station. Acknowledgment is made to the Engineer Research and Development Laboratories which was the development agency for the project until December

1950, particularly to Messrs. G. B. Schoolcraft and P. W. Woodring for their advice and planning. Messrs. R. R. Philippe, R. F. Jackson, J. W. Moss, A. R. Smith, and R. L. Tolbert and other personnel of the Engineer Research and Development Division of the Office, Chief of Engineers, furnished guidance and assistance, particularly in the various conferences held during the program. Consultants who provided valuable assistance in planning the trafficability studies reported herein included Dr. Arthur Casagrande, Dr. Donald Taylor, Professor K. B. Woods, Dr. A. A. Warlam, Mr. Robert Horonjeff, and Mr. M. P. Harrington. Personnel of the Ordnance Department, the Yuma Test Branch, Fort Churchill (Canada), Fort Knox, Fort Benning, and various other military establishments contributed equipment, services, and facilities for the field tests.

Engineers of the Waterways Experiment Station actively connected with the tests and studies under phase I were Messrs. W. J. Turnbull, W. K. Boyd, C. R. Foster, O. B. Ray, S. J. Knight, R. G. Ahlvin, A. A. Rula, and D. R. Freitag. This report was written by Mr. Knight.

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SUMMARY

The trafficability factors, bearing and traction capacity, are a function of shearing strength. The cone penetrometer, a simple hand-operated probe-type instrument, measures an index of shear strength. Cone indexes on fine-grained soils and sands with fines, poorly drained, are related to the performance of military vehicles, but an auxiliary test, the remolding test, must accompany the cone penetrometer test to predict the change in cone index that will occur under traffic. The remolding test is slightly different for fine-grained soils and sands with fines, poorly drained. Slipperiness and stickiness effects on vehicle performance cannot be measured accurately, but can be anticipated approximately from simple tests on the soil. Tests with a few wheeled vehicles on sands show a fair degree of correlation between maximum slope and cone index when tire pressure is given due consideration. A scheme for classifying soils from the trafficability standpoint is developed, a means of computing cone index required for any military vehicle is evolved, and charts are presented to enable a quick estimate of maximum slopes vehicles can climb, maximum loads they can tow, and towing forces required, on a range of soil strengths.

Rules are presented for making actual trafficability measurements for tactical purposes. Examples are given. A method for mapping trafficability for tactical purposes is given. Procedures for estimating trafficability without contact with the soil are briefly indicated. A method for mapping trafficability for strategic purposes is given.

TRAFFICABILITY OF SOILS

A SUMMARY OF TRAFFICABILITY STUDIES THROUGH 1955

PART I: INTRODUCTION

Purpose and Scope of Report

1. The purpose of this report is to summarize the accomplishments to date under phase I, Soil Classification and Trafficability Data, of Subproject 8-70-05-001, "Trafficability of Soils as Related to the Mobility of Military Vehicles," in a form that will be particularly suitable for use by military intelligence and reconnaissance personnel or personnel engaged in vehicle-soil studies in determining soils trafficability by direct measurements. Broad results of initial phase II studies, Soils Trafficability Predictions, are also presented. This work involved principally fine-grained soils, although considerable work has also been done on coarse-grained soils. Tests on fine-grained soils are considered essentially complete, but additional test data are needed on coarse-grained soils.

2. This report includes a review and summary of the phase I studies and tests reported in Trafficability of Soils, published 1 September 1945, and of Technical Memorandum 3-240, and the first thirteen supplements thereto published between November 1947 and the date of this report. Subjects of this technical memorandum series are listed below in the order in which the studies were conducted.

a.	Analysis of Existing Data	5th Supplement, May 1949
b.	Development of Testing Instruments	3d Supplement, Oct 1948
c.	Laboratory Tests To Determine Effects of Moisture Content and Density Variations	1st Supplement, Mar 1948
d.	Pilot Tests--Self-propelled Vehicles	--- Nov 1947
e.	Trafficability Studies--Fort Churchill, Summer 1947	2d Supplement, Aug 1948

f.	Tests on Self-propelled Vehicles, Yuma, Arizona, 1947	4th Supplement, Apr 1949
g.	Tests on Self-propelled Vehicles, Vicksburg, Mississippi, 1947	6th Supplement, Sept 1949
h.	Tests on Towed Vehicles, 1947-48	7th Supplement, June 1950
i.	Vehicle Classification	9th Supplement, May 1951
j.	Slope Studies	8th Supplement, May 1951
k.	Tests on Natural Soils with Self-propelled Vehicles, 1949-1950	10th Supplement, Jan 1954
l.	Soil Classification	11th Supplement, Aug 1954
m.	Tests on Natural Soils with Self-propelled Vehicles, 1951-1953	12th Supplement, Nov 1954
n.	Pilot Study, Tests on Coarse-grained Soils	13th Supplement, Nov 1955

Definitions

3. Certain terms used in connection with the trafficability investigations are defined below.

Soil terms

Trafficability. The capacity of a soil to withstand 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 between the soil and the tread or track of the vehicle to furnish the necessary forward thrust.

Stickiness. The ability of a soil to adhere to vehicles, wheels, and tracks.

Slipperiness. The condition which results in a decrease in traction capacity caused by lubrication of the soil surface by water or very soft mud.

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

Coarse-grained soil. A soil of which more than 50 per cent 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). The effect of internal friction exerts a great influence on the trafficability. The sands tested in this program contained 7 per cent or less of material passing the No. 200 sieve, and little or no gravel (greater than 4.76 mm). These soils usually have good internal drainage.

Sand with fines, poorly drained. A sand in which water content greatly influences the trafficability characteristics. These soils react to traffic in a manner similar to fine-grained soils. Although it is not expected that laboratory tests can fully define the characteristics of plastic sands, it will be noted that those tested in this study contained 7 per cent or more of material passing the No. 200 sieve, and little or no gravel. Actually the gradation of the soil is pertinent only insofar as it tends to restrict the internal drainage.

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

Remolding index. A ratio which expresses the change of strength that may occur under the traffic of a vehicle. The instruments and test procedures for determining the remolding index for soil are described under remolding test, page 7.

Rating cone index. The product of the measured cone index and the remolding index for the same layer of soil.

Critical layer. The layer of soil which is regarded as being most pertinent to establishing relationship between soil strength and vehicle performance. This is usually the 6- to 12-in. layer but may vary with weight of vehicle and soil strength profile.

Liquid limit. The moisture content at which soil, placed in a standard laboratory cup and grooved with a standard tool, will flow together when jarred 25 times by raising the cup a prescribed distance and letting it fall. The liquid limit is generally conceded to represent the moisture content at which the characteristics of a mixture of soil and water change from plastic to liquid.

Plastic limit. The moisture content at which crumbling occurs when a thread of soil is rolled to a diameter of 1/8 in. The plastic limit is generally conceded to represent the moisture content at which a mixture of soil and water begins to take on plastic properties (i.e., undergoes appreciable deformation with little volume change).

Plasticity index. The numerical difference between the liquid and plastic limits. The numerical value of the plasticity index is generally a good indication of the plasticity or clayeyness of a soil; highly plastic clays generally have high plasticity indexes, less plastic clays have lower plasticity indexes.

Plastic range. In certain applications it is more convenient to speak of the difference between the liquid and plastic limits as the plastic range rather than plasticity index. This is particularly true where moisture contents are designated with respect to the liquid and plastic limits. A moisture content midway between the liquid and plastic limit is 50 per cent in the plastic range. The formula for determining the per cent in the plastic range is:

$$\frac{\text{Moisture content - plastic limit}}{\text{Liquid limit - plastic limit}} \times 100 \text{ .}$$

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

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

Per cent saturation. The percentage ratio of the volume of water in the soil voids to the volume of the voids. The per cent saturation can be computed from the moisture content, the dry unit weight of the sample, and the absolute specific gravity of the soil particles with the following formula:

$$\frac{\text{Moisture content* x density}}{(\text{Specific gravity x 62.3}) - \text{density}} \text{ x specific gravity x 100 .}$$

Terms for test media

Prepared lanes. For trafficability studies prepared lanes were made by excavating soil in a strip 100 ft long by 26 ft wide to a depth of approximately 4 ft. This soil was processed and then replaced in layers under controlled moisture conditions.

Natural ground. A measured course on natural undisturbed soil.

Vehicle terms

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

Immobilization. For self-propelled vehicles, failure to complete a substantial number of passes (50) across a test course. For trailers, sinkage to the extent that the axle or undercarriage dragged prior to completing a substantial number of passes (25).

Towed load. A constant load applied at the drawbar of a tractor being tested.

Towing force. The force required to move a towed load at a constant rate of speed.

Vehicle cone index. The minimum cone index that will permit the vehicle to complete 50 passes.

Mobility index. A dimensionless number which results from a consideration of certain vehicle characteristics (see paragraph 126 for formulas).

Instrument and equipment terms

Cone penetrometer. A field instrument consisting of a 30-degree cone with 1/2-sq-in. base area mounted on one end of a 36-in. shaft, and a proving ring with dial gage and handle mounted on the other. The force required to move the cone slowly through a plane of a given material is indicated on the dial inside the proving ring. This force is considered to be an index of the shearing resistance of the penetrated material and is called the cone index of the material in that plane. A capacity load of 150 lb deflects the ring 0.1 in. and gives a cone index reading of 300.

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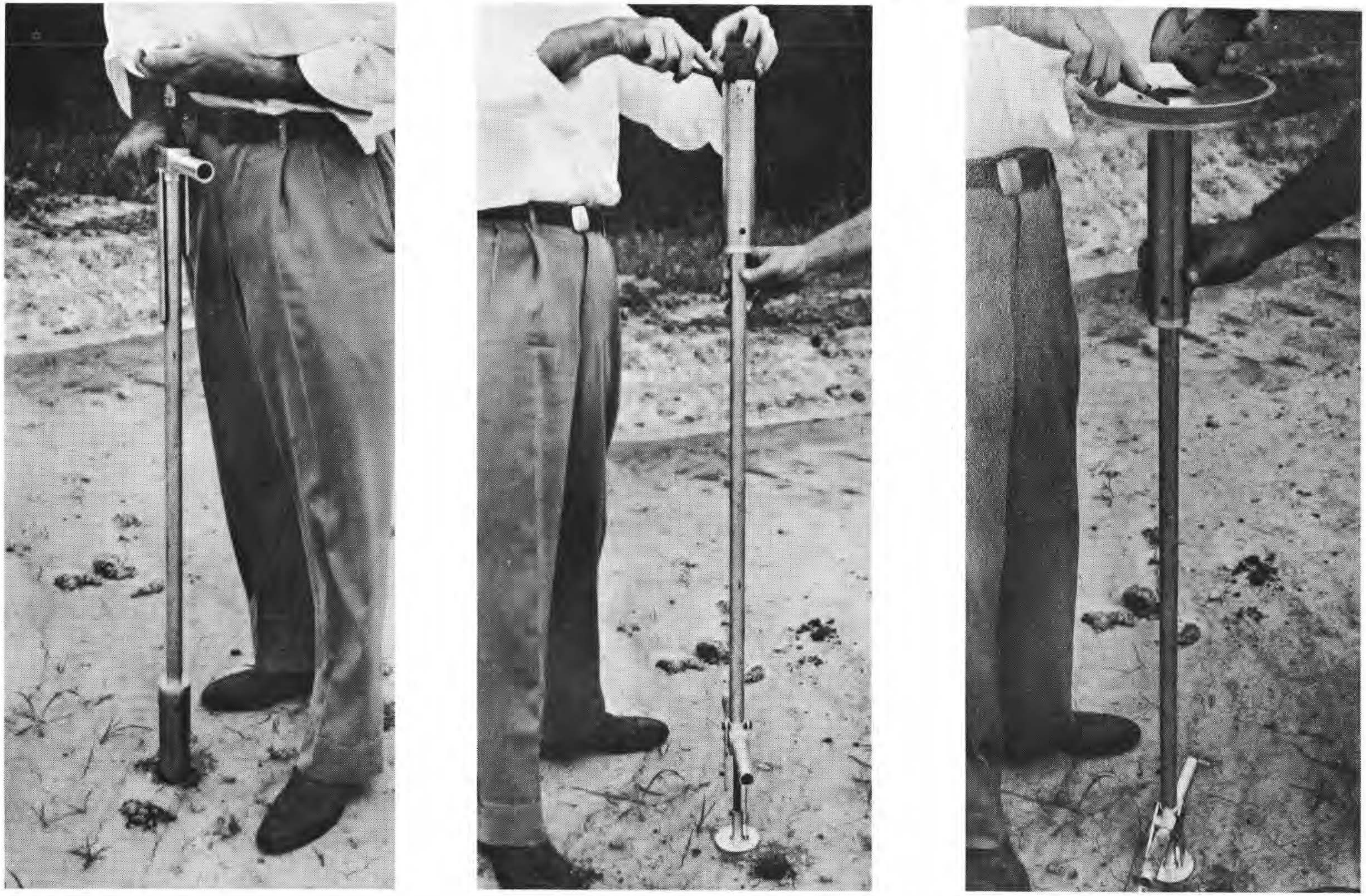
* As ratio and not as percentage.



Forcing tube into soil — Trimming off waste — Cutting off sample

Fig. 1. Steps in use of trafficability hand sampler

Trafficability sampler. A piston-type soil sampler for securing soft soil samples. Spacer bars permit cutting of the sample to such a length that the wet density of the soil in pounds per cubic foot may be obtained by multiplying the weight of the sample in grams by 0.4. A trafficability sampler in use is shown on fig. 1.

Remolding equipment. A cylinder of the same diameter as the trafficability sampler cylinder mounted vertically on a base, and a 2-1/2-lb drop hammer which travels 12 in. on an 18-in. section of a cone penetrometer staff fitted with a circular foot. A cone penetrometer equipped with a 1/2-sq-in. base area cone, and a trafficability sampler are needed to conduct tests. This equipment is shown on fig. 2. A trafficability sampler is used with the remolding equipment.

100-blow remolding test. The remolding test is conducted in the following manner: A sample is taken with the trafficability sampler loaded into the remolding cylinder, and pushed to the bottom with the drop-hammer foot. Cone indexes are measured at the surface and at 1-in.

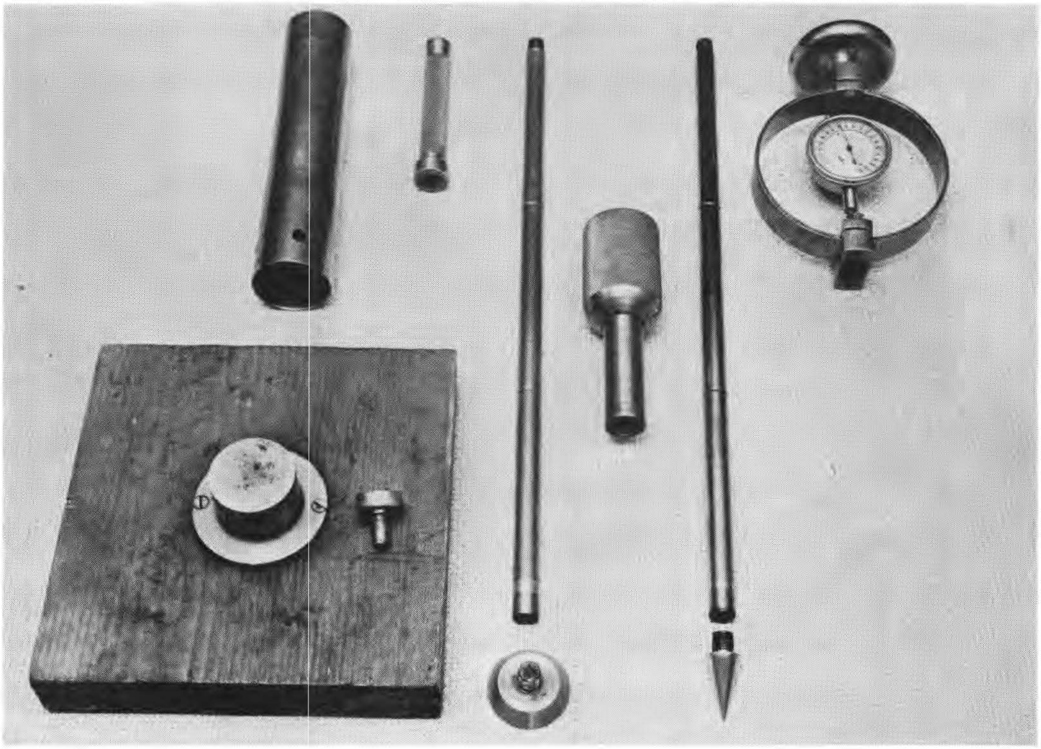


Fig. 2. Remolding equipment

intervals to a depth of 4 in. Next, 100 blows of the hammer are applied and cone indexes are remeasured in the remolded soil. The sum of the five cone index readings made after remolding (a value of 300 is assigned to each depth not measured because of inability to penetrate firm samples) divided by the sum of five readings made before remolding is termed remolding index.

Vibrated remolding test. This remolding test is conducted in the same manner as the 100-blow test, with two exceptions. The cone index measurements are made with the 0.2-sq-in. cone instead of the 0.5-sq-in. cone and the sample is remolded by dropping the remolding cylinder and base with the sample inside 25 times from a height of 6 in.

Dynamometer. An instrument used to measure drawbar pull.

History of Trafficability Test Program

Initial study

4. The Waterways Experiment Station was introduced to the problem of trafficability in the spring of 1945 when it was requested by the Engineer Board (now the Engineer Research and Development Laboratories) to assist in developing a means for measuring the trafficability of soils so that the performance of military vehicles could be predicted for off-road conditions. The investigation was prompted by reverses suffered by our Armed Forces because of immobilized vehicles in the various battlefields of World War II and stimulated by plans for an overland invasion of Japan. The investigation was ordered by the General Staff, U. S. Army, and was assigned to the Office, Chief of Engineers, for prosecution.

5. The Waterways Experiment Station began a program of testing at Vicksburg, Mississippi, immediately upon assignment of the problem, making every effort to complete the work and the report on it before the deadline, 1 September 1945. In a hastily written report, the Waterways Experiment Station acknowledged that only a limited number of vehicles and soil conditions could be tested in the time allotted, and that the data could not be thoroughly and completely analyzed. It recognized that a thorough investigation would require a long-range study and

recommended that a deliberate program be planned. The Engineer Research and Development Laboratories and the Office, Chief of Engineers, concurred in the recommendation, and a project (MRS 597) was approved in December 1945. In July 1946 the scope of the project was enlarged and changed to a development status. A formal notice of approval of the development project and the plan of development were received in September 1946.

Current program

6. The first step in the deliberate program to study the trafficability of soils was an examination of the available data and reports on the subject of trafficability. This was begun in early 1946. It was found that, although a considerable amount of information had been published concerning roadway expedients and the improvement of vehicle design, little information was available as to basic soil-vehicle performance relationships (Technical Memorandum 3-240, 5th Supplement).

7. Laboratory tests on a range of soils were conducted early in the program. These tests emphasized the effects of moisture content and density variations on soil strength and indicated the feasibility of using the cone penetrometer to obtain an index of soil strength (Technical Memorandum 3-240, 1st Supplement).

8. Development of instrumentation also began early in the trafficability program. By the end of 1946, the cone penetrometer, sampler, dynamometer, and other instruments needed for the efficient conduct of tests had been developed to a satisfactory stage (Technical Memorandum 3-240, 3d Supplement).

9. Pilot tests were conducted before beginning an extensive program of field testing aimed at classifying vehicles and soils and establishing practicable soil-vehicle mobility relationships. These tests were conducted in 1946 on two soils in prepared lanes near Vicksburg, and satisfactorily accomplished their purpose, which was to establish efficient test techniques and perfect the instrumentation for more extensive tests to follow (Technical Memorandum 3-240).

10. Full-scale tests with thirteen self-propelled vehicles, selected with the cooperation of the Ordnance Department, were conducted at the Yuma Test Branch, Yuma, Arizona, during the first five months of

1947. Three soils, a coarse sand, a very fine sand, and a soil with a plasticity index of approximately 9, were tested in prepared lanes (Technical Memorandum 3-240, 4th Supplement).

11. The same vehicles mentioned in paragraph 10 were used during the summer of 1947 in tests on prepared lanes of fat clay and lean clay at the Mound site and Rifle Range site, respectively, near Vicksburg (Technical Memorandum 3-240, 6th Supplement).

12. Following these tests, pilot tests were run in the prepared lanes at the Rifle Range site with towed vehicles selected by the Ordnance Department.

13. During the summer of 1947 a limited test program also was conducted in the muskeg areas near Fort Churchill, Canada. This work showed that penetrometer readings in muskeg did not indicate its ability to support traffic. However, readings in the underlying soil were indicative of the soil's trafficability, and thickness of the muskeg, which could be measured with the penetrometer, could, together with cone index of the underlying soil, provide a reasonable basis for the prediction of vehicle performance.

14. Full-scale tests with towed vehicles were conducted on the three prepared soils at the Yuma Test Branch in January and February 1948, and on the two soils near Vicksburg in the summer of 1948. Results of these tests and the earlier pilot tests (paragraph 12) are published in Technical Memorandum 3-240, 7th Supplement.

15. Analysis of the data collected in the tests with self-propelled and towed vehicles on the five prepared soils showed that consistent relationships existed between cone index requirements and vehicle performances. Tests in prepared soils were considered complete. The next step indicated was to test the vehicles in natural soil conditions to determine whether the criteria established by tests on prepared lanes also were valid for natural conditions.

16. Tests were conducted on undisturbed soils in the immediate vicinity of the prepared lanes at Mound and Rifle Range during the early spring of 1949. The former soil exhibited practically the same trafficability characteristics as it had in the artificial state, but the

silty material at the Rifle Range site showed marked differences. Vehicles which had operated on an initial cone index of 50 in prepared lanes of Rifle Range soil became immobilized on an initial cone index of 80 or greater in the natural state of the same soil. Similar results were obtained in tests in another silty soil, at Durden Creek test site on the Waterways Experiment Station reservation. The reason for this apparent discrepancy was soon found to be the change in soil strength that occurred under traffic. The cone index criteria established in tests in prepared lanes were shown to be valid for natural soils provided the cone indexes of the remolded soil were used.

17. Following the recognition of the importance of remolding phenomena, efforts were directed toward producing a simple test that would predict the quantitative changes in strength of soils under traffic. At the end of the test program in the spring of 1949, a satisfactory remolding test was considered to have been developed.

18. A program of tests was conducted during the following wet season, February-April 1950, using a typical tracked and a typical wheeled vehicle in several natural soils in the vicinity of Laurel, Mississippi, and Fort Knox, Kentucky. The remolding test techniques were standardized and correlations between vehicle performance and the cone index of the remolded soil were confirmed. The results of all tests on natural fine-grained soil conditions to this point are contained in Technical Memorandum 3-240, 10th and 12th Supplements.

19. Tests with self-propelled vehicles were conducted at Fort Knox, Kentucky, during March and April of 1950 to supplement slope-climb data that had been collected at various times and places during the trafficability program (Technical Memorandum 3-240, 8th Supplement).

20. A few tests with self-propelled vehicles were conducted in the spring of 1951 on soils susceptible to greater freezing-and-thawing phenomena than had been tested previously. These soils, in Indiana and New Hampshire, reacted similarly to the other soils tested insofar as ability to measure trafficability characteristics was concerned. Results of these tests are contained in Technical Memorandum 3-240, 12th Supplement.

21. Tests to verify criteria for performance of vehicles on slopes, developed in previous tests, were conducted on slopes at Fort Benning, Georgia, Camp Gordon, Georgia, Fort Jackson, South Carolina, and Fort Bragg, North Carolina, during the spring of 1951. Results of these tests confirmed the findings reported in Technical Memorandum 3-240, 8th Supplement.

22. Soils in various sections of the United States were examined during the spring of 1951 to determine their average cone indexes and remolding characteristics during the wet season. Many of the soils tested were suggested by Dr. Arthur Casagrande of Harvard University and Prof. K. B. Woods of Purdue University as probably troublesome from the trafficability standpoint. Similar soil data also were collected in the spring of 1953. The data collected are used in the scheme for classifying soils from the trafficability standpoint published in Technical Memorandum 3-240, 11th Supplement.

23. Some vehicles not previously tested were tested at Fort Knox in 1952, and at Fort Benning and Fort Knox in 1953. These tests are reported in Technical Memorandum 3-240, 12th Supplement. The principal purpose of these tests was to verify formulas for determining the cone index required for military vehicles. These formulas were developed from data collected in the tests in prepared lanes. This work is described in Technical Memorandum 3-240, 9th Supplement.

24. In October 1953, a joint Army-Navy agreement 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 series of these tests was accomplished in 1954 and is reported in Technical Memorandum 3-240, 13th Supplement. Work on beaches will continue. A part of the funds needed for this work is being provided by the Bureau of Yards and Docks, U. S. Navy.

Present Status of Phase I

25. The development work under phase I is considered substantially complete for fine-grained soils, but additional studies of coarse-grained

soils are necessary and are presently programmed.

Fine-grained soils

26. The following paragraphs outline the status of phase I work as it pertains to fine-grained soils. Soil types, instrumentation, vehicle classification, soil classification, and graphic means of presenting vehicle-soil-slope relationships are discussed.

27. Soil types. Up to the present time, all fine-grained soils tested respond in the same way to the techniques of measurement and prediction of vehicle performance described in this report.

28. Instrumentation. Two tests, one to measure existing soil strength and one to obtain an estimate of the soil strength that will develop under traffic, have been devised. The cone penetrometer and remolding equipment are used for these tests, respectively.

29. The cone penetrometer is considered technically adequate in its present form. For troop use, it can readily be made lighter, modified for use at night, and fitted with a carrying case.

30. The remolding equipment is technically satisfactory, but it is heavy, bulky, and the test is noisy. These are undesirable characteristics from the military standpoint and improvements are being considered.

31. Vehicle classification. Formulas have been developed which permit the computation of the soil strength requirements, in terms of cone index, for all military vehicles in existence today. Numerous field checks have thus far verified these formulas.

32. Soil classification. A scheme for classifying soils from the standpoint of their trafficability has been developed. The scheme permits a relative evaluation of soils according to their types under the Unified Soil Classification System and also furnishes numerical estimates of soil strength, in terms of cone index, by type.

33. Graphic means of presenting vehicle-soil-slope relationships. Charts and formulas have been developed that permit the rapid determination of the performance of vehicles with or without tow loads on level and sloping terrain. Two systems for mapping the trafficability characteristics of soils, one for tactical use, the other for strategic use, have been developed.

Coarse-grained soils

34. The following paragraphs outline the status of phase I work as it pertains to coarse-grained soils. Soil types, instrumentation, vehicle classification, and graphic means of presentation of vehicle-soil-slope relationships are discussed.

35. Soil types. To date only quartz sands on beaches and inland areas have been tested. Further testing is planned for gravelly materials and coral, volcanic, and other types of sand. The quartz sands tested so far appear to be of two types, requiring separate techniques for determination of their trafficability: sands with fines, poorly drained, and sands. The two sand types behave differently under traffic. At the present time, it is not known whether they can be distinguished on the basis of their constituent sizes. It is possible that the same soil could behave one way at one water content and differently at another water content.

a. Sand with fines, poorly drained. A sand which usually contains 7 per cent or more (up to 50 per cent) material passing the No. 200 sieve and whose strength is materially reduced under traffic when it is nearly saturated with water is called a sand with fines, poorly drained. When this sand is dry, it behaves like common beach sand under a vehicle, but when wet it has a strong tendency to liquefy under a vehicle and thus behaves similarly to a very wet silt. Internal drainage characteristics of such a sand are poor.

b. Sand. The sands tested usually contained 7 per cent or less material passing the No. 200 sieve. Their strength was apparently almost wholly due to friction. Even when saturated, they did not lose appreciable strength under a moving vehicle. Internal drainage characteristics are good.

36. Instrumentation. The same cone penetrometer as used for fine-grained soils is also used to measure existing strength of sands with fines, poorly drained. A remolding test is used for sands with fines, poorly drained, but the equipment and technique vary somewhat. The remolding test (vibrated test) is described under "Definitions." The remolding index obtained with it is used exactly as it is for fine-grained soils. Only a comparatively few tests in sands with fines, poorly drained,

have been made thus far. Additional testing may reveal the desirability of further changes in instrumentation.

37. Up to the present time it has been found necessary to use only a measure of existing strength in sands since remolding effects have been found to be negligible. However, there is an indication that some sands, especially crusted sands whose crusts are broken by traffic, will require a remolding or compaction test to permit an estimate of the strength of the sands under traffic.

38. Vehicle classification. The same techniques of classifying vehicles in fine-grained soils appear to be adequate in sands with fines, poorly drained, but additional tests in such sands are needed before this can be fully accepted. A sufficient number of tests has not yet been made to permit a complete scheme for classifying vehicles in sands. It is known that tire pressure has a major effect on the performance of trucks in sands.

39. Soil classification. At the present time the classification of coarse-grained soils from the standpoint of trafficability is not refined beyond the recognition of the two types of sands. Additional testing is needed.

40. Graphic means of presenting vehicle-soil-slope relationships. At present the same means of presenting vehicle-soil-slope relationships used for fine-grained soils appear to be adequate for sands with fines, poorly drained. For sands and other coarse-grained materials, however, the effect of varying tire pressure must be included for wheeled vehicles in graphic presentations. Additional wheeled vehicles must be tested. Additional tests must be made on tracked vehicles before a means of graphic representation of their performance on sands and other coarse-grained materials can be developed. The details of a mapping system for coarse-grained soils depend on developments from further tests, but it is likely that a system similar to that now used for fine-grained soils can be applied to coarse-grained soils also.

Future Phase I Work

41. The principal work remaining to be done under phase I is to

continue the development of instruments for measuring the trafficability of coarse-grained soils (mainly beaches) and techniques for predicting the performance of vehicles on them. It is hoped that the instruments now used for fine-grained soils also will serve for coarse-grained soils, but some differences in the manner of their use and in techniques for predicting vehicle performance are expected. Other phase I work will involve continued study of trafficability characteristics of soils in all parts of the world, laboratory and field tests to refine the remolding test and equipment, and checking and analysis of any vehicle-soil data which may be forthcoming from the Armed Forces.

PART II: TRAFFICABILITY FACTORS AND THEIR MEASUREMENT

42. Trafficability in the broad sense is defined as the ability of terrain to permit the movement of vehicles. In this sense the factors that influence trafficability are numerous. They not only include the many variables which combine to determine the capacity of soils themselves to permit traffic but also include such natural deterrents to traffic as slopes, trees, boulders, and streams, and such man-made obstacles as dikes, ditches, hedgerows, and canals.

Factors Affecting Trafficability of Soils

43. The study conducted by the Waterways Experiment Station has been limited to the effects of soils themselves on the movement of military vehicles over level and sloping terrain. It has not treated the other factors which, in many cases, are equally important to vehicle movement. The factors which affect soil trafficability are bearing and traction capacity, slipperiness, and stickiness.

Bearing and traction capacity

44. The trafficability of a soil is considered adequate for a given vehicle primarily if the soil has sufficient bearing capacity to support the vehicle and sufficient traction capacity to develop the forward thrust necessary to overcome the rolling resistance. The actual problem, however, is not straightforward, since in many cases traffic will cause the bearing capacity and traction capacity to decrease at varying and unknown rates, while rolling resistance increases at other rates. When the rolling resistance is equal to the forward thrust, the vehicle becomes immobilized.

Slipperiness and stickiness

45. The movement of vehicles also is influenced by the soil properties, slipperiness and stickiness. Slipperiness is the condition wherein the traction capacity of a thin surface layer is so deficient that the wheels or tracks of the vehicles merely spin without giving the vehicle a forward motion. In the immobilization caused entirely by

slipperiness, sinkage of the vehicle is not deep. Immobilizations of this nature are infrequent, however, and usually are confined to chainless, rubber-tired vehicles. Stickiness is the ability of soils to cling to and build up on the running gear of vehicles, increasing rolling resistance and making steering more difficult. Stickiness was not found to be solely responsible for the immobilization of any military vehicle tested except the light M29C weasel, and this immobilization was attributed to design features of the vehicle rather than to the stickiness of the soil.

The Action of Vehicles in Soils

46. The soils tested to date may be divided into two general groups insofar as the action of vehicles in them is concerned. The first group consists of fine-grained soils and sands with fines, poorly drained. The second group comprises sands. Additional testing is planned using sands which act like fine-grained soils (sands with fines, poorly drained) and various types of coarse-grained soils (see paragraph 35). These tests may possibly result in slight modification to some of the following statements on the differences between the two soil groups.

Water content relationships

47. Fine-grained soils and sands with fines, poorly drained. These soils are troublesome only at comparatively high water contents. They are usually firm to hard when dry. A small increase in water content particularly in the soils with low plasticity indexes can cause these soils to become untrafficable.

48. Sands. Sands rarely cause immobilizations except at relatively low water contents. They are soft and loose when dry and tend to become firmer when wetted, up to a certain point. A poor condition can often be made much better by a small increase in water content.

Traffic effects

49. Fine-grained soils and sands with fines, poorly drained. Repetitive traffic on such soils when they are extremely wet will cause severe loss of strength by remolding, ruts will increase rapidly and

immobilization will occur when the vehicle drags its undercarriage. Many sands with fines, poorly drained, can be transformed from an apparently firm condition into a very loose, almost liquid one, by a few passes. When somewhat drier these soils may undergo slower changes in strength, slower rutting, and may therefore support many more passes of a vehicle before it finally becomes immobilized. When comparatively dry, little or no strength losses will occur (sometimes there may be strength gain), rutting will progress very slowly, and no immobilization will result.

50. Sands. Repetitive traffic usually causes a slight increase in the strength of the surface few inches of the rut in a dry sand. Generally the first pass in sands is the most difficult. The rut formed will usually be fairly deep (2 to 3 in.) on the first pass but will not increase significantly with additional passes. If one pass can be made, then repetitive passes also can be made, and with less difficulty. Sands, of course, can cause the immobilization of rubber-tired vehicles, particularly on slopes and at high tire pressures. When these immobilizations occur usually there is considerable clearance remaining between the vehicle and the sand surface. The wheels either spin freely or they alternately grip, then shear, the sand surface. Several tests were observed in which this jerking action reduced the forward speed of the vehicle to 40 or 50 ft per minute. However, even after such a labored first pass, a second pass could be made with ease. When moist, as on the foreshore of a beach a few feet from the water's edge, sands usually show a higher cone index with little rutting and no immobilizations even under repetitive traffic.

Effects of tire pressure

51. Fine-grained soils and sands with fines, poorly drained. A few tests were conducted on these sands in which a vehicle was operated at several tire pressures. These tests indicated that tire pressure variations within the range of normal operating pressures had little effect on vehicle mobility in these soils. This agrees with observations made in tests on fine-grained soils.

52. Sands. Tire pressure was an important factor in sands. A reduction in tire pressure resulted in marked improvement in vehicle

mobility. The performance gain at lower tire pressures for a particular vehicle was in proportion to the resulting increase in contact area.

Critical depth

53. Fine-grained soils and sands with fines, poorly drained. From the tests on fine-grained soils it was determined that the trafficability of a soil could usually be expressed in terms of the effective strength of the soil between 6 and 12 in. below the surface. The critical layer in tests on sands with fines, poorly drained, conformed to the same criteria as the fine-grained soils.

54. Sands. The differences in traffic behavior in these sands, particularly the generally shallow ruts, dictated a new standard for these soils. It was found that measurements made at depths greater than 6 in. were usually not related to the test results. Measurements at lesser depths proved to be most indicative of vehicle performance and the best correlations were found when the properties of the surface 6 in. were considered.

Measurement of Soil Trafficability Factors

55. The principal factors that affect the trafficability of a soil, bearing capacity and traction capacity, are primarily a function of strength or shearing resistance. Tests to determine shear strength have been used for many years in soils engineering work and at the beginning of the program consideration was given to the employment of one of the standard tests in an approach to measuring trafficability. The complete application, however, necessitated a knowledge of the stresses induced in soils under moving vehicles. Since this knowledge was meager and adequate data probably could not be obtained without an expensive, long-term study, decision was made to adopt an empirical approach to the study of the trafficability of soils.

56. The empirical approach consisted of first choosing instrumentation to measure trafficability factors and then conducting tests with a representative range of military vehicles on a variety of measured soil conditions. It was felt that if the performance of representative

vehicles could be related to the measured parameters of representative soils, interpolative processes could establish adequately the relationships for any vehicle on any soil.

57. Instruments and techniques for measuring initial bearing and traction capacities, slipperiness, and stickiness, and instruments and techniques for determining quantitative changes in bearing capacity and traction capacity expected to occur under traffic are described in the following paragraphs.

Bearing and traction capacity

58. Consideration of the standard laboratory tests for measuring soil strength (direct shear, triaxial shear, unconfined compression, etc.) as index tests for use in the trafficability study led to their elimination because of complexity and slowness of operation. Study of reports of the successful use of probe-type and vane-type instruments in other soils engineering problems indicated their possible application in the trafficability study. Comparative tests with instruments of these types resulted in decision to use the cone penetrometer to determine an index to bearing and traction capacities.

59. The cone penetrometer shown in use on fig. 3 and in detail on fig. 4 is light (weight 5 lb when made entirely from stainless steel), durable, and can be operated by one man, although a second man usually acts as note-keeper.

60. The procedure for using the cone penetrometer is as follows: The dial is zeroed while the instrument is suspended by its handle. The point of the cone then is set on the ground surface and the operator places his hands on the handle (see fig. 3). Force is applied (by pressure of the chest against the hands on the handle for the first 12 in. or so of penetration), until a steady downward movement occurs. The dial is read as the base of the cone and each 6-in. mark on the staff enters the ground. This can be done by watching the marks on the staff until the mark for the depth of reading desired is about 1/4 in. above the ground surface, then shifting the eyes to the dial at the approximate moment the mark reaches the surface. Readings can be made to a depth of 30 in. unless the capacity of the instrument is reached at a lesser depth,

in which case the operator should satisfy himself that he has encountered a significant stratum of firm soil, and not a thin crust or a rock. The rate of penetration is such that the six readings to 30 in. can be made and called out to the note-keeper in 15 or 20 seconds in fairly soft soils. Slower or faster rates of penetration will yield lower or higher values, respectively, but the variations will not be severe. An operator can obtain the "feel" for the proper penetration rate by a little practice using a stop watch.

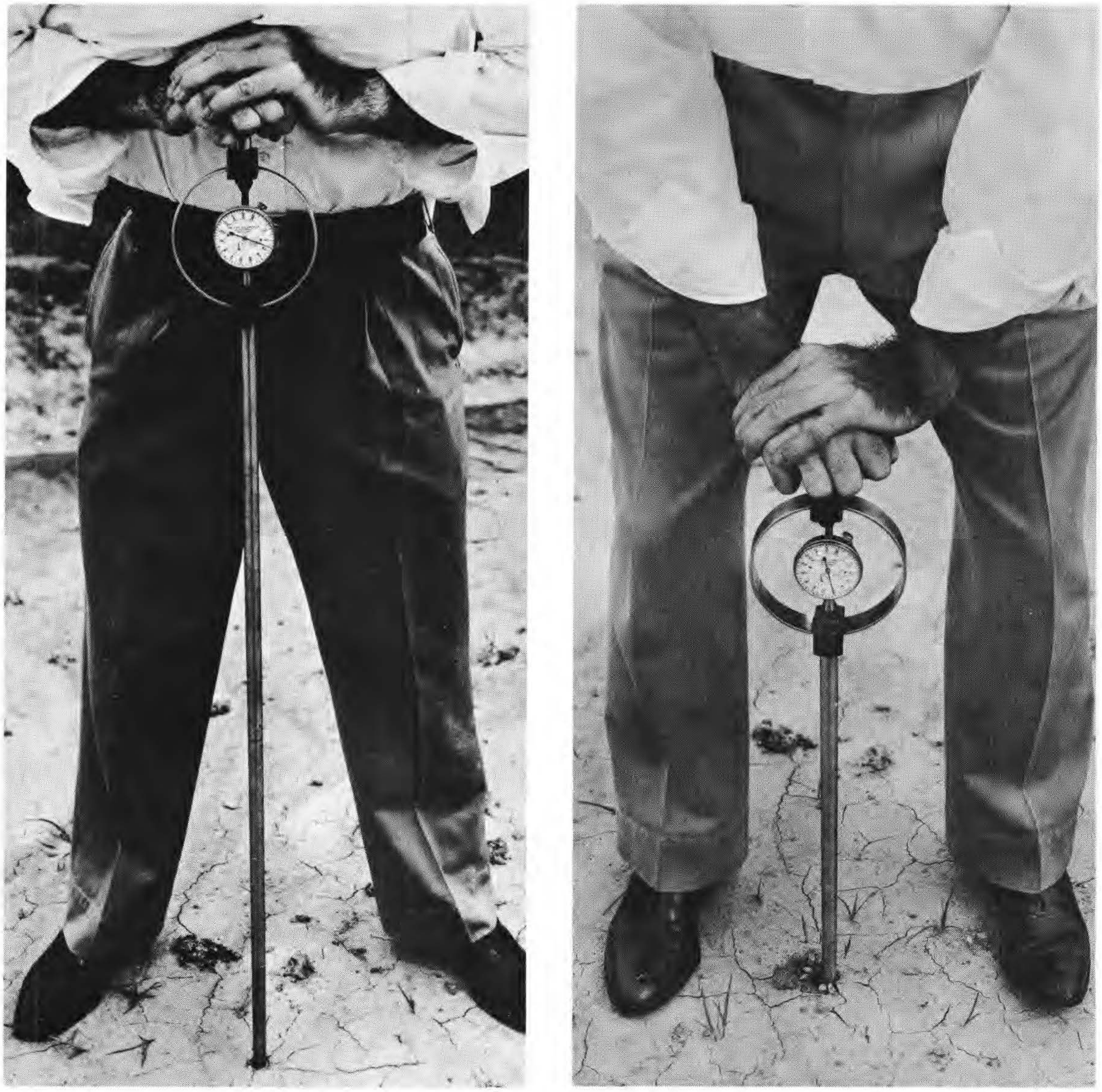


Fig. 3. Cone penetrometer in use

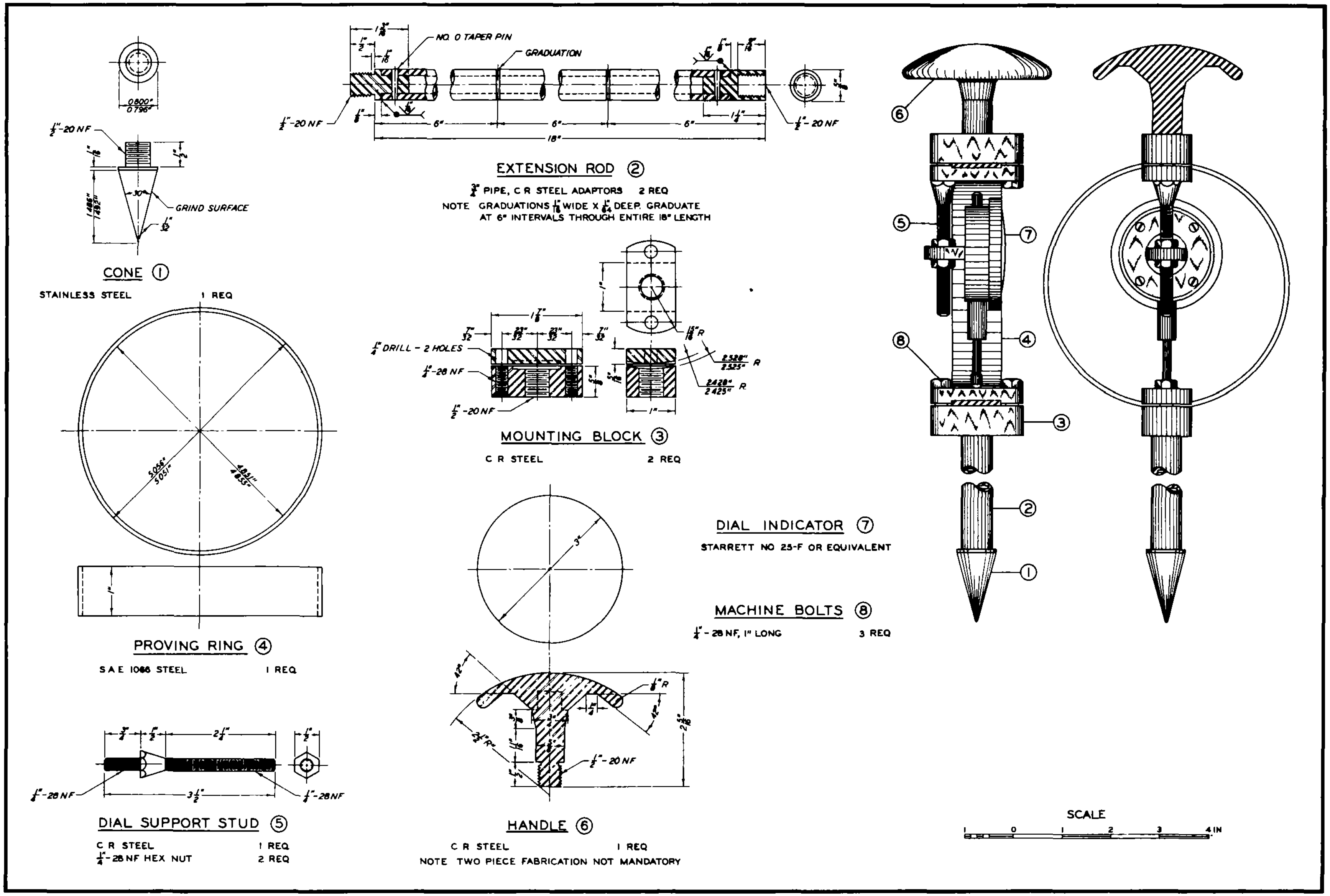


Fig. 4. Cone penetrometer

Slipperiness

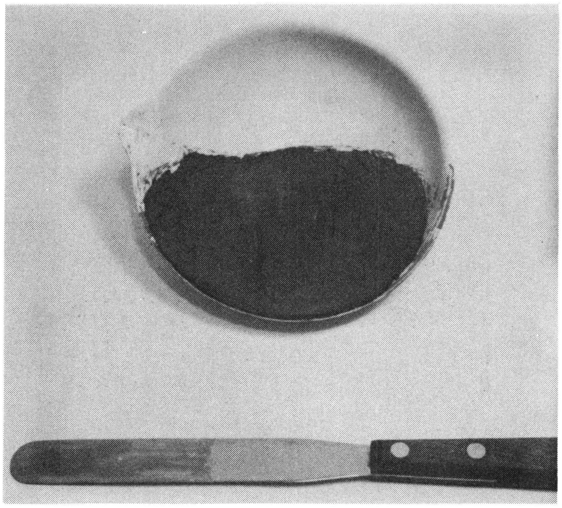
61. Attempts were made to devise an instrument that would measure the slipperiness of a soil in terms that would reflect vehicle performance, but no such instrument was devised. Lack of an instrument is not too critical, however, because slipperiness was not found to be a major cause for immobilization of any vehicles except rubber-tired ones and the use of chains on the tires usually would overcome the slipperiness effects. Moreover, a slippery condition is readily apparent (free water on the surface or wet, slimy appearance of the surface), and also is revealed by the cone penetrometer (readings of less than 20 in the top few inches followed by readings of 100 or above).

Stickiness

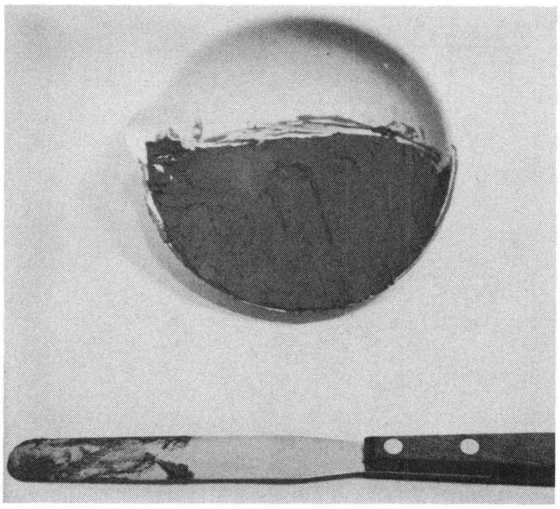
62. The effects of stickiness on vehicles can be measured in a general way by use of the spatula test. This test is made by merely drawing a stainless steel spatula across the soil sample. Three degrees of stickiness, depending on the proportion of the blade covered by the soil adhering after the test, are defined. If stickiness is "complete" or "some," the soil probably will increase the rolling resistance and make steering more difficult. If stickiness is "none," the soil will not cling to the vehicle. As has already been mentioned, sticky soils are not major problems for military vehicles. Fig. 5 illustrates the three degrees of stickiness.

Changes in soil strength under traffic

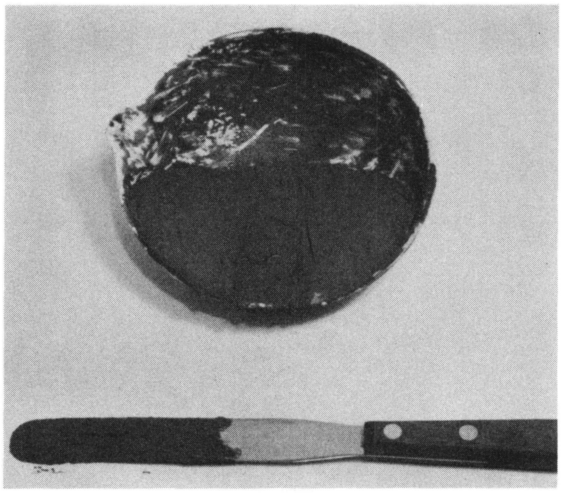
63. The first vehicle tests under the trafficability program were performed on soils which were processed and placed in bins to a depth of 4 ft. Apparently the processing stabilized the soils because it was found that little change in soil strength occurred under traffic. However, the strengths of certain soils in their natural states were found to be reduced materially under traffic. These soils are wet fine-grained soils and sands with fines, poorly drained. A technique was needed to predict the strength of soil that would result under traffic. This need was met by the remolding test, which yields a remolding index. The remolding index is a percentage figure which expresses the proportion of



"None"



"Some"



"Complete"

Fig. 5. Spatula stickiness

original strength that will be retained under the traffic of approximately 50 passes. The average initial cone index multiplied by the average remolding index, expresses the probable cone index that will obtain under the traffic of 50 passes. This cone index is called rating cone index.

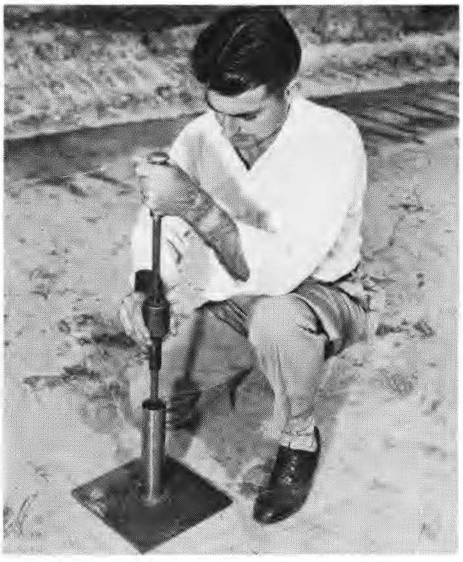
64. Test for fine-grained soils. The equipment for the remolding test is shown in use on fig. 6. The test consists of taking the sample (fig. 6a), ejecting it directly into the cylinder (fig. 6b), and pushing it to the bottom of the cylinder with the foot on the end of the 18-in. staff. The strength is then measured with the cone penetrometer at the

surface and at 1-in. intervals to a depth of 4 in. (fig. 6c). Then 100 blows are applied with the hammer and the strength of the remolded soil is measured in the same manner as before. If a sample is so hard it cannot be penetrated fully, a value of 300 is arbitrarily assigned for each

a. Sampling with trafficability sampler

b. Loading remolding cylinder

c. Measuring cone index in remolding cylinder



d. Applying hammer blows

Fig. 6. Remolding equipment in use

depth not measured. The remolding index is equal to the sum of the five cone index readings in the tube after applying 100 blows divided by the sum of the five readings before applying the effort.

65. Test for sands with fines, poorly drained. The test for predicting strength changes in such sands is the same as in fine-grained soils except that cone index measurements are made with a 0.2-sq-in. cone instead of the 0.5-sq-in. cone and the sample is remolded by dropping it (along with cylinder and base) 25 times from a height of 6 in. onto a firm surface.

66. Test for sands. No test is yet available for predicting strength changes in sands. However, most sands usually undergo strength increases with traffic, and only crusted sands will undergo strength losses. In either case the strength changes which occur have not been found to be significant thus far, and at the present time a test for sands does not appear to be needed.

PART III: VEHICLES AND SOILS TESTED, AND DATA OBTAINED

Vehicles

67. The vehicles tested on soils during the course of trafficability studies by the Waterways Experiment Station in the ten years since 1945 include self-propelled tracked and wheeled vehicles, towed tracked and wheeled vehicles, and sleds. These vehicles are listed in table 1 together with data on their physical characteristics that are used in the computation of vehicle cone index (described in paragraph 126). It will be noted that 25 self-propelled tracked, 14 self-propelled wheeled, 1 towed tracked, 4 towed wheeled, and 1 sled type are shown. These vehicles are shown in photographs 1-10.

Soils

Prepared lanes

68. Five soils were used in prepared lanes. Three of these, a sandy silt (site sand), a coarse sand (concrete sand), and a blend of clay and sandy silt (blend), were tested at Yuma. The other two, a lean clay (Rifle Range) and a fat clay (Mound), were tested at Vicksburg. Grain-size curves, Atterberg limits, and specific gravities for these soils are shown on plate 1.

Natural soils

69. Many different soil types (mostly fine-grained) were tested in their natural states. The soils ranged from dune sands to highly plastic clays and included homogeneous and profiled soils (in the upper two feet). Detailed information on these soils may be found in the 2d, 8th, 10th, 12th, and 13th supplements to TM 3-240. The majority of tests on natural conditions were performed in the vicinities of Vicksburg and Laurel, Mississippi, but tests also were performed in Arizona, California, Kentucky, Indiana, Tennessee, Virginia, New Hampshire, North Carolina, Alabama, Florida, Georgia, and Canada.

Data Obtained in Vehicle Tests on Prepared Soils

70. Nine hundred and forty-six tests with self-propelled and towed vehicles were conducted in prepared lanes during the period from the spring of 1945 to the summer of 1948. The left side of table 2 contains information on the number and type of tests conducted with each vehicle on level and sloping fine- and coarse-grained prepared soils. Important features of the test program are described briefly in the following paragraphs.

Preparation of test lanes

71. A test lane was prepared by first digging a pit 100 ft long, 24 ft wide, and 4 ft deep. The pit was then filled with material which had been allowed to dry and plowed repeatedly until it was in a fine, powdery state. The material was placed in the pits in 6-in. lifts; each lift was wet with a predetermined amount of water. Much of the filling and spreading of material was done by hand labor to achieve uniformity.

Tests with self-propelled vehicles

72. Before-traffic data. As soon as a test lane was ready certain data were collected prior to traffic testing. These data were as follows:

- a. Cone index measurements were taken at the surface and at 6-in. intervals to a depth of 36 in. every 4 ft along each track the vehicle was to make.
- b. Samples for stickiness, water content, and density determinations were taken in 6-in. sections to a depth of 24 in. at two or three places in each track the vehicle was to make.
- c. Surface profiles were established for each track by taking elevation measurements at 4-ft intervals.

73. Traffic tests. The test vehicle was driven a vehicle length into the test lane, and halted. One end loop of a special dynamometer was hooked to the pintle hook of the test vehicle and a cable from the other end of the dynamometer was attached to a heavier vehicle located outside the test lane. The drawbar pull the vehicle developed with its wheels or track spinning (while anchored) then was measured. Following this the dynamometer was removed and the vehicle proceeded to the far end of the 100-ft test lane, halted, and backed up in the same path to

the first end of the lane. The test vehicle continued back-and-forth traffic until it became immobilized, until it was halted to measure additional data, or until it had completed 50 passes with no evidence of imminent immobilization. With only a few exceptions, test vehicles were operated in their lowest gears.

74. Towing-type vehicles such as tractors were tested while towing various loads. The loads were provided by vehicles connected to the test vehicle by cables over 100 ft long. Load vehicles remained outside the test lane, on a smooth surface, at all times.

75. During-traffic data. If a vehicle made several passes (usually 20), and apparently could make more, the test was halted and data measurements similar to those made before traffic (including a drawbar measurement) were obtained.

76. After-traffic data. Measurements of cone index, moisture content, density, stickiness, and track profiles were made at the same locations in the test lane as had been used for pretraffic and during-traffic data. A drawbar measurement was made at the end of a test in which the vehicle had not been immobilized, but no drawbar measurement was attempted at the end of a test in which immobilization had occurred.

77. Test notes. Engineers and technicians observed each test carefully. Complete notes were recorded concerning the apparent ease or difficulty of operation, slippage, stickiness, apparent cause of immobilization, and other pertinent observations. Numerous photographs were made.

78. Typical data. Complete data for each test were assembled on a single sheet for analysis purposes. A typical set of data for a test with a towing-type vehicle and the analysis of the test are shown on plate 2.

Tests with towed vehicles

79. Data. Measurements of cone index, moisture content, density, stickiness, and track profiles were made before, during, and after each test with a towed vehicle. The force required to tow the vehicle through the test condition was measured on the first and second pass and at varying intervals thereafter, depending on test conditions. Complete

notes concerning the performance of the vehicle were recorded. A summary of the data for one test with a towed vehicle and the analysis of the test are shown on plate 3.

80. Traffic test. The test vehicle was towed the length of the lane, turned around outside the lane, and pulled back in the same path to the first end of the lane. This pattern was repeated until the sinkage of the vehicle caused the undercarriage to drag, or until a substantial number of passes (approximately 25) was completed without the undercarriage dragging. A cable longer than 100 ft connected the test vehicle to a prime mover which remained off the test lane. The tongue of a single-axled vehicle was supported by a sled built especially for the purpose. The sled also supported the dynamometer used to measure the pull. Fig. 7 shows a test being made with the M21 trailer. The dynamometer sled is in the foreground. The tests with the Engineer Board sled also employed the dynamometer sled.

Data Obtained in Vehicle Tests on Natural Soils

81. Four hundred and eighty-five tests with self-propelled vehicles were conducted on natural level and sloping surfaces between the spring of 1949 and the date of this report. The right side of table 2 contains information on the number and type of tests conducted with each vehicle on level and sloping fine- and coarse-grained natural soils. Important features of the tests are described briefly in the following paragraphs.

Tests on level soils

82. Data. The quantity, type, and frequency of data measured in the 175 tests on natural level fine-grained soils varied considerably, especially in the early tests. Drawbar measurements were seldom made. The pretraffic data usually were of the same type and quantity as had been collected for tests on prepared lanes and also included measurements of remolding index at places in the test lane chosen for representativeness if the soil was expected to permit 50 passes or for softness if an immobilization was expected. Spots for remolding index measurements were selected from a study of pretraffic cone indexes. Cone indexes

M21 loaded with 12,000 lb, tire pressure 30 psi, on the 12th pass in blended soil. Test 7

M21 loaded with 8,000 lb, tire pressure 30 psi, on the 2d pass in dry concrete sand. Test 12

Fig. 7. Trafficability tests with M21 ammunition trailer

were measured at frequent intervals during traffic. After-traffic data usually consisted merely of rut measurements. Notes describing details of vehicle performance and soil action were kept, and numerous photographs were taken. Plate 4 shows the data and analysis for one typical test on a level, natural fine-grained soil.

83. Traffic tests. Traffic was run back and forth in the same 100-ft path until immobilization occurred or for 50 passes if at the completion of these passes it seemed that no immobilization would occur soon. The lowest gear of the vehicle usually was used. A few tests also were made to determine the soil strength required for zigzagging, sudden stops and starts, backing out of tracks, and other common maneuvers. It was concluded that the cone index criteria for a single such maneuver was approximately equal to that for 50 straight-line passes.

Tests on sloping surfaces

84. Fifty-five tests were made on fine-grained soils to compare drawbar pulls made with the vehicle anchored on slopes and on level surfaces and to determine the maximum slope vehicles could climb with and without tow loads. One hundred and sixty-nine single vehicle tests were made on slopes of various magnitudes in conjunction with studies on coarse-grained soils. Most of these tests were made with rubber-tired vehicles.

85. Anchored drawbar-pull tests. A measurement of the force developed by a vehicle spinning its wheels or tracks while anchored to a heavier vehicle was made on level ground and on a slope. Cone indexes, moisture contents, and densities were measured.

86. Maximum slopes. Tests were made in which a single vehicle or a vehicle with a tow load was permitted to climb a gradually increasing slope until it was immobilized or until it reached the top of the slope. Slope, cone index, moisture, and density were measured at the immobilization spot or in the steepest part of the slope negotiated. Most tests of this type were performed on beach and dune sands with rubber-tired vehicles.

PART IV: TRAFFICABILITY PROCEDURES FOR TACTICAL PURPOSES

Measuring Trafficability of Fine-grained Soils and Sands with Fines, Poorly Drained

87. In those cases in which scouting parties can enter an area to make measurements, data can be obtained to permit determination of the number and type of vehicles that can cross the area, the loads they can tow, and the slopes they can climb. The procedures for measuring trafficability are described in this part. It should be remembered that measurements are only valid for the time of measurement and short periods thereafter, provided no rain occurs.

Range of cone indexes

88. The range in cone indexes in the critical layer (see paragraphs 92-97) which is of maximum interest is between 30 and 200. Only the most mobile of military vehicles (M29 weasel, T46E1 otter, and Canadian snowmobile type) can travel on soils with a cone index as low as 30, and only a few special vehicles require cone indexes over 200 (before application of traffic). These limits usually make it possible, in gathering data for trafficability evaluation, to classify large areas as above or below the critical range without extensive testing.

Number of measurements

89. The number of measurements to be taken is determined by available time tempered by judgment as to the range of soil strengths and the general uniformity of the area. Only a few readings are needed in an area with cone indexes above or below the critical range of 30 to 200 but if cone indexes are within this critical range or, more particularly between about 30 and 150, many readings should be taken to assure complete and accurate coverage of the area. The trafficability measuring instruments have been designed to facilitate rapid observations and the accuracy of the average of any series of readings increases with the number included. It has been found, for example, that variations in a typical soft soil are such that about 15 readings are needed to establish a true average cone index at any particular spot (at a given depth),

and that if 15 readings are made within a radius of 3 ft in a uniform-appearing area, the addition of another reading will not significantly change the average. It is not anticipated that time will be available for this large number of readings and judgment should be used to reduce the number, in accordance with instructions in the following subparagraphs.

a. Where cone indexes are above 200 a very few penetrometer readings normally will suffice to verify the extent of the area. Two sets of readings at each of a few locations should be adequate, and remolding tests should be made at the first two or three locations. If these show a remolding index of 0.80 or more, no additional remolding tests need be made. Sufficient tests should be made to establish the range for the area if the remolding index is below 0.80, and especially if it is much below. Generally this can be established with tests at about four locations.

b. Where readings range from 150 to 200 sufficient locations should be selected to verify the limits of the area as established by visual inspection. Three or four sets of readings should be made at each location. Remolding tests should be made at the first two or three locations; if these show a remolding index of 0.90 or more, no additional remolding tests need be made. If the remolding index is below 0.90, and especially if it is much below, sufficient remolding tests should be made to establish the range for the area. Generally this can be established with tests at about six locations.

c. The most readings are required in areas where the cone index ranges from 30 to 150. Readings should be made at enough locations to establish the boundaries of the area and the average cone index within fairly close limits. At least three sets of readings should be made at each location. Remolding tests should also be run at a sufficient number of locations to establish the range of remolding indexes. In addition, if a proposed route can be selected in the field, penetrometer and remolding readings should be made at closely spaced intervals along it to insure against soft spots.

d. Where cone indexes are below 30, readings should be limited to the number needed to establish the limits of the nontrafficable area. No remolding tests will be needed.

Remolding test

90. Techniques of the remolding test for fine-grained soils differ somewhat from techniques for sands with fines, poorly drained. It therefore is necessary that the two types be recognized for conditions where

remolding tests must be made. In such conditions both soil types are wet in appearance and wet to the touch. If squeezed and rolled between the finger tips, the fine-grained soil will feel soft and smooth because fine-grained soil particles are small and flat in shape. The other soil type will have a definite abrasive feel because of the presence of the larger, rounder particles of sand. However, there will be many cases in which the observer cannot confidently distinguish the two types. In such cases, the remolding test for fine-grained soils should be made first. If the remolding index obtained is below 0.50, then it is very likely that the soil is a fine-grained one. If the remolding index is above 0.50 and especially if it is above 1.00, then the remolding test for sands with fines, poorly drained (the vibrated test), should be employed. If this test shows a smaller remolding index than the other, it may be safely assumed that the soil is a sand with fines, poorly drained, and all remolding index measurements should be made with the test for this type of sand. A good rule to follow in cases of doubt is to run both types of tests and use the lower remolding index.

Rating cone index

91. The rating cone index is the cone index that will result under traffic. It is the product of the cone index and the remolding index, and is the final cone index evaluation of a given area. Assume that the cone index for an area is 85 and the remolding index is 0.80. The rating cone index then would be 85 x 0.80 = 68.

Critical layer

92. The depth of the critical layer varies with the soil's strength profile and the vehicle type and weight.

93. Variations with vehicle type and weight. The normal depths of the critical layer for various vehicle types and weights are:

Type of Vehicle	Depth of Normal Critical Layer, in.
Sleds	0 to 3
M29, T46E1, Canadian snowmobile	3 to 9
Wheeled, up to 50,000 lb	6 to 12
Tracked, up to 100,000 lb	6 to 12
Wheeled, over 50,000 lb	9 to 15
Tracked, over 100,000 lb	9 to 15

94. Normal strength profile. In a soil with a normal strength profile, the cone index readings either increase or remain constant with each increment of depth. In this case, remolding tests will be run only on samples taken from the normal critical depth for the vehicle in question, since a decrease in remolding index with increasing depth is not common. The rating cone index for this layer is used as the criterion of trafficability for this particular vehicle.

95. Abnormal strength profile. In a soil with an abnormal strength profile, there is at least one cone index reading which is lower than the reading immediately preceding it. In this case, remolding tests must be run on samples taken from the normal critical layer and also on the 6-in. layer below. The lower rating cone index is used as the measure of trafficability. Sleds are an exception to this rule. The 0- to 3-in. layer is always used as the critical layer.

96. Interpolating values. Intermediate values for the 3-, 9-, and 15-in. depths can be interpolated whenever the vehicle types under consideration require them.

97. Example. It is desired to investigate the following soil areas for trafficability of vehicles which are of such type and weight that the 6- to 12-in. depth is the normal critical layer.

Depth	Area A (Normal)		Area B (Abnormal)	
in.	Cone Index	Remolding Index	Cone Index	Remolding Index
Surface	30		30	
6	50	0.90 (6 to 12 in.)	75	0.90 (6 to 12 in.)
12	70		45	0.90 (12 to 18 in.)
18	80		35	
24	90		50	

Since Area A in the tabulation has a normal profile, a remolding test was run only for the 6- to 12-in. layer. The rating cone index for Area A is 60 x 0.90 = 54. In Area B, remolding tests were necessary for both the 6- to 12-in. and 12- to 18-in. layers. In the case of Area B, the rating cone index of the 6- to 12-in. layer is 60 x 0.90 = 54 and of the 12- to 18-in. layer is 40 x 0.90 = 36. The rating cone index of the 12- to 18-in. layer, 36, is the governing value for trafficability in Area B.

Other factors

98. In addition to the cone index of an area other factors also should be considered in evaluating trafficability.

99. Slope. The steepest slope, or ruling grade, which must be negotiated should be measured in terms of per cent, or may be determined from study of a contour map. The effect of slope can be expressed as an increase in cone index requirements over the requirements for level terrain. Detail procedures for determining slope effects are contained in paragraphs 117-120.

100. Stickiness. No instrument for measuring the effects of stickiness on the performance of vehicles has been devised. Stickiness will occur in all fine-grained soils when they are comparatively wet. The greater the plasticity of the soil, the more severe are the effects of stickiness. Some stickiness may occur in sands with fines, poorly drained, but it will not be severe. In general, stickiness will have adverse effects on the speed and facility of travel and steering of all vehicles, but will not in itself cause the immobilization of any vehicle except small tracked vehicles like the M29 weasel. Even the worst conditions of stickiness are nothing more than a nuisance to the larger, powerful military vehicles. Removal of fenders will reduce stickiness effects on some vehicles.

101. Slipperiness. Like stickiness, the effects of slipperiness cannot be measured quantitatively. Soils which are covered with water or a layer of soft mud usually are slippery and often cause steering difficulty, especially to rubber-tired vehicles. Immobilization can occur in some instances. Immobilizations due entirely to slipperiness, wherein the vehicle merely spins its wheels without either sinking (bearing capacity failure) or moving forward, are not frequent, but nevertheless should be anticipated. Immobilizations occur frequently when slipperiness is associated with low bearing capacity. Slipperiness effects assume greater significance on slopes, and sometimes slopes whose soil strength is adequate may not be passable because of slipperiness. The use of chains on rubber-tired vehicles usually will be of benefit in slippery conditions. The following three categories are used to rate slipperiness.

Condition	Symbol
1. Not slippery under any condition	N
2. Slippery when wet	P
3. Slippery at all times	S

P and S conditions should always be approached with caution.

102. Vegetation. The particular effects of vegetation on trafficability are not within the scope of this report, but some points are worthy of mention. Dense grass, especially if wet with dew or rain, may provide slippery conditions. Tall grasses will often restrict visibility. Soil strength requirements will be greater than normal if small trees or thick brush must be pushed down by the vehicle.

103. Nonsoil areas. Much of the terrain in northern latitudes is covered by a layer of mixed roots, mosses, and other vegetation in various states of decomposition. The cone penetrometer and remolding tests cannot be expected to measure the trafficability of such nonsoil materials. Limited testing has shown that if the mat of partially decayed vegetation is 6 in. or more in thickness it will support 40 to 50 passes of very light vehicles of the M29, T46E1, or Canadian snowmobile type, but will usually permit no more than 2 or 3 passes of a heavier vehicle before the vehicle breaks through into the soil below.

104. Other obstacles. A complete assessment of the trafficability of a given area must include an evaluation of obstacles such as forests, rivers, boulder fields, ditches, hedgerows, etc. Exact effects of such obstacles on the performance of vehicles are not within the scope of this report.

Measuring Trafficability of Sands

105. Procedures for measuring the trafficability of sands are based on a comparatively brief program of testing.

Recognition of a sand

106. Sand in the dry state is easily recognizable. It will be fairly clean in appearance, fly in the air when kicked sharply with the toe, and spill from the hand like grains of sugar. It is the rounded,

granular material found on most beaches and in sand dunes.

107. When wet, however, there is some possibility that a sand might be confused with a sand with fines, poorly drained, or even with a sandy fine-grained soil. A quick test that will assure that the soil in question is a sand consists of pushing a penetrometer into the soil. If the color of the soil in the area of the penetrometer immediately becomes lighter, this signifies good internal drainage and therefore a sand. Another test consists of confining a sample of soil in the remolding cylinder and attempting to penetrate it with the cone penetrometer. If the soil is a sand, penetration will be extremely difficult to impossible, even if the soil has been vibrated in the remolding test.

Number of measurements

108. Sands are usually fairly uniform in strength in a given area. The number of cone penetrometer readings to be made is that number which the operator feels is sufficient to obtain a true average. The number of measurements needed for characterizing the trafficability of a sand is usually less than that for a fine-grained soil or a sand with fines, poorly drained. For most sands, no remolding test is necessary. For some sands, such as crusted sands, a remolding test may be necessary, but none is yet available.

Critical layer

109. The critical layer for sands appears to be the top 6 in. for all vehicles, with the possible exception of sleds. Although no tests have been done with sleds on sands, it is probable that the condition of the top 3 in. will govern the force required to tow them. Additional tests in sands may possibly result in revision of critical layers, but at the present time this is not considered likely.

Stickiness and slipperiness

110. There are no stickiness or slipperiness problems in sands.

Vegetation

111. The presence of vegetation in sands usually is a sign that the sands are stabilized and of high trafficability. This effect will be reflected in high cone index readings.

Application of Trafficability Procedures to Vehicle Performance in Fine-grained Soils and Sands with Fines, Poorly Drained

112. The procedures and criteria presented in the foregoing paragraphs are intended for use in tactical operations. The criteria have been established so that when the rating cone index for a given area is equal to or higher than the vehicle cone index of the using vehicle, sufficient strength will be available in the soil to withstand the passage of 40 to 50 of the same vehicles (or vehicles with smaller vehicle cone indexes) operating at slow speeds in the same ruts, and to permit stopping if necessary. A larger number of vehicles can be moved through the area if space is available to permit spreading the traffic. The strength will also be sufficient to permit a vehicle to enter the area, stop, back out of the ruts while turning, and retreat from the area. This is the most difficult maneuver from the standpoint of soil strength. It is recognized that criteria to assure the passage of a single vehicle across an area would often be desirable. Strength criteria for one-pass operation cannot be established positively because the strength of any soil, even though it seems to be homogeneous, varies over a greater range than the strength represented by the difference between a soil condition which will not permit one pass and the condition which will permit only one pass. However, as a general rule a rating cone index equal to 75 per cent of the vehicle cone index will be adequate to permit one or two straight-line passes of the vehicle.

Cone index requirements for vehicles on level terrain in fine-grained soils and sands with fines, poorly drained

113. The ability of a given vehicle to complete 50 passes over a level area is assured if the rating cone index of the area (in the critical layer) is greater than the vehicle cone index (see vehicle cone indexes listed in the appendix). There is danger of immobilization if the rating cone index is below the vehicle cone index. Immobilization will definitely occur if the rating cone index is well below the vehicle cone index. In addition to this, free water on the surface or a cone

index of 20 or less at the surface, with firmer material immediately below, indicates danger of immobilization of wheeled vehicles because of slipperiness.

Cone index requirements for vehicles with towed loads on level fine-grained soils and sands with fines, poorly drained

114. A vehicle towing a load must overcome not only its own rolling resistance but that of the towed vehicle as well. Since additional shearing strength is required to produce the necessary thrust, a tow load applied to a vehicle increases the cone index requirements. Plates 5 and 6 present curves to be used in evaluating the increase in cone index requirements for 40 to 50 passes of the vehicles caused by addition of a towed load or by a slope. Criteria for towed vehicles on level terrain are presented on plate 5, wherein rating cone index is correlated with required towing force as a percentage of vehicle gross weight for various weights and types of vehicles. Given the vehicle and the rating cone index (in the critical layer), the force required to tow the vehicle on level terrain can be determined. Criteria for self-propelled vehicles are presented on plate 6, wherein the rating cone index is related to the maximum towing force that the vehicle can apply on level terrain as a percentage of its gross weight and to the maximum slope the vehicle can negotiate with no towed load. If the rating cone index is expressed as the value over and above that required for operation on level ground without a tow load, all vehicles can be grouped into three types: wheeled vehicles, tracked vehicles with grousers less than 1-1/2 in. long, and tracked vehicles with grousers greater than 1-1/2 in. long. The cone index over and above that required for operation on level ground is equal to the rating cone index minus the vehicle cone index. Separate curves are shown on plate 6 for the three types of vehicles. Given the vehicle and the required towing force, the necessary rating cone index can be determined, or given the vehicle and the rating cone index, the maximum slope negotiable can be determined.

115. Example. It is required to know whether an M24 tank can tow a 2-1/2-ton cargo truck, equipped with high-flotation tires at low

pressure, on level fine-grained soil or sands with fines, poorly drained, with a cone index of 100 and a remolding index of 0.80 in the critical layer. Pertinent data from the appendix are as follows:

M24 Tank	2-1/2-ton Cargo Truck
Gross weight, 40,500 lb	Gross weight, 15,700 lb
Vehicle cone index, 61	Vehicle cone index, 68
Grousers less than 1-1/2 in. long	
The rating cone index is 100 x 0.80 = 80	

Interpolating for the 15,700-lb truck between curves for wheeled vehicles on plate 5 yields a required towing force of 25 per cent of the truck weight, or: 0.25 x 15,700 = 3,900 lb required towing force.

The maximum towing force of the M24 tank is read as 36 per cent of its weight at 80 - 61 = 19; using the middle curve of plate 6, 0.36 x 40,500 = 14,600 lb. Since the available towing force of the tank, 14,600 lb, exceeds the required force to tow the truck, 3,900 lb, the tank can easily tow the truck under the stated conditions. NOTE: Towing force in the above example and forces in all other examples in this report are rounded off to the nearest 100 lb.

116. Example. It is required to know whether the 2-1/2-ton truck can tow the M24 tank on level terrain in a dry, loose sand which has a cone index of 95 and remolding index of 1.00 in the critical layer. The vehicles are the same as those in paragraph 115.

Rating cone index: 95 x 1.00 = 95.

Interpolating for 40,500 lb between the curves for tracked vehicles on plate 5 yields a required towing force of 15 per cent of the tank weight, or: 0.15 x 40,500 = 6,100 lb required towing force.

The maximum towing force of the 2-1/2-ton truck (from the lower curve of plate 6, at rating cone index 95 minus vehicle cone index 68 = 27) is 37 per cent of its weight, or 0.37 x 15,700 = 5,800. Since the material is sand, only 90 per cent, or 0.90 x 5800 = 5200 lb, is available. The required force is 6100 lb; therefore, the truck will not be able to tow the tank.

Cone index requirements for vehicles on slopes

117. The maximum slope negotiable by a given vehicle for 40 to 50

passes may be determined by reference to plate 6 when the rating cone index is known. An example is given in the following paragraph.

118. Required: the maximum slope the M24 tank described in paragraph 115 can climb in a fine-grained soil or sands with fines, poorly drained, with a cone index of 100 and a remolding index of 0.85 in the critical layer.

Rating cone index: 100 x 0.85 = 85.

Rating cone index minus vehicle cone index: 85 - 61 = 24.

Then from plate 6, the maximum slope is 43 per cent.

This is the maximum slope the M24 can be expected to climb under the given conditions.

Cone index requirements for vehicles with towed loads on slopes on fine-grained soils and sands with fines, poorly drained

119. The maximum slope a vehicle towing another can negotiate for 40 to 50 passes may be determined from the formula $\frac{T_1 - T_2}{W_1 + W_2}$, where T_1 is the maximum tractive power available (in pounds), T_2 is the towing force (in pounds) required on level ground, and W_1 and W_2 are the weights (in pounds) of the towing and towed vehicles, respectively. The curves on plates 5 and 6 may be used for determining T_1 and T_2. (It is cautioned that this relation does not apply to slippery surfaces.) An example is given in the following paragraph.

120. Required: the maximum slope which can be negotiated by an M24 tank towing a 2-1/2-ton truck on a fine-grained soil or sands with fines, poorly drained, with a cone index of 100 and a remolding index of 0.85 in the critical layer. The vehicles are the same as those in paragraph 115.

Rating cone index: 100 x 0.85 = 85.

Rating cone index minus vehicle cone index for the M24 tank: 85 - 61 = 24.

From plate 6, the tractive power available, T_1, is 43 per cent of the gross weight of the M24, or: T_1 = 0.43 x 40,500 = 17,400 lb tractive power available. From plate 5 interpolating for 15,700 lb between the curves for wheeled vehicles, the required towing

force on level ground at cone index of 85, T_2 , is found to be 24 per cent of the gross weight of the 2-1/2-ton truck, or:
$T_2 = 0.24 \times 15{,}700 = 3{,}800$ lb towing force required on level ground. Then:

$$\frac{T_1 - T_2}{W_1 + W_2} = \frac{17{,}400 - 3{,}800}{40{,}500 + 15{,}700} = 0.24 \text{ or } 24 \text{ per cent.}$$

The maximum slope negotiable under the given conditions is 24 per cent.

Application of Trafficability Procedures to Vehicle Performance in Sands

121. Level sands tested thus far have been found to be trafficable to all tracked vehicles and to all all-wheel-drive trucks equipped with high-flotation tires at low pressures, no matter what the magnitude of the measured cone indexes in the sands. Some sands can and often do cause the immobilization of trucks which have rear-wheel drive only or trucks equipped with standard tires at high pressures. However, it is not intended at this time to investigate the performance of such trucks, and no further mention of them will be made in this report.

122. Only pilot studies on the trafficability of sands have been made to date. These pilot studies have concentrated on a few trucks operating at various tire pressures on level and sloping sands. No information on drawbar ability of trucks has been obtained. However, previous work by WES as well as recent work done by the Detroit Arsenal indicates that the maximum slope (expressed in per cent) a vehicle can climb on a given sand condition is approximately equal to the maximum drawbar the vehicle can develop, expressed as a percentage of its own weight. Until further tests shed additional light on this feature, it will be assumed that it is true.

123. Data for the following vehicles are available in estimating performances on sands.

Wheeled Vehicles

- 1/4-ton M38 jeep
- 3/4-ton M37 truck
- 2-1/2-ton CCKW353 cargo truck
- 2-1/2-ton M34 and M135 trucks
- 2-1/2-ton M211 truck
- 2-1/2-ton truck, wrecker
- 2-1/2-ton DUKW, amphibian, loaded
- 2-1/2-ton DUKW, amphibian, empty

Wheeled Vehicles (Continued)

2-1/2-ton M47 truck, loaded	5-ton M41 truck
2-1/2-ton M47 truck, empty	5-ton M62 wrecker

Tracked Vehicles

D7 Engineer tractor	M4 tank

The performance of the wheeled vehicles is best expressed in the form of a family of curves for each vehicle at different tire pressures on a plot of slope versus cone index. The cone index is that measured in the 0- to 6-in. layer which is considered the critical layer for trucks on sands. Curves for the following vehicles are shown as plates 7 to 12, respectively: 2-1/2-ton truck with 11.00x20 tires, 2-1/2-ton truck with 9.00x20 tires, 2-1/2-ton truck with 7.50x20 tires, 2-1/2-ton truck with 11.00x18 tires (amphibian), 3/4-ton truck with 9.00x16 tires, and 1/4-ton truck with 7.00x16 tires. All vehicles were loaded to their nominal capacities.

Classification of Vehicles in Fine-grained Soils and Sands with Fines, Poorly Drained

Classes

124. The appendix contains a list of vehicles which are divided into four classes: self-propelled tracked vehicles, self-propelled wheeled vehicles, towed tracked vehicles, and towed wheeled vehicles. Under each class the vehicles are grouped according to type and alphabetically, i.e., amphibious vehicles, cargo carriers, etc. Under each type the vehicles are listed according to ascending vehicle cone index. Each vehicle is identified by its standard nomenclature and, in addition, a reference is made to the technical manual or bulletin and page number which contains its description. The performance category into which each vehicle falls and its mobility index also are shown in the appendix.

Performance category

125. Military vehicles are divided into seven arbitrary categories according to cone index requirements. The range of cone index for each category and an indication of the type of vehicle which falls under each category (exceptions are numerous) are shown in the following tabulation:

Category	Cone Index Range	Vehicles
1	20-29	The M29 weasel, T46E1 otter, and Canadian snowmobile are the only known standard vehicles in this category.
2	30-49	Engineer and high-speed tractors with comparatively wide tracks and low contact pressures.
3	50-59	The tractors with average contact pressures, the tanks with comparatively low contact pressures, and some trailed vehicles with very low contact pressures.
4	60-69	Most medium tanks, tractors with high contact pressures, and all-wheel-drive trucks and trailed vehicles with low contact pressures.
5	70-79	Most all-wheel-drive trucks, a great number of trailed vehicles, and heavy tanks.
6	80-99	A great number of all-wheel-drive and rear-wheel-drive trucks, and trailed vehicles intended primarily for highway use.
7	100 or greater	Rear-wheel-drive vehicles and others that generally are not expected to operate off roads, especially in wet soils.

Mobility index

126. The mobility index is a dimensionless number obtained by applying certain characteristics of the vehicle to the formulas given subsequently. The mobility index has been correlated with the minimum cone index requirements (termed vehicle cone index) for a range of military vehicles of all classes. The mobility and vehicle cone indexes for the majority of the military vehicles are shown in the appendix. For vehicles not shown in the appendix, the formulas given below can be used to compute the mobility index. The mobility index can be applied to the curve shown on plate 13 to determine the vehicle cone index.

a. Self-propelled tracked vehicles.

$$\text{Mobility index} = \left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{track factor} \times \text{grouser factor}} + \text{bogie factor} - \text{clearance factor} \right) \times \text{engine factor} \times \text{transmission factor}$$

wherein,

$$\text{contact pressure factor} = \frac{\text{gross weight in lb}}{\text{area of tracks in contact with ground in sq in.}}$$

weight factor: less than 50,000 lb = 1.0
50,000 to 69,999 lb = 1.2
70,000 to 99,999 lb = 1.4
100,000 lb or greater = 1.8

$$\text{track factor} = \frac{\text{track width in in.}}{100}$$

grouser factor: grousers less than 1.5 in. high = 1.0
grousers more than 1.5 in. high = 1.1

$$\text{bogie factor} = \frac{\text{gross weight in lb divided by 10}}{\text{(total number of bogies on tracks in contact with ground)} \times \text{(area of 1 track shoe in sq in.)}}$$

$$\text{clearance factor} = \frac{\text{clearance in in.}}{10}$$

engine factor: 10 or greater hp per ton of vehicle wt = 1.0
less than 10 hp per ton of vehicle wt = 1.05

transmission factor: hydraulic = 1.0 ; mechanical = 1.05

b. Self-propelled wheeled vehicles.

(1) All-wheel-drive vehicles.

$$\text{Mobility index} = 0.6\left[\left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{tire factor} \times \text{grouser factor}} + \text{wheel load} - \text{clearance factor}\right) \times \text{engine factor} \times \text{transmission factor}\right] + 20$$

wherein,

$$\text{contact pressure factor} = \frac{\text{gross weight in lb}}{\text{tire width x rim diam x No. of tires}}$$

weight factor: greater than 35,000 lb = 1.1
15,000 to 35,000 lb = 1.0
less than 15,000 lb = 0.9

tire factor = 1.25 x tire width in in. ÷ 100

grouser factor: with chains = 1.05
without chains = 1.00

$$\text{wheel load} = \frac{\text{gross weight in kip}}{\text{No. of wheels}}$$ (wheels may be single or dual)

$$\text{clearance factor} = \frac{\text{clearance in in.}}{10}$$

engine factor: greater than 10 hp per ton = 1.0
less than 10 hp per ton = 1.05

transmission factor: hydraulic = 1.0 ; mechanical = 1.05

(2) Rear-wheel drive only. If vehicle being considered is not equipped with an all-wheel drive, the cone index is computed as above, then multiplied by 1.4 to obtain the vehicle cone index.

(3) Half-tracked vehicles. The above formula is used to obtain the vehicle cone index of half-tracked vehicles by assuming that the vehicle has wheels instead of tracks on the rear end, that the wheels are of the same size and have the same load as the front wheels, and using a grouser factor of 1.1.

c. Towed tracked vehicles.

$$\text{Mobility index} = \left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{track factor}} + \text{bogie factor} - \text{clearance} \right) + 30$$

wherein,

$$\text{contact pressure factor} = \frac{\text{gross weight in lb}}{\text{area of tracks in contact with ground in sq in.}}$$

weight factor: 15,000 lb or greater = 1.0
below 15,000 lb = 0.8

$$\text{track factor} = \frac{\text{track width in in.}}{100}$$

$$\text{bogie factor} = \frac{\text{gross weight in lb divided by 10}}{(\text{total No. of bogies on track in contact with ground}) \times (\text{area of 1 track shoe in sq in.})}$$

clearance = clearance in in.

d. Towed wheeled vehicles.

$$\text{Mobility index} = 0.64 \left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{tire factor}} + \text{axle load} - \text{clearance} \right) + 10$$

wherein,

$$\text{contact pressure factor} = \frac{\text{normal tire pressure in lb per sq in.}}{2}$$

weight factor: 15,000 lb per axle or greater = 1.0
12,500 to 14,999 lb = 0.9
10,000 to 12,499 lb = 0.8
7,500 to 9,999 lb = 0.7
less than 7,500 lb = 0.6

$$\text{tire factor: single tire} = \frac{\text{width in in.}}{100}$$

$$\text{dual tire} = \frac{1.5 \times \text{width in in.}}{100}$$

$$\text{axle load} = \frac{\text{axle load in lb}}{1000}$$

clearance = clearance in in.

Tactical Mapping of Fine-grained Soils and Sands with Fines, Poorly Drained

Mapping of measured trafficability factors

127. This section discusses mapping of fine-grained soils and sands with fines, poorly drained. Techniques for mapping coarse-grained soils probably will be similar, but details are not yet available. Since vehicle cone indexes vary widely, it is desirable to present the basic terrain data in such form that direct comparison with vehicle cone indexes may be made. The four basic factors in describing trafficability are soil type, rating cone index, slope, and slipperiness. Soil type may be shown by a letter symbol (as described in paragraph 147), cone index by a single value, slope by a number indicating ruling grade in per cent, and slipperiness by a letter (paragraph 101). (Stickiness effects are not considered serious enough to include on maps.) The four factors may be presented in "fractional" form, with two items in the

"numerator" and two in the "denominator." For example, in $\frac{B - 80}{25 - S}$, B is the soil type (see paragraph 147), 80 is the rating cone index, the ruling grade is 25 per cent, and the surface is slippery. It thus becomes apparent that the area is trafficable for wheeled vehicles with vehicle cone indexes less than 63 (80-17 (the excess required for the slope, see plate 6)), for conventional tracked vehicles with vehicle cone indexes less than 67 (80-13), and for long-grousered tracked vehicles with vehicle cone indexes less than 69 (80-11). It also is seen that the slopes will be slippery. The operations officer should order all trucks fitted with chains and should expect some sliding and steering difficulty from all vehicles. The photo map (fig. 8) shows how areas can be delineated in this fashion.

Illustrative problem

128. Problem. It is desired to move part of a medium tank company from X to Y (fig. 8). Movement must be cross-country since the road net in the area is heavily mined. The vehicles to be moved include 17 M26 medium tanks (86,500 lb), two 2-1/2-ton cargo trucks (15,700 lb), and two 1-ton, two-wheel cargo trailers (3,300 lb). Trafficability data consisting of soil types, rating cone indexes, maximum slopes, and slipperiness conditions have been measured and are shown on fig. 8.

129. Solution. Refer to the appendix for vehicle cone index requirements for the vehicles concerned and compute requirements for one pass (0.75 x minimum requirements).

Vehicle	Vehicle Cone Index	Cone Index for One Pass
Tank	61	46
Truck	68	51
Trailer	91	68

130. Examine possibility of travel through flat terrain. All vehicles can negotiate areas 1 and 6. However, it will be noted that the 50 cone index and slipperiness of area 3 will not assure the passage of any of the tank company vehicles, except that M26 tanks probably can negotiate one pass by traveling carefully. If the situation requires it, one or possibly two tanks may proceed in the same ruts from X

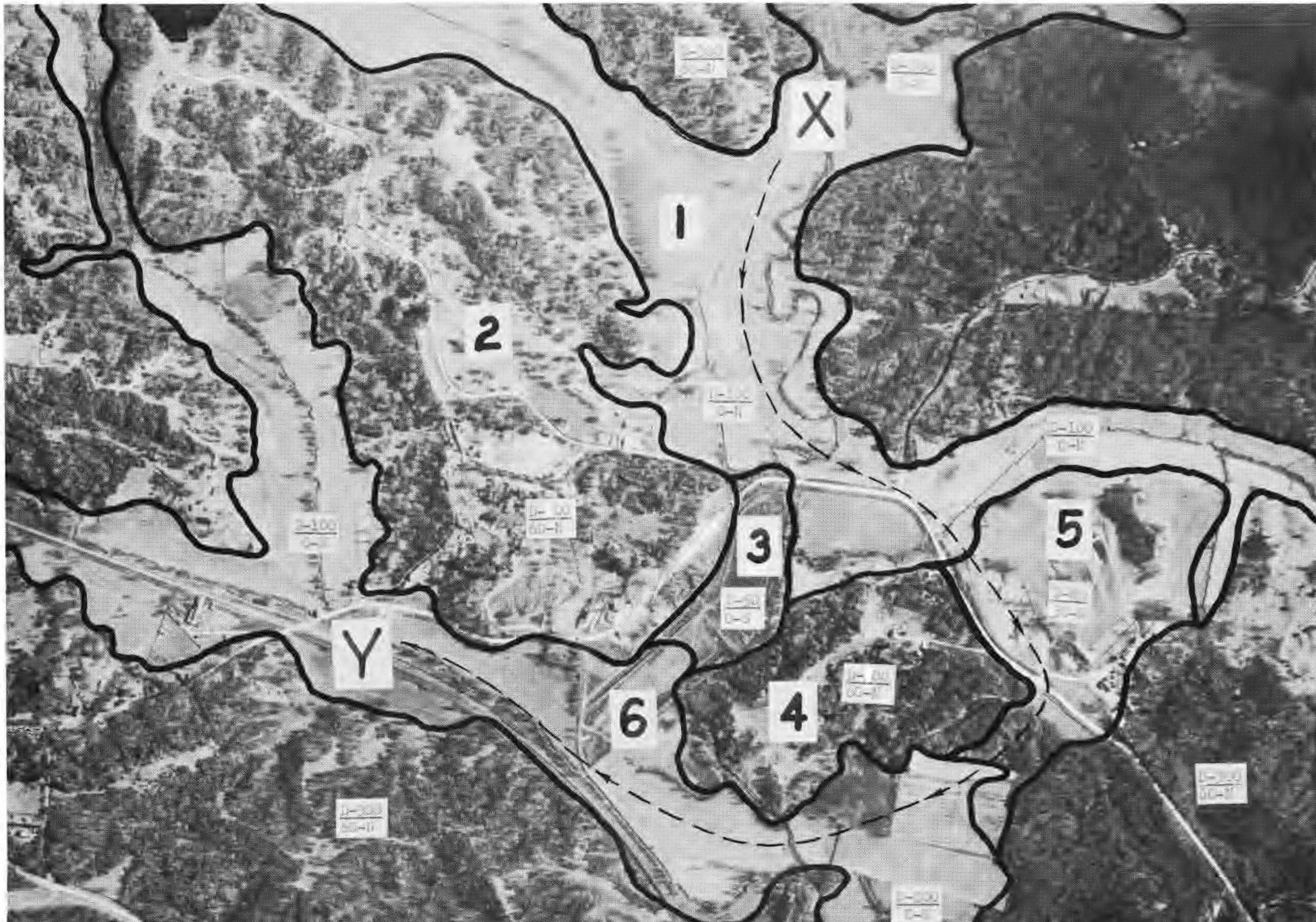


Fig. 8. Photomap with trafficability data added

through area 1, area 3, and through area 6 to Y, but this route could not be used for all the vehicles unless they fanned out.

131. Check possibility of the tank, the vehicle with the lowest cone index requirement and best slope climbing characteristics, traveling through area 2 or area 4. Refer to middle curve of plate 6, 100 - 61 = 39. Read 53 per cent slope at +39 cone index. The M26 cannot negotiate area 2 or area 4 (slope of 60 per cent).

132. Check possibility of travel through area 5. Refer to middle curve of plate 6. For M26, 80 - 61 = +19. At +19 cone index, read 36 per cent slope. The M26 can negotiate area 5 (slope of 30 per cent). For truck, 80 - 68 = 12. At +12 cone index, read 19 per cent slope on bottom curve. Truck cannot negotiate area 5.

133. Check possibility of using the M26 to tow truck and trailer assuming dead engine on truck. Compute towing force required, T_2, from plate 5. Truck at cone index 80 requires 0.25 x 15,700 lb = 3,900 lb. Trailer requires 0.23 x 3,300 = 800 lb. 3,900 + 800 = 4,700, total towing force required, T_2. Using plate 6, the maximum towing force of the M26 (at +19 cone index) = 0.36 x 86,500 = 31,200 lb. Substituting in

$$\frac{T_1 - T_2}{W_1 + W_2} = \frac{31{,}200 - 4{,}700}{86{,}500 + 15{,}700 + 3{,}300} = \frac{26{,}500}{105{,}500} = 0.25 = 25$$

per cent slope. Since slopes to be negotiated are 30 per cent, the M26 towing the truck and trailer cannot negotiate area 5.

134. Check possibility of same combination, assuming truck engine is operating. The negative 3,900 lb in paragraph 133 becomes a positive 0.19 (from plate 6 at +12 cone index) x 15,700 = 3,000 lb and the figures

for this case are $\frac{31{,}200 + 3{,}000 - 800}{86{,}500 + 15{,}700 + 3{,}300} = \frac{33{,}400}{105{,}500} = 0.32$ or 32

per cent. This combination can traverse area 5.

135. The only route by which all the vehicles can be moved from X to Y is through areas 1, 5 (tank towing operating truck and trailer), and 6 in that order. Therefore, it is recommended that the path indicated by the dashed line on fig. 8 be followed in moving the company.

136. Although use of a tank to pull a truck and trailer may not be common, the example shows how vehicle combinations can be used if imagination and ingenuity are exercised.

Classification of Vehicles in Sands

137. A comprehensive scheme for classifying military vehicles according to their performance in sands (and other coarse-grained soils) is not now available. Future testing will be directed toward collection of data that will permit a reasonable basis for classifying vehicle performance in sand.

138. Sands present far fewer trafficability problems than do fine-grained soils or sands with fines, poorly drained. The following statements may be used for judging the performance of vehicles on sands, until such time as additional data permit more specific rules.

Tracked vehicles

139. Regardless of initial cone index (or other measures of soil strength) military tracked vehicles can negotiate level sands (except those in a quick or near-quick condition) without difficulty. On the basis of the testing done to date, it is estimated that a given tracked vehicle can climb a slope or pull a tow load of about 75 to 85 per cent of the slope or tow load it can attain on the firmest fine-grained soils, except on extremely loose sands (cone index below 30). Where sands are very firm, as they are when moist or when stabilized by vegetation, and cone index readings are in excess of 150, the performance on sands will be comparable to that on the firmest fine-grained soils.

Wheeled vehicles

140. Tire pressure plays an extremely important role in the performance of a vehicle on sands, as can be seen from an inspection of plates 7-12. If a truck is equipped with high flotation tires operated at very low pressure (10 to 15 psi) it is considered that the truck can negotiate any smooth, level stretch of dry or moist sand. However, operation in many very loose dry sands will be extremely critical to driver influence and irregularities in the surface. The driver should in these

cases minimize acceleration of the truck, make very shallow turns, and avoid spots where the surface is irregular. Slope climbing ability and load towing ability may be judged approximately from the curves shown on plates 7-12.

PART V: TRAFFICABILITY PROCEDURES FOR STRATEGIC PURPOSES

Estimating Trafficability

141. Trafficability analysis for strategic purposes may be made well in advance of a proposed operation and without actual contact with the area. An estimate of trafficability can be made if something is known of the general weather conditions, soils, and topography of the area. Information about weather and climate usually is available, even for remote areas, from meteorological records, climatology textbooks, or interrogation of prisoners. Soils and topography data may be obtained from topographic maps, soil maps, geologic maps, aerial photographs, or interrogation. The accuracy of a trafficability estimate will depend on the type, quantity, and accuracy of the data available. It also will depend largely on the ability of the analyst to interpret these data, especially if soil types must be deduced from geologic maps or airphotos. The techniques of such interpretation are beyond the scope of this report and will be discussed only briefly.

Weather conditions

142. It is feasible to consider only two general conditions of weather as it applies to trafficability estimates. These conditions are referred to as "dry period" and "wet period," and are defined below.

143. Dry period. A dry period is defined as a time when climatic and vegetal factors combine to produce soil moistures that are generally low. For temperate, humid climates north of the equator, such as that in the United States east of the Mississippi River, the dry period is from about 1 May to 1 November, when evaporation of water from the soil is high because of long days, high temperatures, and few clouds, and when water is being rapidly extracted from the soil and transpired to the atmosphere by growing plants. A dry period also may occur at other times of the year as a result of long spells of fair weather. Areas in arid climates may be said to be constantly in a dry period.

144. Wet period. A wet period is one in which the combination of pertinent factors serves to produce generally high soil moistures. In

temperate, humid climates north of the equator this period extends from about 1 November to 1 May. During this time frequent rains, low temperatures, heavy cloud cover, and absence of growing plants tend to keep soil moisture high and constant near a maximum value. Wet periods may occur at other seasons as a result of long-enduring rains, floods, or irrigation.

145. Trafficability in dry period. During a dry period all soils will usually be passable unless they are low-lying and poorly drained, or are wet by underground springs or there is a high water table for any other reason.

146. Trafficability in wet period. Moisture added to a soil immediately causes changes in its strength. Different soils are affected differently by moisture. During a wet period all soils with the exception of clean sands and gravels should be suspected of poor trafficability. The relative trafficability ratings of soil types are described in the next paragraph.

Soil types and trafficability ratings

147. Soils may be divided into four general groups from the standpoint of their trafficability (particularly during a wet period) and rated with respect to each other in the following order: A, B, C, and D. The soils within each group are listed in approximate order of their trafficability. The letter symbols (GW, CH, etc.) are the same as employed in the Unified Soil Classification System.

Group	Soils
A	Well-graded gravels (GW), poorly graded gravels (GP), well-graded sands (SW), and poorly graded sands (SP).
B	Inorganic clays of high plasticity, fat clays (CH).
C	Clayey gravels (GC), clayey sands (SC), and CL soils (gravelly clays, sandy clays, inorganic clays of low to medium plasticity, lean clays, and silty clays).
D	Silty gravels (GM), silty sands (SM), ML and CL-ML soils (inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity), MH soils (inorganic silts, micaceous or diatomaceous fine sandy or silty soils and elastic silts), OL soils (organic silts and organic silty clays of low plasticity), and OH soils (organic clays of medium to high plasticity and organic silts).

Peat, muck, swamp soils, etc., are not classified in the list on the preceding page since such soils are practically always impassable for all except light amphibious-type vehicles.

Estimates of cone indexes and remolding indexes

148. Table 3 contains a summary of the four groups, the soils included in each, estimates of cone index, remolding index, rating cone index, and slipperiness and stickiness effects, and general comments on trafficability, for the wet season.

Topography

149. The effects of slopes on soil requirements for vehicle performance can be shown in quantitative units when actual measurements of cone index can be made, but in estimates of trafficability only general statements concerning slopes are feasible. It is well to remember that slopes do require better soil conditions for vehicle support than does similar level terrain, that ridges will generally be more trafficable than adjacent valleys, and that downhill travel is easier than uphill travel, etc.

Use of soil maps

150. Maps which delineate surface soils according to their Unified Soil Classification can be used readily to make estimates of trafficability by employing the information contained in paragraphs 142-149. However, maps of this type are scarce, and the more common types of soil maps are those employing an agricultural system of soil classification. These agricultural maps must first be translated into engineering terms before a trafficability estimate can be made. No exact method exists for doing this, but analysts familiar with the two systems of classification can usually make good comparisons. A compilation of soils in engineering terms (Unified Soil Classification System) and their approximate equivalents under the U. S. Department of Agriculture System (based on data collected by the Waterways Experiment Station) is shown in table 4.

Use of geologic maps

151. Soils are formed by the action of five factors: parent

material, climate, age, topography, and vegetation. Given a geologic map for parent material and age data, and a general knowledge of the other three factors, trained analysts can estimate the soil types likely to occur in the area.

Use of aerial photographs

152. The full utilization of aerial photographs in estimating trafficability is presently being studied. It is expected that a bulletin on the subject will be published in the future. In the interim, a few notes concerning the use of aerial photographs are given below.

153. Topography. Airphotos are a good source of topographic information. Estimates of elevations and slopes can be determined from stereopairs by personnel after a minimum of instruction. Accurate elevations and slopes can be obtained by trained operators using mechanical equipment such as Multiplex and Kelch plotters.

154. Obstacles. Aerial photographs are an excellent means of identifying such obstacles as rivers, forests, escarpments, embankments, etc.

155. Soils and moisture conditions. In the present stage of development, the techniques for identifying soils from airphotos are so complex that only well-trained technicians can employ them to their fullest extent. However, certain general facts may be used to advantage by personnel with a minimum of training. For instance, orchards usually are planted in well-drained, sandy soils; vertical cuts are an evidence of deep loessial (silty) soils; tile drains in agricultural areas indicate the presence of poorly drained soils, probably silts and clays. On a given photograph, light color tones generally signify higher elevations, sandier soils, and lower moisture contents than do dark color tones. It is cautioned that the same color tone sometimes will not even signify exactly the same conditions throughout the same photograph, and may have entirely different significance on two separate photographs. Also, natural tones are apt to be obscured and modified by tones created by vegetation (natural and cultivated), plowed fields, and shadows of clouds.

Strategic Mapping

156. The presentation of trafficability data for strategic purposes is best done for a single vehicle. The medium tank, M48, with a vehicle cone index of 62 is generally selected as standard; conditions for other vehicles should be specified whenever it is feasible to do so. In general, the statements concerning trafficability are also applicable to all vehicles with vehicle cone indexes of 62 or less. The following paragraphs recommend certain techniques of mapping.

Mapping techniques

157. Base. The base of the map should be a standard topographic map printed in a gray monochrome with streams in a strong blue.

158. Trafficability symbols. Five soil-slope combinations should be shown according to the following tabulation.

a. Soil-slope condition.

Dry Period	Wet Period	Letter Symbol	Color
Passable	Passable	A	Dark green
Passable	Doubtful or impassable	B	Light green
Doubtful	Doubtful or impassable	C	Orange
Impassable	Impassable	D	Red
Generally impassable because of steep slopes or rough ground. Soils not evaluated		E	Red stripes

b. Special references to obstacles, etc., should be indicated by red numbers circled in red.

159. Forests. Forests should be shown by appropriate open-type patterns in strong green.

160. Back of map. The reverse side of the trafficability map should contain an inset map of the principal physiographic provinces, land forms, geologic areas, etc., which were used in making the analysis and should expand in detail important data on soils, topography, obstacles,

etc., which cannot readily be shown on the face of the map.

Example

161. Plate 14 is offered as an example of strategic trafficability mapping. This plate is inclosed in the pocket on the back cover of this report.

PART VI: SUMMARY OF IMPORTANT FINDINGS IN TRAFFICABILITY INVESTIGATIONS THROUGH CALENDAR YEAR 1955

Fine-grained Soils and Sands with Fines, Poorly Drained

162. The repetitive traffic of tracked and wheeled self-propelled and towed military vehicles can be predicted from measurements of cone index and remolding index. Cone index multiplied by remolding index gives rating cone index, a single number which is compared with the vehicle cone index, the minimum soil strength required for the vehicle. The test to determine remolding index differs slightly for fine-grained soils and sands with fines, poorly drained.

163. Charts are available which permit estimation of the maximum slope a vehicle can climb, the maximum load it can tow, and the towing force required to tow it when rating cone index, vehicle cone index, and vehicle weight are known.

164. An empirical comparison of various physical characteristics of vehicles and the performance ability of the vehicle has permitted evolution of formulas for the computation of vehicle cone index for all military vehicles.

165. Data from hundreds of tests in many soils have permitted the development of a scheme for classifying soils from the trafficability standpoint according to their names under the Unified Soil Classification System.

166. Methods for applying trafficability principles in the field have been developed and systems for mapping of trafficability conditions evolved.

Sands

167. Only a limited amount of testing has been done with vehicles in coarse-grained soils, all of which was done on quartz sands. This work shows that cone index is a reasonable indication of soil strength required for vehicles in sands when tire pressure (of wheeled vehicles)

is considered. Additional studies on sands and other coarse-grained materials are needed to develop data on slope-climbing and towing ability of tracked and wheeled vehicles to permit classification of the vehicles according to their physical characteristics, and to form the basis for mapping techniques.

Table 1

Vehicle Data

Self-propelled Vehicles Tracked	Index Photo	Index Fig.	Test Weight lb	Tracks Contact Length in.	Tracks Width in.	Tracks Shoe Length in.	Contact Pressure psi	Bogies per side	Clearance in.	Engine Brake hp	Transmission Type *	Remarks
M29C cargo carrier (weasel)	8	4	5,640	78	20	4-1/4	1.8	8	10	65	M	
Canadian penguin**			8,800	93	31-1/2		1.5	4				Estimated data. Bogies are dual
M76 amphibious cargo carrier (otter)	6	3	12,200	96-1/2	30	4	2.1	4	17	127	M	
D4 engineer tractor‖	1	1	13,300	62	13	6-1/2	8.2	6	11	44	M	
D4 Trackson tractor†			16,900	79-1/2	15	7	7.1	7	11	41	M	
TD14 engineer tractor‡‖			21,600	78-1/2	18	6	7.6	6	9	54	M	Shoe length and number of bogies estimated. Tested with 60-in. extensions bolted to tracks
M5 hi-speed tractor	2	2	27,000	108	12	5-1/2	10.4	5	20	207	M	
D7 engineer tractor‖	1	3	32,350	97	22	8	7.6	7	14	126	M	Another D7 weighing 23,600 lb was tested at Vicksburg in 1945. With 60-in. extensions its contact pressure was 2.5 psi. Without extensions its contact pressure was 6.3 psi
M4 hi-speed tractor	1	4	33,400	126	17	6	7.8	5	17	190	H	
LVT4 landing vehicle‖	9	1	33,400	139	14	8	8.6	9	15	250	M	
Special D7 engineer tractor§			34,800	113	32	8	4.8	7	14	126	M	Track length computed from gross weight, contact pressure, and track width
M24 light tank	7	2	36,800	102	16	5-1/2	11.3	5	18	220	H	Has 2 engines at 110 hp each
M4A1 hi-speed tractor	2	1	37,100	126	24	6	6.1	5	19	190	H	
T18E1 armored infantry vehicle	6	4	42,000	120	21	6	8.3	5	18	295	H	
D8 engineer tractor‖	1	2	44,000	98	22	8	10.2	8	10-1/2	126	M	With 60-in. extensions the contact pressure was 3.7 psi. Track length and width are estimated
M8 cargo tractor carrier	2	4	49,700	151	21	6	7.8	6	14	450	M	
T41E1 light tank	7	1	50,800	128	21	6	9.5	5	17	500	H	
M4 medium tank	8	2	67,700	147	16-9/16	6	13.9	6	17	350	M	
M6 hi-speed tractor	2	3	74,300	178	22	6	9.5	7	20	380	H	Has 2 engines at 190 hp each
M26 medium tank	8	3	92,000	150	23	6	13.3	6	18	500	H	
M46 medium tank	8	1	97,000	160	23	6	13.2	6	19	810	H	
M47 medium tank	7	4	97,200	154	23	6	13.7	6	19	810	H	
T48 medium tank	7	3	98,400	157-1/2	28	7	11.2	6	19	810	H	
T92 240mm howitzer	9	2	124,700	178	28	6	12.5	7	15	500	H	
T28 super heavy tank**			188,000	210	20	6	11.2	8	14	500	M	Shoe length estimated. Double tracks on each side. Contact area = 2(210x20x2) = 16,800 sq in.

Self-propelled Vehicles Wheeled	Index Photo	Index Fig.	Test Weight lb	Tires No.	Tires Size	Contact Pressure Factor	Clearance in.	Engine Brake hp	Transmission Type *	Remarks
M38 1/4-ton truck (jeep) 4x4	3	1	3,500	4	7.00x16	7.8	9	51	M	
M37 3/4-ton truck (weapons carrier) 4x4	3	2	7,400	4	9.00x16	12.8	11	78	M	
Standard 2-1/2-ton truck 6x6	3	3	16,300	6	10.50x18	14.4	10	87	M	
CCKW353 2-1/2-ton truck 6x6	4	4	16,600	10	7.50x20	11.1	10	91-1/2	M	
M34 2-1/2-ton truck 6x6	4	2	17,500	6	11.00x20	13.3	12-1/2	127	M	
M135 2-1/2-ton truck 6x6	4	3	17,700	6	11.00x20	13.4	12-1/2	130	H	
M47 2-1/2-ton dump truck (loaded) 6x6	5	1	18,500	6	11.00x20	14.0	14	127	M	Also tested empty at 13,500 lb. Contact pressure factor = 10.2
M211 2-1/2-ton truck 6x6	5	3	18,900	10	9.00x20	10.5	12	130	H	
M35 2-1/2-ton wrecker 6x6	5	2	19,800	10	9.00x20	11.0	12	127	M	
DUKW353 2-1/2-ton amphibious truck (loaded) 6x6	5	4	20,100	6	11.00x18	16.9	11-1/2	91-1/2	M	Also tested empty at 15,100 lb. Contact pressure factor = 12.7
4-ton truck 6x6	3	4	25,100	6	14.00x20	14.9	15	112	M	
M41 5-ton truck 6x6	6	1	29,800	6	14.00x20	17.7	13	196	M	
M62 5-ton wrecker 6x6	6	2	33,300	10	11.00x20	15.1	10	224	M	
6-ton truck 6x6	4	1	34,800	6	14.00x20	20.7	13	202	M	

Towed Vehicles, Tracked	Index Photo	Index Fig.	Test Weight lb	Tracks Contact Length in.	Tracks Width in.	Tracks Shoe Length in.	Contact Pressure psi	Bogies per side	Clearance in.	Remarks
Athey wagon	10	3	13,500	48	30	6.75	4.7	2	15	With 6,000-lb load. Also tested with 12,000-lb and 18,000-lb loads

Towed Vehicles, Wheeled	Index Photo	Index Fig.	Weight Test	Weight Per Axle	Weight Factor	Contact Pressure psi	Contact Pressure Factor	Tires Width in.	Tires Type ¶	Tires No.	Tires Factor	Axles No.	Axles Load kip	Clearance in.	Remarks
M21 ammunition trailer	9	4	9,300	9,300	0.7	60	30.0	14	S	2	.14	1	9	13	With 4,000-lb load. Also tested with 8,000-lb and 12,000-lb loads
M1 155mm howitzer	9	3	12,800	12,800	0.9	55	27.5	14	S	2	.14	1	13	14	Tested with and without sleds
M1A1 90mm gun mount	10	1	18,700	18,700	1.0	70	35.0	10	D	4	.15	1	19	12	Tested with and without sleds
M2 90mm AA gun mount	10	2	32,000	16,000	1.0	65	32.5	14	S	4	.14	2	16	15	Tested with and without sleds

Towed Vehicles, Sleds	Index Photo	Index Fig.	Test Weight lb	Size Length, ft Total	Size Length, ft Contact	Size Width ft	Remarks
Engineer Board sled	10	4	1,800	18.4	15.0	7.0	Tested with loaded weights of 4,000, 6,000, 8,000, and 12,000 lb

* M = mechanical; H = hydraulic.
** Not shown.
† Not shown. Similar to D4 except equipped with overhead hydraulic loading shovel and no grousers on tracks.
‡ Not shown. Similar to D4.
§ Not shown. Similar to D7 but had 32 in. tracks.
¶ S = single; D = dual.
‖ These vehicles are equipped with grousers more than 1.5 in. high, grouser factor = 1.1. Other vehicles, not noted in this manner, have grousers less than 1.5 in. high, grouser factor = 1.0.

Table 2

Summary of Tests Conducted

Vehicle	Tracked	Wheeled	Prepared Lanes: Level: Fine-grained	Prepared Lanes: Level: Coarse-grained	Prepared Lanes: Slope: Fine-grained	Prepared Lanes: Slope: Coarse-grained	Prepared Lanes: Slope: As-phalt	Prepared Lanes: Total	Natural Soils: Level: Fine-grained	Natural Soils: Level: Coarse-grained	Natural Soils: Level: Mus-keg	Natural Soils: Slope: Fine-grained	Natural Soils: Slope: Coarse-grained	Natural Soils: Total	Total	Remarks
Towing Tests																
M29C cargo carrier (weasel)	X		15					15							15	
D4 engineer tractor	X		28	9				37							37	
M5 hi-speed tractor	X		29	5				34							34	
D7 engineer tractor	X		39	7	1			47							47	
M4 hi-speed tractor	X		28	9				37							37	
LVT4 landing vehicle	X		14		1			15							15	
M4A1 hi-speed tractor	X		26	6				32							32	
M6 hi-speed tractor	X		27	8				35							35	
2-1/2-ton truck 6x6		X	20					20							20	
Total			226	44	2			272							272	
Nontowing Tests Straight-line Repeated Traffic																
M29C cargo carrier (weasel)	X		3	5				8	3		3			6	14	
Canadian penguin	X										1			1	1	
M76 amphibious cargo carrier (otter)	X								1					1	1	
D4 engineer tractor	X											1		1	1	
D4 Trackson tractor	X								4	1				5	5	
TD14 engineer tractor	X		1					1							1	
D7 engineer tractor	X		11					11	9		2	19	6	36	47	
LVT4 landing vehicle	X		10	6				16				2		2	18	
Special D7 engineer tractor	X		6					6							6	
M24 light tank	X		10	6				16	44	2		13		59	75	
M4A1 hi-speed tractor	X											1		1	1	
T18E1 armored infantry vehicle	X								5					5	5	
D8 engineer tractor	X		21		2			23							23	
M8 cargo tractor	X		4	1				5							5	
T41E1 light tank	X								2					2	2	
M4 medium tank	X												6	6	6	
M26 medium tank	X		18	7				25							25	
M46 medium tank	X								2					2	2	
M47 medium tank	X								12	4				16	16	
T48 medium tank	X								2					2	2	
T92 240mm howitzer	X		9	4				13							13	
T28 super heavy tank	X			2				2							2	
M38 1/4-ton truck (jeep) 4x4		X							1	1			3	5	5	
M37 3/4-ton truck (weapons carrier) 4x4		X							2	7			18	27	27	
Standard 2-1/2-ton truck 6x6		X	50	7			1	58	61	5		17	21	104	162	Tested with and without chains
CCKW353 2-1/2-ton truck 6x6		X								18			16	34	34	
M34 2-1/2-ton truck 6x6		X							3	8			13	24	24	
M135 2-1/2-ton truck 6x6		X				55		55	6	7			60	73	128	
M47 2-1/2-ton dump truck 6x6, empty		X								5				5	5	
M47 2-1/2-ton dump truck 6x6, loaded		X								10				10	10	
M211 2-1/2-ton truck 6x6		X				45		45		1			1	2	47	
M35 2-1/2-ton wrecker 6x6		X											3	3	3	
DUKW353 2-1/2-ton amphibious truck 6x6, empty		X								2			6	8	8	
DUKW353 2-1/2-ton amphibious truck 6x6, loaded		X								1			13	14	14	
4-ton truck 6x6		X	73	6				79				1	1	2	81	Tested with and without chains
M41 5-ton truck 6x6		X							1	6				7	7	
M62 5-ton wrecker 6x6		X							1	2			2	5	5	
6-ton truck 6x6		X	73	5	2			80							80	Tested with and without chains
Total			289	49	4	100	1	443	159	80	6	54	169	468	911	

(Continued)

Table 2 (Continued)

Vehicle	Tracked	Wheeled	Prepared Lanes: Level: Fine-grained	Prepared Lanes: Level: Coarse-grained	Prepared Lanes: Slope: Fine-grained	Prepared Lanes: Slope: Coarse-grained	Prepared Lanes: Slope: As-phalt	Prepared Lanes: Total	Natural Soils: Level: Fine-grained	Natural Soils: Level: Coarse-grained	Natural Soils: Level: Mus-keg	Natural Soils: Slope: Fine-grained	Natural Soils: Slope: Coarse-grained	Natural Soils: Total	Total	Remarks
Maneuver Tests																
M24 light tank	X								7					7	7	Includes turnaround, zig-zag,
M6 hi-speed tractor	X								5			1		6	6	coverage, and circle tests
Standard 2-1/2-ton truck 6x6		X							4					4	4	Tested with and without chains
Total									16			1		17	17	
Towed Vehicle Tests Towed Vehicle Only, in Lane																
Athey wagon	X		29	6				35							35	6,000-, 12,000-, and 18,000-lb load
M21 ammunition trailer		X	63	13				76							76	4,000-, 8,000-, and 12,000-lb load
M1 155mm howitzer		X	13					13							13	Tested with and without sleds
2-1/2-ton truck 6x6		X	3					3							3	5,000-lb load
4-ton truck 6x6		X	4					4							4	8,000-lb load
M1A1 90mm gun mount		X	5					5							5	Tested with and without sleds
M2 90mm AA gun mount		X	13					13							13	Tested with and without sleds
Engineer Board sled			51					51							51	4,000-, 8,000-, and 12,000-lb load
Subtotal			181	19				200							200	
Towing and Towed Vehicles (Train) in Lane																
D8 + 2 Athey wagons	X		13					13							13	
D8 + Mud sled	X		4					4							4	
D7 + 2 Athey wagons	X		8					8							8	
Special D7 + Mud sled	X		4					4							4	
Special D7 + 2 Athey wagons	X		2					2							2	
Subtotal			31					31							31	
Total			212	19				231							231	
Grand Total			727	112	6	100	1	946	175	80	6	55	169	485	1431	

Table 3

Trafficability Characteristics of Soils in Wet Season

Group	Soils	Unified Soil Classification System	Probable Cone Index Range	Probable Remolding Index Range	Probable Rating Cone Index Range	Slipperiness Effects	Stickiness Effects	Comments
A	Coarse-grained, cohesionless sands and gravels	GW, GP, SW, SP	80 to 300	>1	80 to 300	Slight to none	None	Will support continuous traffic of military vehicles with tracks or with high-flotation tires. Moist sands are good, dry sands only fair. Wheeled vehicles with standard tires may be immobilized in dry sands.
B	Inorganic clays of high plasticity, fat clays	CH	55 to 165	0.75 to 1.35	65 to 140	Severe to slight	Severe to slight	Usually will support more than 50 passes of military vehicles. Going will be difficult at times
C	Clayey gravels, gravel-sand-clay mixtures Clayey sands, sand-clay mixtures Gravelly clays, sandy clays, inorganic clays of low to medium plasticity, lean clays, silty clays	GC SC CL	85 to 175	0.45 to 0.75	45 to 125	Severe to slight	Moderate to slight	Often will not support 40 to 50 passes of military vehicles, but usually will support limited traffic. Going will be difficult in most cases.
D	Silty gravels, gravel-sand-silt mixtures Silty sands, sand-silt mixtures Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts Organic silts and organic silty clays of low plasticity Organic clays of medium to high plasticity, organic silts	GM SM ML and CL-ML MH OL OH	85 to 180	0.25 to 0.85	25 to 120	Moderate to slight	Slight	Usually will not support 40 to 50 passes of military vehicles. Often will not permit even a single pass. Going will be difficult in most cases.

Table 4

Comparison of Engineer and Agricultural Grouping of Soil Classes

Trafficability Classification	Corps of Engineers Unified Soil Classification System: Symbol	Corps of Engineers Unified Soil Classification System: Typical Names	U. S. Department of Agriculture Soil Textural Classification — Basic Soil Textural Class Names and Symbols*: Sand S	Clay C	Silty Clay SiC	Silty Clay Loam SiCL	Clay Loam CL	Sandy Clay SC	Sandy Clay Loam SCL	Sandy Loam SL	Loamy Sand LS	Loam L	Silt Loam SiL	Silt Si
A	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	No agricultural soil class equivalent											
A	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	No agricultural soil class equivalent											
A	SW	Well-graded sands, gravelly sands, little or no fines	X											
A	SP	Poorly graded sands, gravelly sands, little or no fines	⊗											
B	CH	Inorganic clays of high plasticity, fat clays		⊗	⊗	X	X							
C	GC	Clayey gravels, gravel-sand-clay mixtures						X†	X†	X†				
C	SC	Clayey sands, sand-clay mixtures						⊗	⊗	X				
C	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays				⊗	⊗	X	X			X	X	
D	GM	Silty gravels, gravel-sand-silt mixtures	X†							X†	X†			
D	SM	Silty sands, sand-silt mixtures	X							⊗	⊗			
D	ML (ML-CL)	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity										⊗	⊗	⊗
D	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		X								X	X	
D	OL	Organic silts and organic silty clays of low plasticity										X	X	X
D	OH	Organic clays of medium to high plasticity, organic silts		X	X	X	X							

Note:

* Listed in approximate order from best to worst average trafficability conditions.

X Indicates the agricultural soil class and its most likely engineer soil class equivalent.

O Indicates the predominant equivalent.

† Indicates an equivalent class only when the agricultural soil is prefixed with the term gravelly, cobbly, or stony and the coarse aggregate (larger than #4 sieve) of such soil is greater than 50%.

Fig. 1. D4 engineer tractor

Fig. 2. D8 engineer tractor (with extensions)

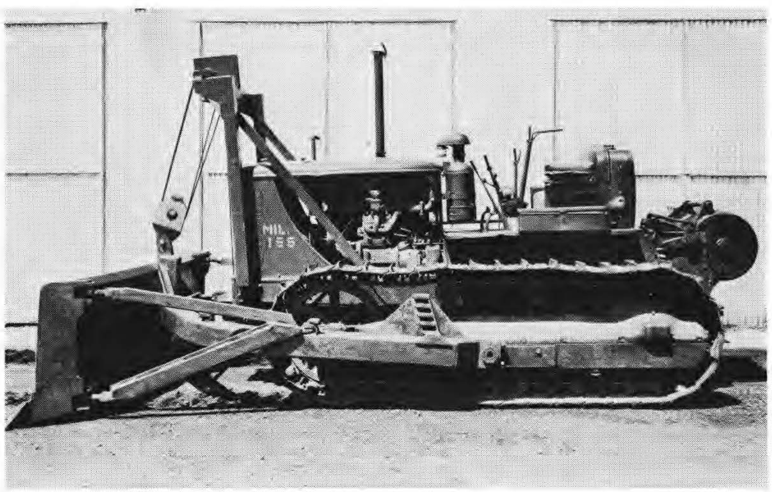


Fig. 3. D7 engineer tractor

Fig. 4. M4 hi-speed tractor

Photograph 1. Self-propelled tracked vehicles (engineer and hi-speed tractors) used in tests

Fig. 1. M4A1 hi-speed tractor

Fig. 2. M5 hi-speed tractor

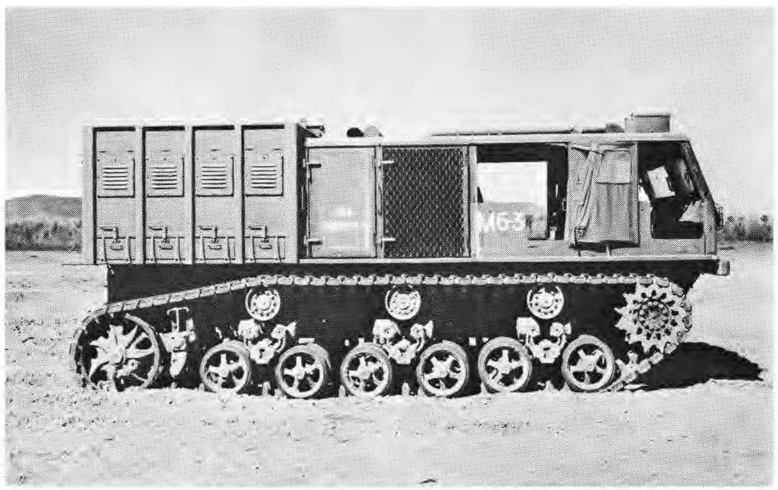


Fig. 3. M6 hi-speed tractor

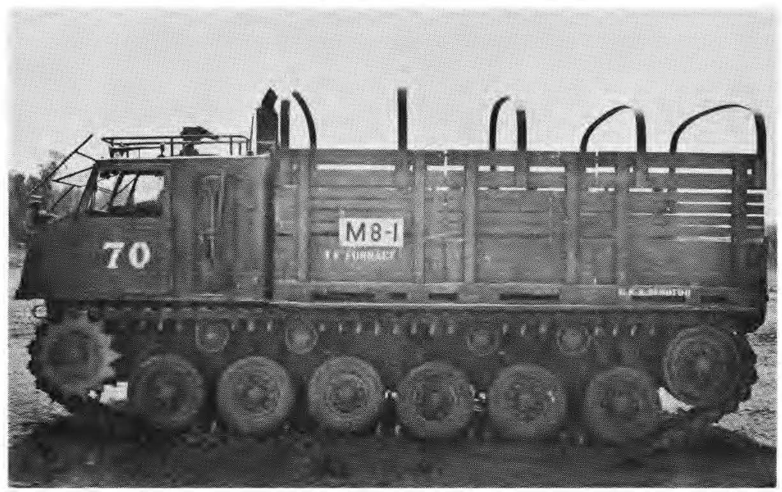


Fig. 4. M8 cargo tractor carrier

Photograph 2. Self-propelled tracked vehicles (hi-speed and cargo tractors) used in tests

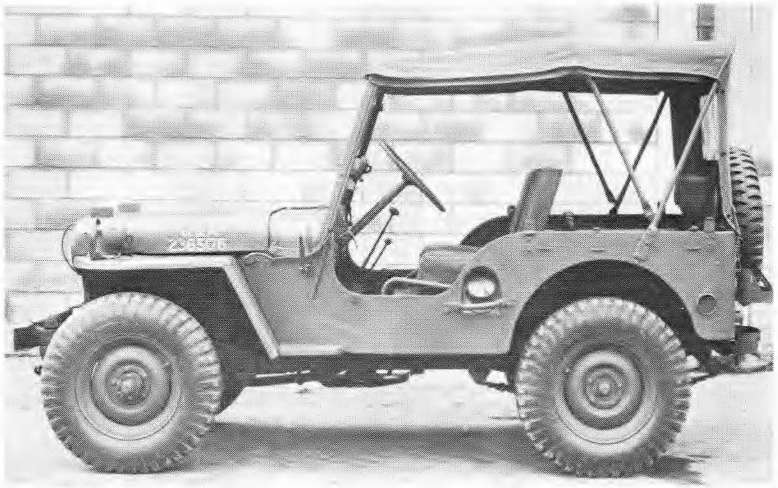


Fig. 1. M38 1/4-ton truck (jeep) 4x4

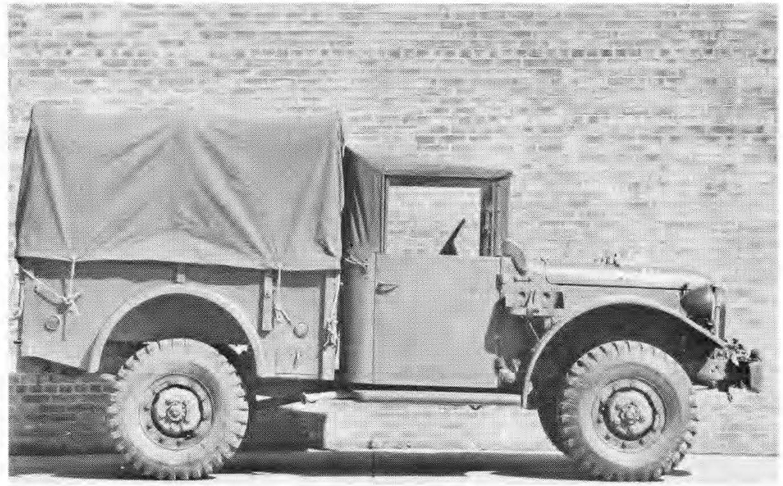


Fig. 2. M37 3/4-ton truck (weapons carrier) 4x4

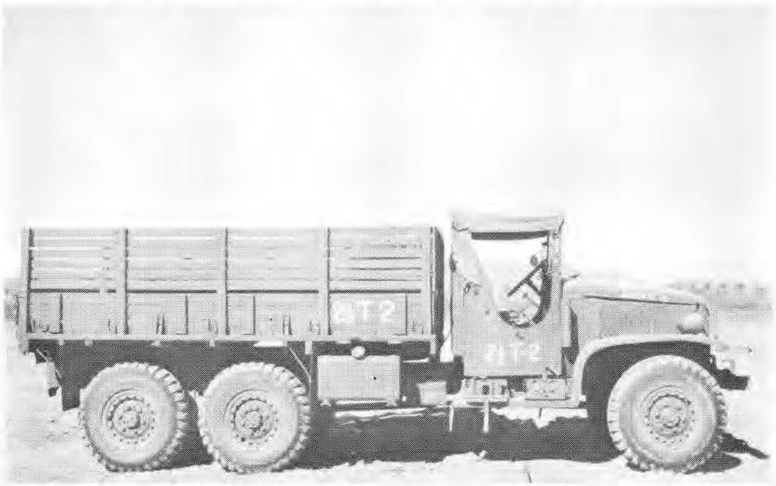


Fig. 3. Standard 2-1/2-ton truck 6x6

Fig. 4. 4-ton truck 6x6

Photograph 3. Self-propelled wheeled vehicles (4x4 and 6x6 trucks) used in tests

Fig. 1. 6-ton truck 6x6

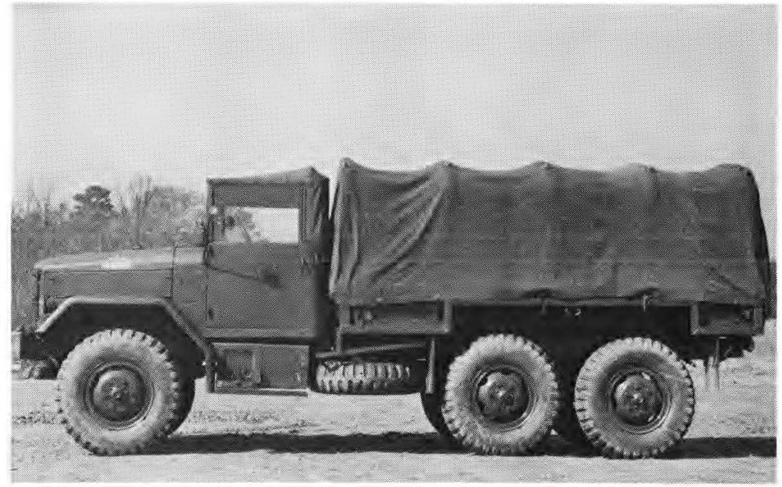


Fig. 2. M34 2-1/2-ton truck 6x6

Fig. 3. M135 2-1/2-ton truck 6x6

Fig. 4. CCKW 353 2-1/2-ton truck 6x6

Photograph 4. Self-propelled wheeled vehicles (6x6 trucks) used in tests

Fig. 1. M47 2-1/2-ton dump truck 6x6

Fig. 2. M35 2-1/2-ton wrecker 6x6

Fig. 3. M211 2-1/2-ton truck 6x6

Fig. 4. DUKW353 2-1/2-ton amphibious truck 6x6

Photograph 5. Self-propelled wheeled vehicles (6x6 trucks and wrecker) used in tests

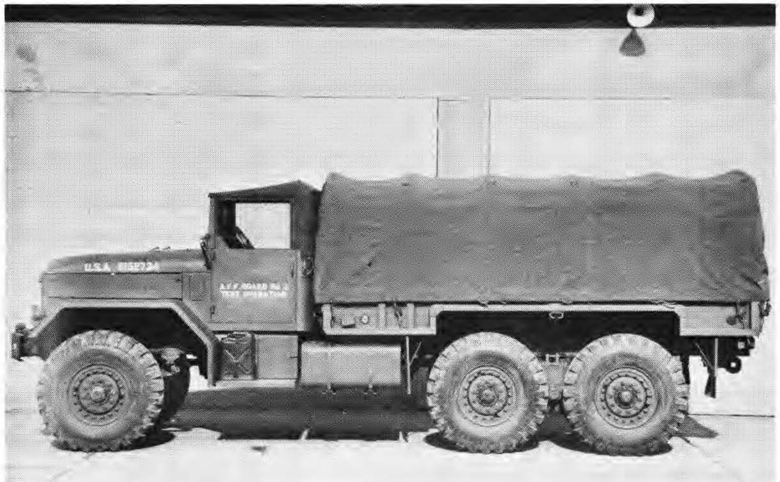


Fig. 1. M41 5-ton truck 6x6

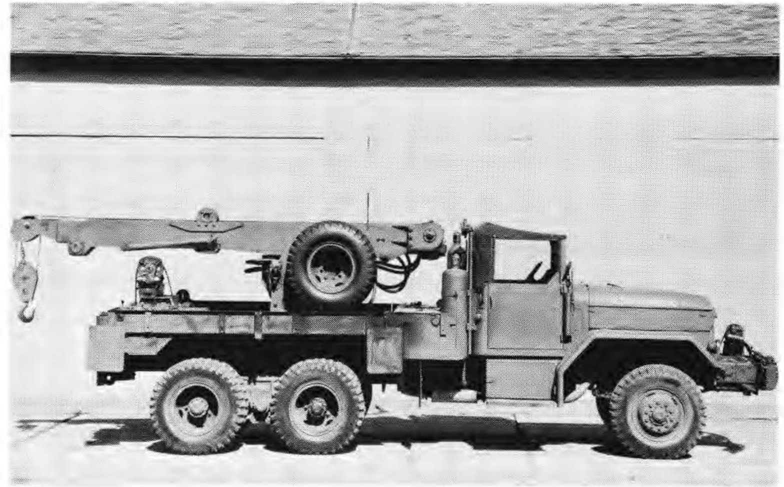


Fig. 2. M62 5-ton wrecker 6x6

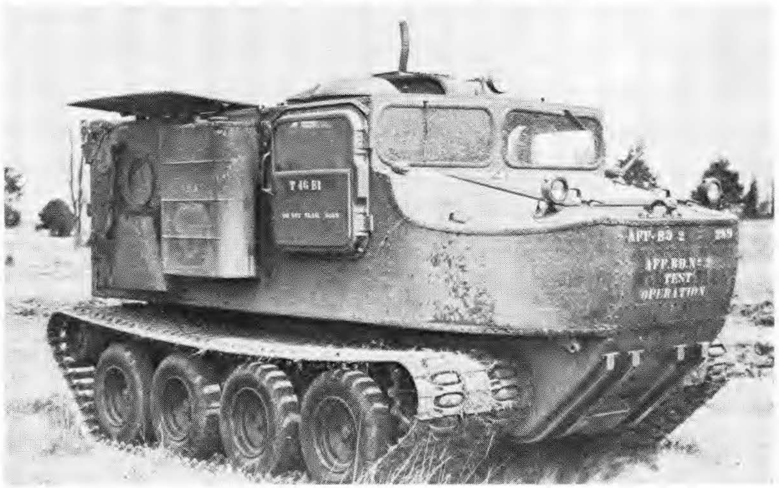


Fig. 3. M76 amphibious cargo carrier (otter)

Fig. 4. T18E1 armored infantry vehicle

Photograph 6. Self-propelled wheeled vehicles (6x6 truck and wrecker) and self-propelled tracked vehicles (cargo and personnel carriers) used in tests

Fig. 1. T41E1 light tank

Fig. 2. M24 light tank

Fig. 3. T48 medium tank

Fig. 4. M47 medium tank

Photograph 7. Self-propelled tracked vehicles (light and medium tanks) used in tests

Fig. 1. M46 medium tank

Fig. 2. M4 medium tank

Fig. 3. M26 medium tank

Fig. 4. M29C cargo carrier (weasel)

Photograph 8. Self-propelled tracked vehicles (medium tanks and cargo carriers) used in tests

Fig. 1. LVT4 landing vehicle

Fig. 2. T92 240mm howitzer

Fig. 3. M1 155mm howitzer

Fig. 4. M21 ammunition trailer

Photograph 9. Self-propelled tracked vehicles (landing vehicle and gun carriage) and towed wheeled vehicles (gun and ammunition trailers) used in tests

Fig. 1. M1A1 90mm gun mount

Fig. 2. M2 90mm AA gun mount

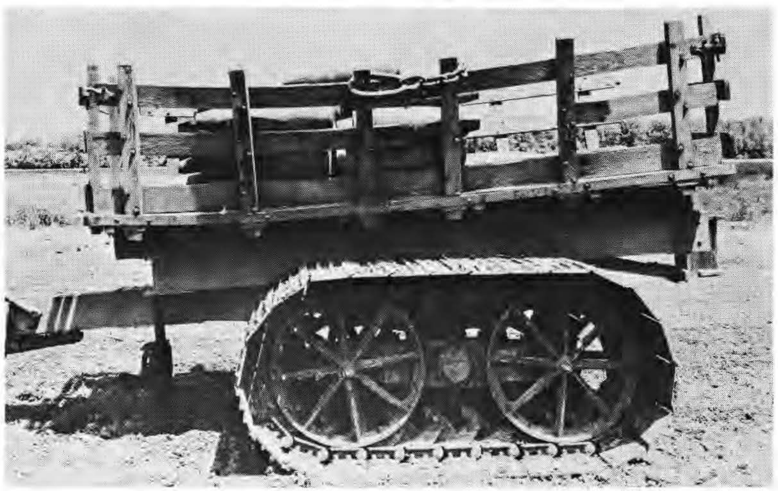
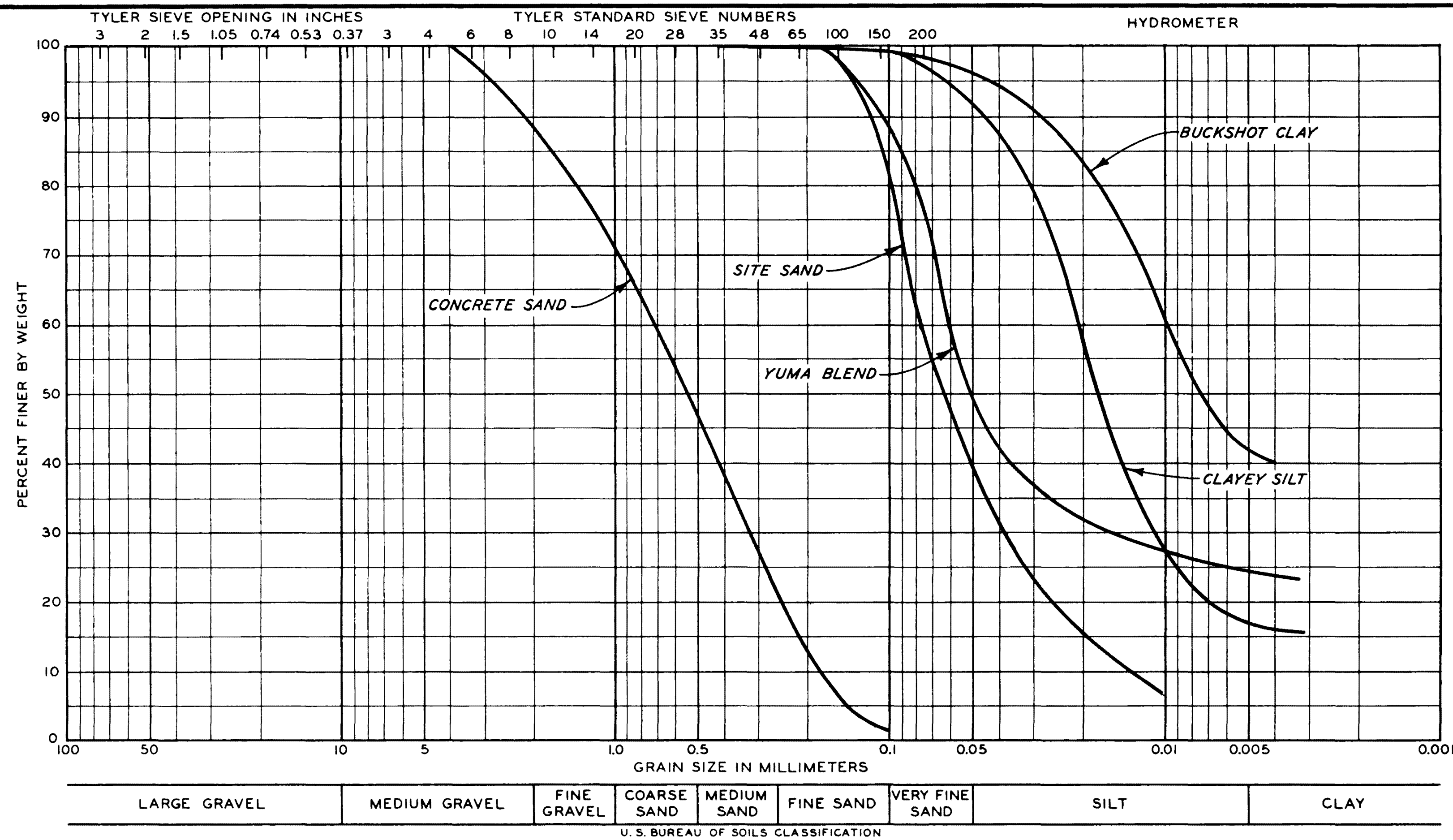


Fig. 3. Athey wagon

Fig. 4. Engineer Board sled

Photograph 10. Towed wheeled vehicles (gun mounts), towed tracked vehicle (Athey wagon), and Engineer Board sled used in tests



MATERIAL	LIQUID LIMIT	PLASTICITY INDEX	SPECIFIC GRAVITY
RIFLE RANGE CLAYEY SILT	32	8	2.61
MOUND BUCKSHOT CLAY	59	31	2.65
CONCRETE SAND	NONPLASTIC		2.64
SITE SAND	NONPLASTIC		2.65
YUMA BLEND	31	15	2.68

MECHANICAL ANALYSES OF SOILS USED IN TESTS

PLATE 1

VEHICLE - M5
SOIL - Clayey Silt

TEST NO - 8
LANE NO - 2

PASSES COMPLETED 5 IMMOBILIZED on 6th pass AT STATION 0+69

NOTES

CONE INDEX - NO UNITS
MOISTURE CONTENT - PERCENT OF DRY WT.
DENSITY - POUNDS PER CUBIC FOOT
RUTS - DISTANCE IN INCHES FROM BEFORE TRAFFIC ELEVATION
L - LEFT
R - RIGHT
FIRM AT - DEPTH IN INCHES BELOW RUT SURFACE AT WHICH A CONE INDEX OF 120 OCCURS

CONE INDEX

BEFORE TRAFFIC

STA	SFC L	SFC R	6-IN L	6-IN R	12-IN L	12-IN R	18-IN L	18-IN R	24-IN L	24-IN R	30-IN L	30-IN R	FIRM AT L	FIRM AT R
0+16	16	82	34	120	32		38		120				24	6
0+20	24	32	46	76	32	54	36	120	120				24	18
0+24	26	50	64	86	120	48		104					12	22
0+28	22	36	40	62	46	58	70	94	120				24	20
0+32	48	32	24	86	36	76	34	54	120	120			24	24
0+36	24	34	28	120	90		38		60				26	6
0+40	20	42	70	104	42	62	84	52	120	96		120	24	30
0+44	40	26	84	120	46		80		120				24	6
0+48	34	26	50	66	40	70	48	110	120	106		120	24	30
0+52	22	16	24	98	46	38	60	56	120	86		120	24	30
0+56	54	26	40	56	48	42	82	40	120	70		120	24	30
0+60	44	16	30	24	42	100	22	60	70	88		120	28	30
0+64	36	14	48	52	32	60	36	86	50	100	120	120	30	30
0+68	26	36	42	46	50	60	44	64	62	70		120	28	30
0+72	64	44	36	80	50	94	84	70	76	78	120	108	30	30+
0+76	42	30	34	66	36	120	36	60	44	120	120		30	24
0+80	26	44	48	46	34	80	52	120	38		120		30	18
0+84	54	40	30	56	28	120	36		44		120		30	12
AVG	35	35	43	76	47	80	54	87	91	105	120+	119+	26	22
ALL	35		59		63		70		98		119+		24	
0+52 / 0+68	36	22	37	55	44	60	49	61	84	83	120+	120+	27	30
	29		46		52		55		83		120+		28	
0+ / 0+														

DURING TRAFFIC AT ____ PASSES

STA	SFC L	SFC R	3-IN L	3-IN R	6-IN L	6-IN R	12-IN L	12-IN R	18-IN L	18-IN R	FIRM AT L	FIRM AT R	RUTS L	RUTS R

AFTER TRAFFIC AT 5 PASSES

STA	SFC L	SFC R	3-IN L	3-IN R	6-IN L	6-IN R	12-IN L	12-IN R	18-IN L	18-IN R	FIRM AT L	FIRM AT R	RUTS L	RUTS R
0+16	46	48	48	70	38	120	120				12	6	13.7	8.1
0+20	38	44	46	60	44	118	120	90		104	12	20	14.1	7.7
0+24	40	40	40	50	80	60	120	120			12	12	15.4	8.7
0+28	40	42	40	48	46	60	120	80		120	12	18	15.4	9.4
0+32	40	54	44	110	120	76		120			6	12	16.0	14.3
0+36	38	60	38	70	30	120	120				12	6	14.4	14.6
0+40	44	48	44	50	50	92	92	120			15	12	12.6	11.5
0+44	38	46	40	66	44	86	120	70		120	12	18	13.1	6.0
0+48	40	60	42	110	40	80	120	120			12	12	13.2	12.3
0+52	40	50	44	84	120	104		70		120	6	18	12.8	9.9
0+56	36	50	38	100	42	120	62				15	6	11.5	11.5
0+60	44	76	44	96	46	86	120	120			12	12	11.1	12.3
0+64	42	88	68	86	50	70	120	120			12	12	16.1	14.3
0+68	76	66	42	56	120	86		100		120	6	18	7.5	6.1
0+72	40	60	42	86	44	50	120	66		120	12	18	11.6	12.7
0+76	36	70	40	84	38	66	120	120			12	12	16.7	17.1
0+80	30	52	34	70	40	60	120	120			12	12	17.1	19.4
0+84	30	40	36	40	80	40	120	80		90	12	24	12.4	15.7
AVG	41	55	43	74	60	83	115+	104	120+	117+	11	14	13.6	11.8
ALL	48		58		71		109		118+		12		12.7	
0+52 / 0+68	48	66	47	84	76	93	120+	106	120+	120+	10	13	12.9	12.0
	57		65		84		113		120+		11		12.4	
0+ / 0+														

DRAWBAR PULL (LBS)

	BEFORE TRAFFIC	AFTER ___ PASSES	AFTER TRAFFIC
MAXIMUM	12,700		
CONTINUOUS	2,600		

SUMMARY ANALYSIS

The M5 began operation on a cone index of 45 to 50. Towing a load of 2,600 lbs, it was immobilized on its 6th pass while traveling backward, because of sinkage. The ruts were 12½ in. deep. The cone index in them was 65 to 85.

REMARKS

Slippage was high during this test, but was not measured.

MOISTURE CONTENT

BEFORE TRAFFIC

STA	0-6 In. L	0-6 In. R	6-12 In. L	6-12 In. R	12-18 In. L	12-18 In. R	18-24 In. L	18-24 In. R
0+35	26.6	25.0	26.6	24.8	26.0	25.9	26.4	
0+65	26.8	27.8	26.8	26.3	27.5	26.0	27.3	26.7
0+								
0+								
AVG	26.7	26.4	26.7	25.5	26.7	25.9	27.0	21.9
ALL	26.5		26.1		26.3		24.4	
0+52 / 0+68	26.8	27.8	26.8	26.3	27.5	26.0	27.3	26.7
	27.3		26.5		26.7		27.0	
0+ / 0+								

AT ___ PASSES

STA	L	R	L	R	L	R	L	R
0+								
0+								
0+								
0+								
AVG ALL								
0+ / 0+								
0+ / 0+								

AFTER TRAFFIC

STA	0-6 In. L	0-6 In. R
0+25	27.0	26.0
0+50	26.6	25.3
0+75	26.8	24.6
0+		
AVG	26.8	25.3
ALL	26.0	
0+52 / 0+68	26.6	25.3
	25.9	
0+ / 0+		

DENSITY

BEFORE TRAFFIC

STA	0-6 In. L	0-6 In. R	6-12 In. L	6-12 In. R	12-18 In. L	12-18 In. R	18-24 In. L	18-24 In. R
0+35	92.1	94.4	91.8	96.3	93.2	92.1	86.9	
0+65	93.0	90.8	92.0	94.2	87.8	94.4	90.4	
0+								
0+								
AVG	92.5	92.6	91.9	95.2	90.5	93.2	88.6	
ALL	92.5		93.5		91.8		88.6	
0+52 / 0+68	93.0	90.8	92.0	94.2	87.8	94.4	90.4	
	91.9		93.1		91.1		90.4	
0+ / 0+								

AT ___ PASSES

STA	L	R	L	R	L	R	L	R
0+								
0+								
0+								
0+								
AVG ALL								
0+ / 0+								
0+ / 0+								

AFTER TRAFFIC

STA	0-6 In. L	0-6 In. R
0+25	92.3	91.8
0+50	92.2	92.5
0+75	92.0	96.8
0+		
AVG	92.2	93.7
ALL	92.9	
0+52 / 0+68	92.2	92.5
	92.3	
0+ / 0+		

TYPICAL DATA AND ANALYSIS SHEET

TOWING VEHICLE

LEVEL, NATURAL FINE-GRAINED SOIL

VEHICLE - M21
LOAD - 8,000 lb
SOIL - Yuma Blend

TEST NO - 29
LANE NO - 7

PASSES COMPLETED - 10 IMMOBILIZED - No AT STATION

NOTES

CONE INDEX - NO UNITS
MOISTURE CONTENT - PERCENT OF DRY WT.
DENSITY - POUNDS PER CUBIC FOOT
RUTS - DISTANCE IN INCHES FROM BEFORE TRAFFIC ELEVATION
L - LEFT
R - RIGHT
FIRM AT - DEPTH IN INCHES BELOW RUT SURFACE AT WHICH A CONE INDEX OF 120 OCCURS

CONE INDEX

BEFORE TRAFFIC

STA	SFC		6-IN		12-IN		18-IN		24-IN		30-IN		FIRM AT	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R
0+16	48	28	52	56	62								15	10
0+20	40	38	42	68	100	76							13	14
0+24	28	28	48	60	90	64							14	13
0+28	52	22	66	120	82								14	6
0+32	24	44	62	80	94								14	9
0+36	62	84	42	120	110								13	6
0+40	42	40	64	120	120								12	6
0+44	12	38	24	68	28	110							17	13
0+48	28	44	22	72	14	60		120					17	18
0+52	18	90	36	52	58	72							16	16
0+56	30	44	14	28	58	64	120	120					18	18
0+60	34	84	26	68	78								17	9
0+64	32	66	28	92	64		120						18	10
0+68	22	52	24	78	100	120							17	12
0+72	32	44	40	50	120	48		120					12	18
0+76	52	94	18	48	64	100	82						19	14
0+80	24	28	30	22	70	90	90						19	17
0+84	38	44	34	80	68		120						18	9
AVG	34	51	37	71	77	98	120+	120+	120+	120+			16	12
ALL	42		54		87		120+		120+				14	

DURING TRAFFIC AT 1 PASSES

STA	SFC		3-IN		6-IN		12-IN		18-IN		FIRM AT		RUTS	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R
0+16	44	68	62	120	120						6	3	5.2	4.8
0+20													6.1	5.5
0+24	82	92	102	120							5	3	4.0	4.2
0+28													4.5	3.4
0+32	54	90	108	120							4	3	3.7	4.2
0+36													3.6	4.1
0+40	70	92	100	110							4	4	4.2	5.2
0+44													4.1	6.5
0+48	46	52	108	44		90					5	8	4.8	5.5
0+52													6.3	6.4
0+56	58	70	120	48		54		120			3	12	4.0	6.5
0+60													6.0	3.8
0+64	56	80	78	120	54		120				12	3	5.6	5.1
0+68													10.7	5.2
0+72	82	64	38	120	120						6	3	4.2	5.6
0+76													6.0	5.5
0+80	28	68	30	32	52	34	94	78			14	16	7.8	4.6
0+84	36	78	24	44	28	38	110	42			15	17	6.1	5.7
AVG	56	75	77	88	97	94	120+	120+	120+	120+	7	7	5.4	5.1
ALL	65		82		95		120+		120+		7		5.2	

AFTER TRAFFIC AT 10 PASSES

STA	SFC		3-IN		6-IN		12-IN		18-IN		FIRM AT		RUTS	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R
0+16	38	110	60	120							4	3	7.9	6.9
0+20	54	84	120	120							3	3	9.0	8.2
0+24	48	100	120	120							3	3	4.0	5.1
0+28	48	120	110		120						6	0	3.2	3.9
0+32	80	120	120								3	0	2.9	4.8
0+36	90	74	120	120							3	3	2.3	5.4
0+40	58	110	120	120							3	3	5.3	5.3
0+44	34	112	78	120	94						10	3	4.5	6.1
0+48	38	74	24	72	120	110		120			6	12	9.7	7.2
0+52	60	54	120	40		48		54			3	17	9.3	7.8
0+56	30	22	94	28		48		92			4	13	8.3	8.7
0+60	100	34	120	38		84		102			3	14	11.9	4.5
0+64	48	100	120	54		38		52			3	17	10.6	5.9
0+68	44	110	64	74	120	38		120			6	12	8.6	7.0
0+72	54	48	44	28	68	32	120	120			12	12	6.8	6.2
0+76	54	32	38	34	56	36	74	44			13	16	7.7	7.0
0+80	18	48	34	48	82	32	58	120			13	12	11.1	6.8
0+84	22	56	120	120							3	3	7.6	6.8
AVG	51	78	90	83	120+	86	120+	120+	120+	120+	6	8	7.3	6.3
ALL	64		86		120+		120+		120+		7		6.8	

DRAWBAR PULL (LBS)

PASS NO	PULL	PASS NO	PULL
1	3,800	10	2,600
2	3,500		
3	2,800		
4	2,800		

SUMMARY ANALYSIS

Traffic began with a cone index of 55 to 85. After one pass ruts were 5 in. deep and the cone index was 80 to 95. At the end of ten passes ruts were 7 in. deep and the cone index in them was 85 to 105. The average pull was 3,100 lb. Varying pulls are accounted for by the difficulty in keeping the M21 in its original tracks. When the M21 left its tracks the pull was usually increased.

REMARKS

There was no stickiness in this lane.

The WES dynamometer sled was used.

MOISTURE CONTENT

BEFORE TRAFFIC

STA	0-6 IN.		6-12 IN.		12-18 IN.			
	L	R	L	R	L	R	L	R
0+25	19.1	20.2	13.9	16.9		16.7		
0+50	20.8		19.7	16.8	21.9	16.6		
0+75	19.3	20.0	16.0	18.0	17.3	17.9		
AVG	19.7	20.1	16.5	17.2	19.6	17.1		
ALL	19.9		16.8		18.3			

AT 1 PASSES

STA	0-6 IN.		6-12 IN.					
	L	R	L	R	L	R	L	R
0+50	15.1	21.4		16.4				
AVG ALL	18.2		16.4					

AFTER TRAFFIC

STA	0-6 IN.	
	L	R
0+25	18.1	17.5
0+50	18.0	20.3
0+75	19.3	21.5
AVG	18.5	19.8
ALL	19.1	

DENSITY

BEFORE TRAFFIC

STA	0-6 IN.		6-12 IN.		12-18 IN.			
	L	R	L	R	L	R	L	R
0+25	97.4	99.5	96.1	103.7				
0+50	96.9		98.6	104.9	101.7			
0+75	88.7	104.8	108.3	106.9				
AVG	94.3	102.1	101.0	105.2				
ALL	98.2		103.1		101.7			

AT 1 PASSES

STA	0-6 IN.		6-12 IN.					
	L	R	L	R	L	R	L	R
0+50	101.5	101.8		114.3				
AVG ALL	101.6		114.3					

AFTER TRAFFIC

STA	0-6 IN.	
	L	R
0+25	109.0	88.2
0+50	88.1	106.3
0+75	111.8	102.6
AVG	103.0	99.0
ALL	101.0	

TYPICAL DATA AND ANALYSIS SHEET

TOWED VEHICLE

LEVEL, NATURAL FINE-GRAINED SOIL

PLATE 4

TEST NO. 1
VEHICLE M34, 2-1/2-ton Truck
SITE Fort Knox, Kentucky, 1952
SOIL CL Sandy Clay
PASSES COMPLETED 4 / 6 **IMMOBILIZED** on 5th pass / on 7th pass **AT STATION** 0+64 / 0+40

NOTES:
MC - MOISTURE CONTENT
D - DENSITY
LL - LIQUID LIMIT
PL - PLASTIC LIMIT
PI - PLASTICITY INDEX
G - GRAVEL > 4.76 mm
S - SAND 0.074 TO 4.76
F - FINES < 0.074 mm
L - LEFT
R - RIGHT
RI - REMOLDING INDEX
CONE INDEX - NO UNITS
MOISTURE CONTENT - PER CENT OF DRY WT
DENSITY - POUNDS PER CUBIC FOOT
RUTS - DISTANCE IN INCHES FROM BEFORE-TRAFFIC ELEVATION

BEFORE-TRAFFIC CONE INDEX

STA	SFC L	SFC R	3 IN. L	3 IN. R	6 IN. L	6 IN. R	9 IN. L	9 IN. R	12 IN. L	12 IN. R	15 IN. L	15 IN. R	18 IN. L	18 IN. R	24 IN. L	24 IN. R	30 IN. L	30 IN. R	After-Traffic Rut Depth L	After-Traffic Rut Depth R
0+00																				
0+04																				
0+08																				
0+12																				
0+16	90	65	300	170	200	95			300	110			300	230	300	125	300	85		
0+20	95	90	130	85	130	95			300	100			300	300	300	300	300	300		
0+24	100	75	200	105	220	60			220	120			300	300	220	165	300	230		
0+28	100	85	100	135	180	120			300	85			300	155	300	120	300	140		
0+32	80	65	90	105	70	75			300	95			300	120	300	85	300	---		
0+36	80	70	110	160	300	90			100	205			260	200	300	Rock	300	Rock		
0+40	95	80	95	90	80	100			100	120			300	180	300	Rock	300	Rock		
0+44	85	35	210	100	180	100			100	125			220	180	300	60	300	Rock		
0+48	80	55	110	85	260	135			240	205			280	300	300	300	300	300		
0+52	100	50	110	75	130	75			160	80			300	40	300	Rock	300	Rock		
0+56	120	70	120	90	100	Rock			110	Rock			210	Rock	280	Rock	300	Rock		
0+60	110	50	160	90	130	105			280	130			300	Rock	300	Rock	300	Rock		
0+64	160	65	140	80	180	45			210	35			300	230	300	270	300	Rock		
0+68	80	50	90	70	130	120			100	150			200	300	240	Rock	300	Rock		
0+72	90	45	90	85	120	85			240	130			300	85	300	Rock	300	Rock		
0+76	100	60	120	75	180	120			110	Rock			220	Rock	240	Rock	300	Rock		
0+80	50	70	80	90	110	160			90	60			180	180	300	300	300	Rock		
0+84	60	45	70	65	80	80			160	105			180	Rock	300	Rock	300	Rock		
0+88																				
0+92																				
0+96																				
1+00																				
AVG	93	63	129+	97	154+	98			190+	116			263+	200+	287+	192+	300+	211+		
ALL	78		113+		126+				153+				231+		240+		255+		14.0	
0+44 to 0+64	109	54	142	87	163	92			183	115			268+	287+	297+	210+	300+	300+		
	81		115		127				149				277+		253+		300+			
0+20 to 0+40	92	77	121	113	163	90			220	121			293+	209+	287+	167+	300+	223+		
	84		117		126				170				251+		227+		261+			

ATTERBERG LIMITS

DEPTH	LL	PL	PI
6-12	29	22	7

MECHANICAL ANALYSIS

DEPTH	G	S	F
6-12	0	11	89

MOISTURE CONTENT AND DENSITY

STA	0-6 IN. MC	0-6 IN. D	6-12 IN. MC	6-12 IN. D	12-18 IN. MC	12-18 IN. D	18-24 IN. MC	18-24 IN. D
0+40L			30.5	89.7				
0+66L			30.0	87.9				
0+60R			27.7	87.9				
0+24L			26.3					
0+20R			27.4	89.5				

SUMMARY ANALYSIS

The areas in which the immobilizations occurred have rating cone indexes of 32 and 34. The rating cone index for the entire lane is 34. It therefore appears that immobilization could have occurred anywhere in the lane. The left track in each case was considerably stronger than the right track but not strong enough to support the truck. Therefore the analysis of this test and for both immobilizations is based on the 6- to 12-in. data for the entire lane.

The rating cone index was 34. The truck was immobilized twice; once on the 5th pass and again on the 7th pass. After the 5th-pass immobilization at sta 0+64 it was pulled out forward and reentered the lane at sta 0+00. Travel was continued from there to sta 0+50. On the 7th pass it was immobilized again at sta 0+40. Both immobilizations were caused by sinkage.

A rating cone index of 34 would permit the truck to complete only 4 to 6 passes.

REMARKS

The measured cone index was 140 and the remolding index was 0.24 (avg of 0.23 and 0.26). The rating cone index was 34.

Tires were inflated to 50 psi. Tires were 11.00 x 20.

No during-traffic data were taken.

6- to 12-in. Standard Remolding Test

STA	DEPTH	0	100	0	100	0		0	
0+40L	SFC	45	15	40	15				
	1 IN.	55	15	60	15				
	2 IN.	85	30	75	20				
	3 IN.	180	25	100	15				
	4 IN.	170	45	110	20				
	5 IN.								
TOTALS		535	130	385	85				
RI		0.24		0.22					
AVG RI		0.23							

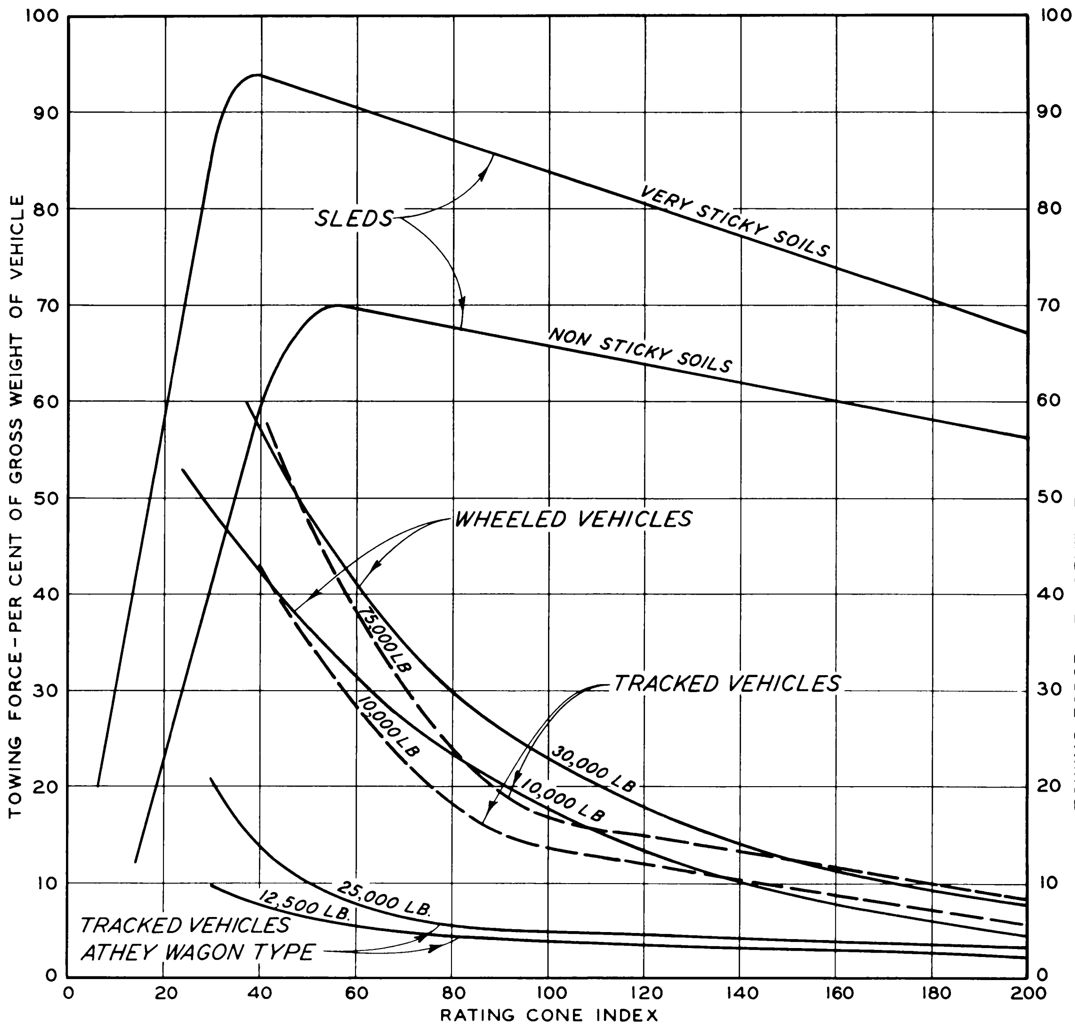
(Number of blows)

6- to 12-in. Standard Remolding Test

STA	DEPTH	0	100	0	100	0		0	
0+40R	SFC	55	25	65	20				
	1 IN.	100	35	110	20				
	2 IN.	110	35	125	25				
	3 IN.	125	35	170	30				
	4 IN.	105	35						
	5 IN.								
TOTALS		495	165	470	95				
RI		0.33		0.20					
AVG RI		0.26							

(Number of blows)

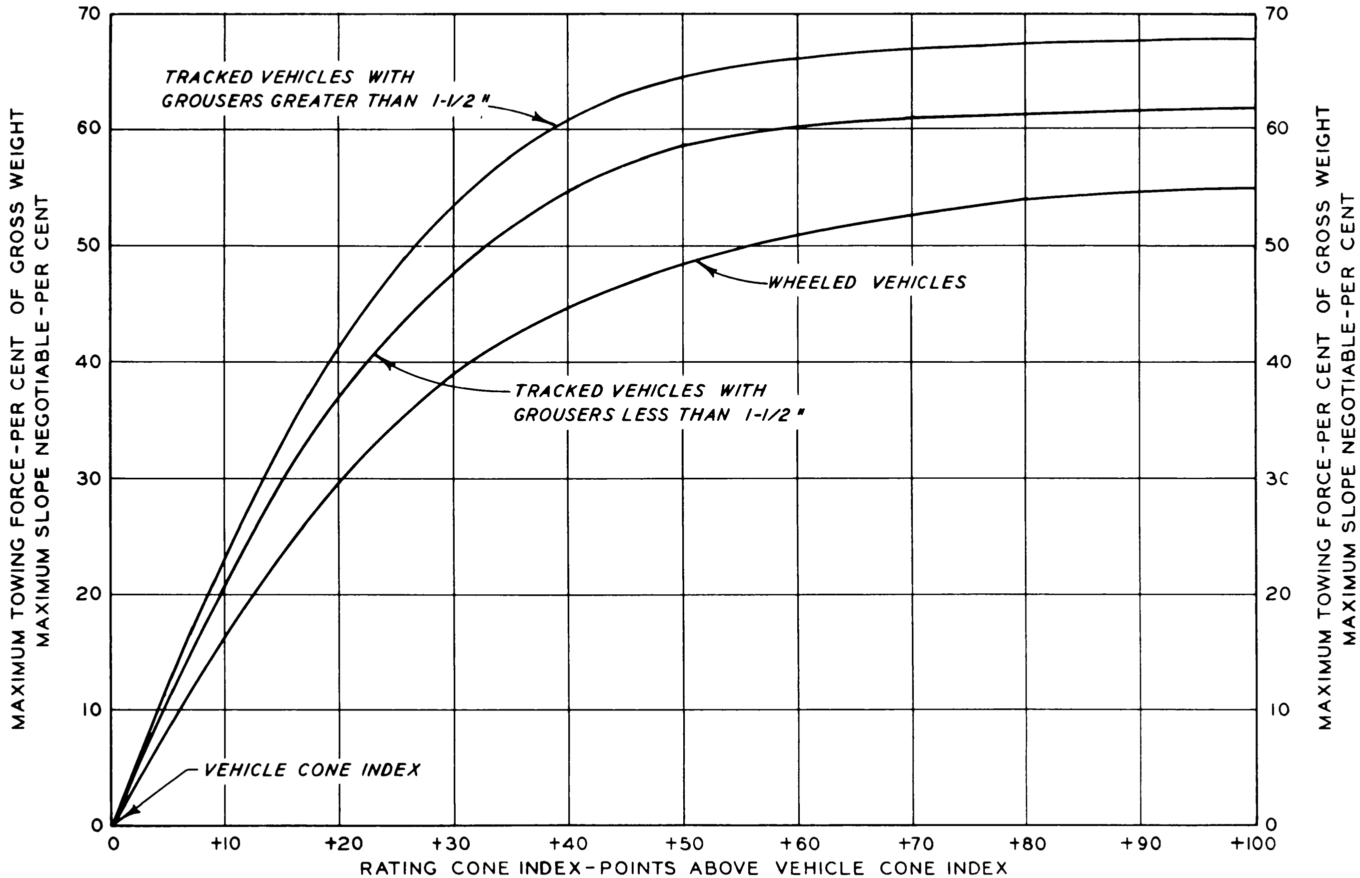
TYPICAL DATA AND ANALYSIS SHEET
SELF-PROPELLED VEHICLE
LEVEL, NATURAL FINE-GRAINED SOIL



NOTE: THE TOWING FORCE REQUIRED IN AN AREA WHOSE CONE INDEX IS 20 POINTS OR MORE BELOW THE MINIMUM FOR THE VEHICLE MAY EQUAL OR EXCEED THE WEIGHT OF THE VEHICLE.

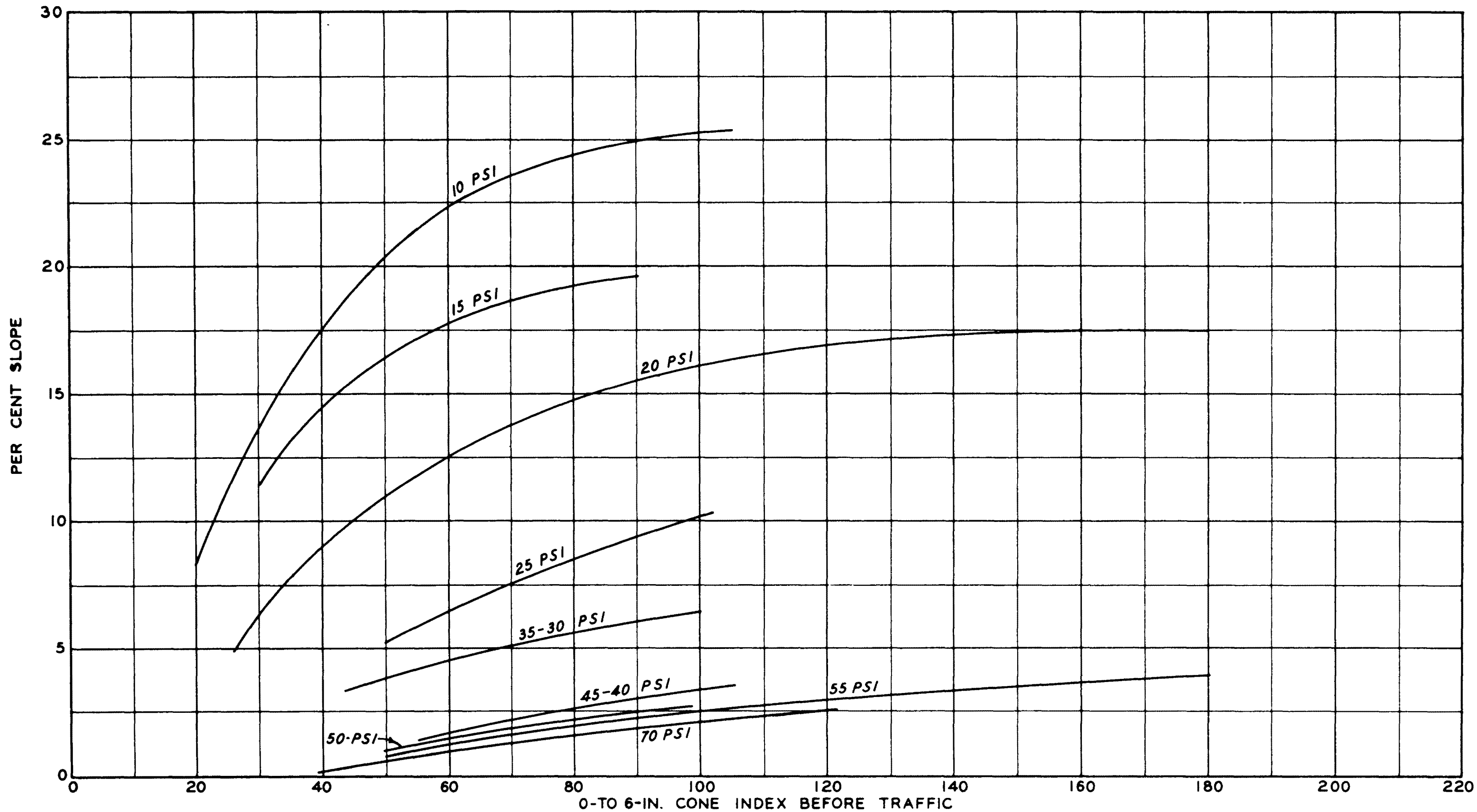
CRITERIA FOR TOWED VEHICLES ON FINE-GRAINED SOILS AND SANDS WITH FINES, POORLY DRAINED

FORCE REQUIRED TO TOW VEHICLES ON LEVEL GROUND



CRITERIA FOR SELF-PROPELLED VEHICLES ON FINE-GRAINED SOILS AND SANDS WITH FINES, POORLY DRAINED

MAXIMUM TOWING FORCE THAT CAN BE DEVELOPED ON LEVEL GROUND AND MAXIMUM SLOPE THAT CAN BE CLIMBED



NOTE: TIRE PRESSURE INDICATED IN PSI.

VEHICLE PERFORMANCE

BEFORE TRAFFIC

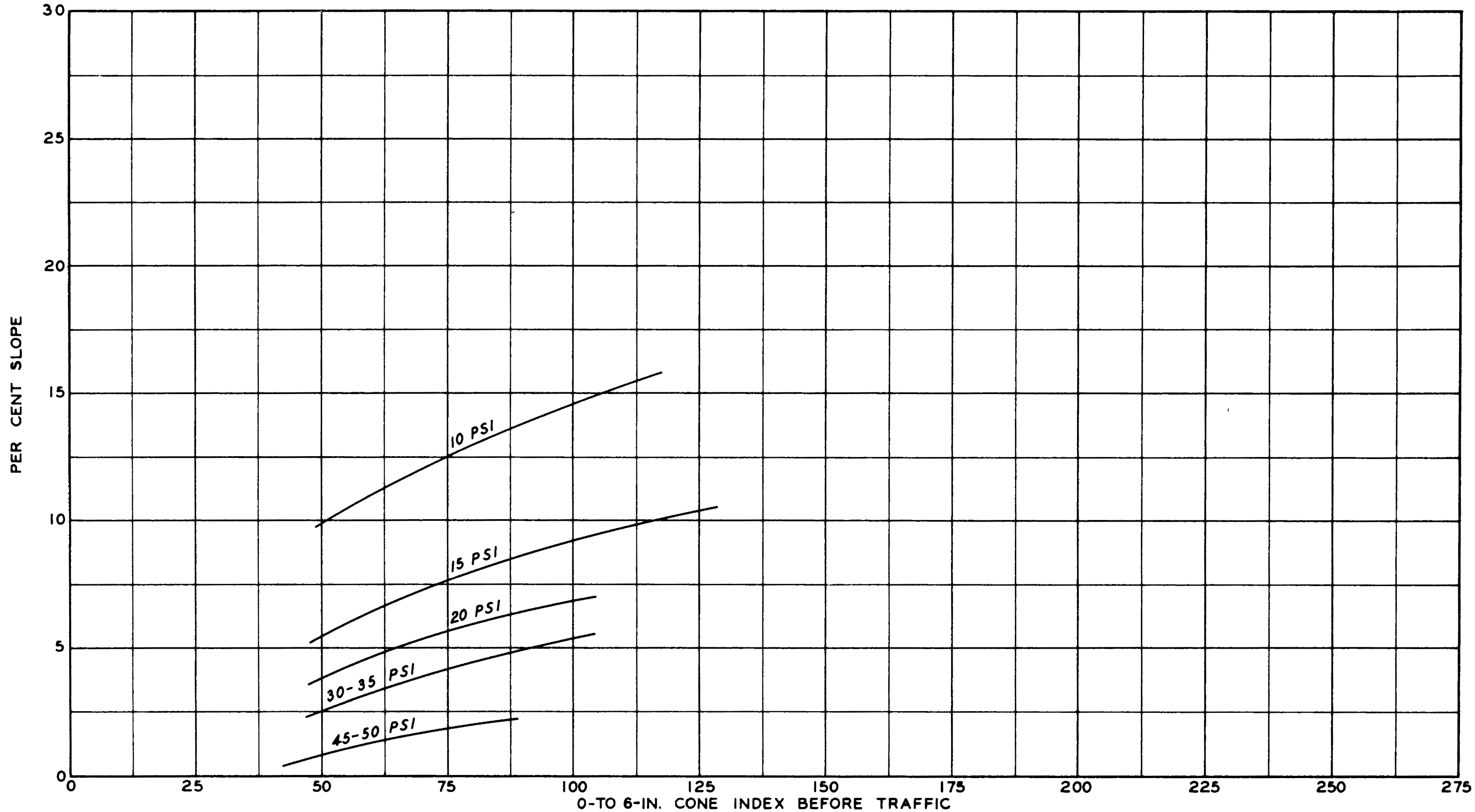
PER CENT SLOPE VS CONE INDEX

2½-TON TRUCK 11.00 X 20 TIRES

ON SAND

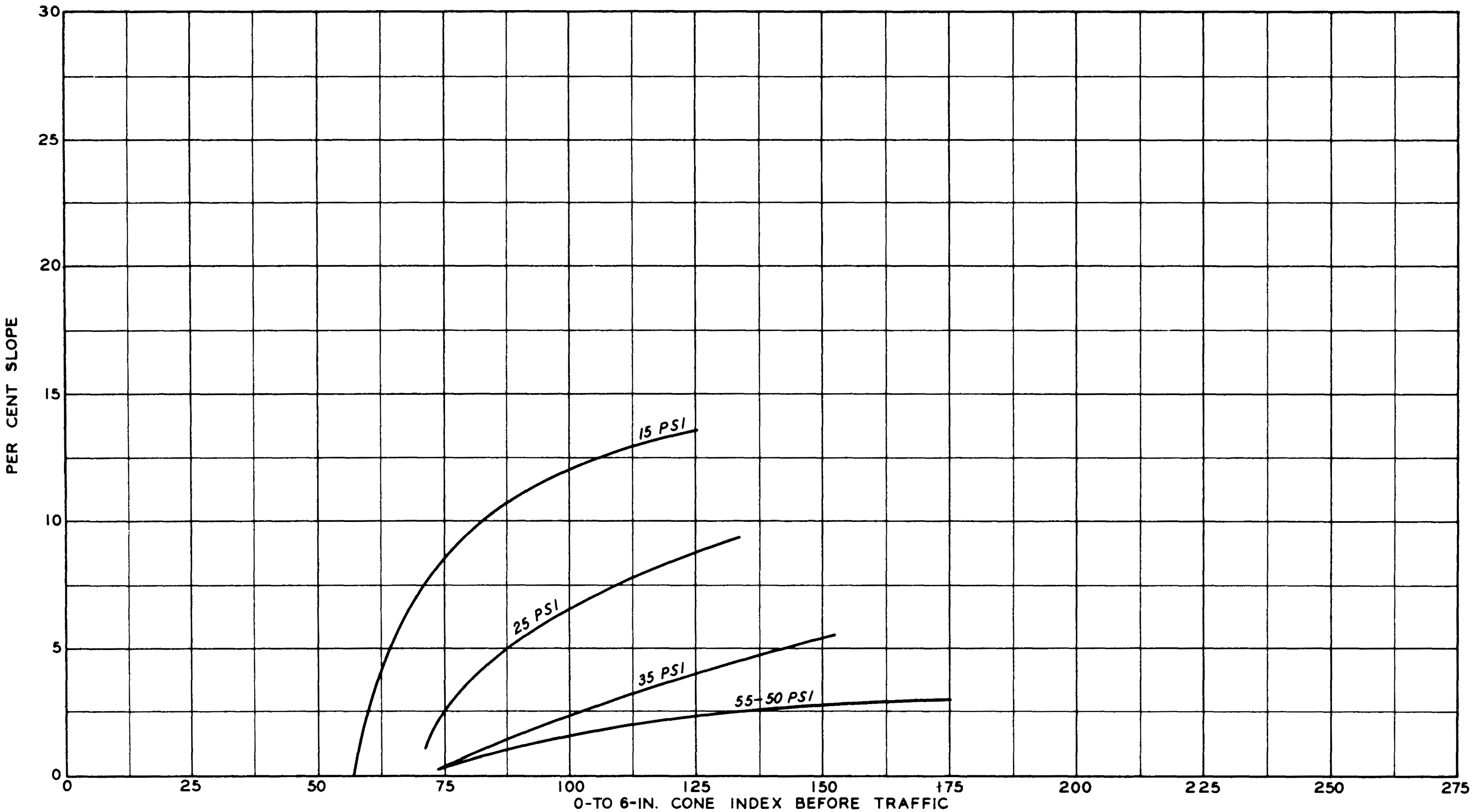
PLATE 7

PLATE 8



NOTE: TIRE PRESSURE INDICATED IN PSI.

VEHICLE PERFORMANCE
BEFORE TRAFFIC
PER CENT SLOPE VS CONE INDEX
2 ½-TON TRUCK 9.00X20 TIRES
ON SAND



NOTE: TIRE PRESSURE INDICATED IN PSI.

VEHICLE PERFORMANCE

BEFORE TRAFFIC

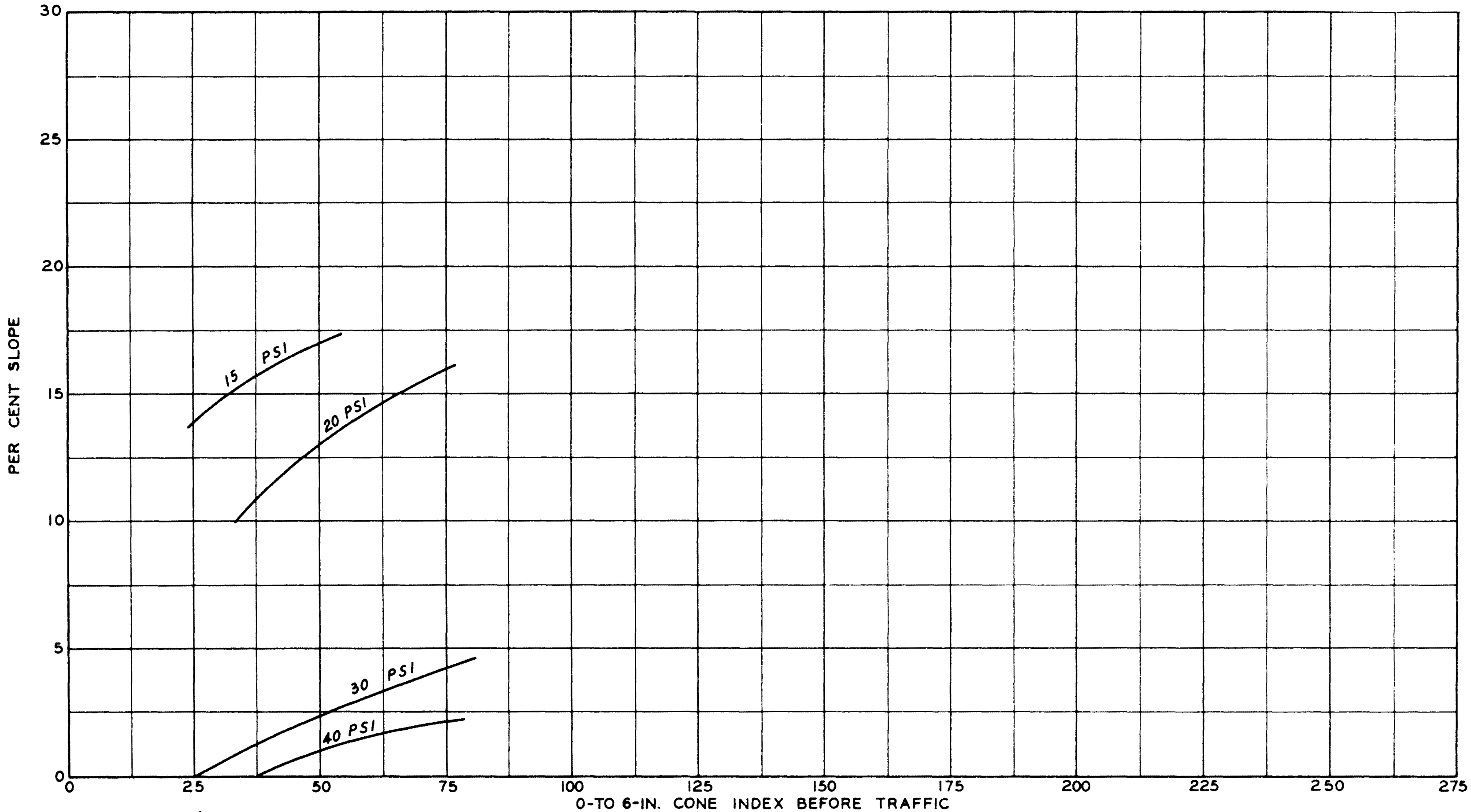
PER CENT SLOPE VS CONE INDEX

2 ½-TON TRUCK 7.50X20 TIRES

ON SAND

PLATE 9

PLATE 10



NOTE: TIRE PRESSURE INDICATED IN PSI.

VEHICLE PERFORMANCE

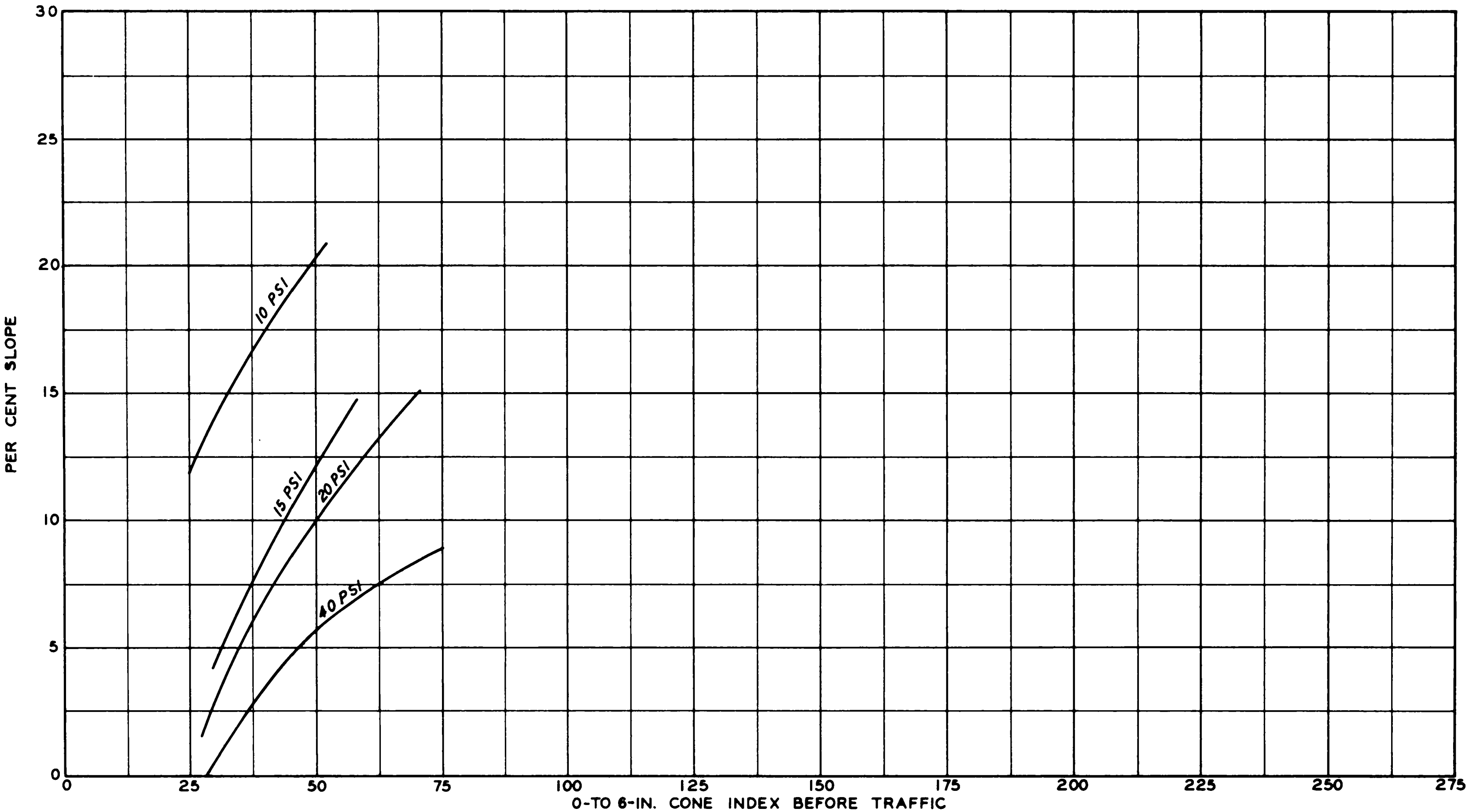
BEFORE TRAFFIC

PER CENT SLOPE VS CONE INDEX

2 1/2-TON TRUCK 11.00 X 18 TIRES

AMPHIBIAN

ON SAND



NOTE: TIRE PRESSURE INDICATED IN PSI.

VEHICLE PERFORMANCE

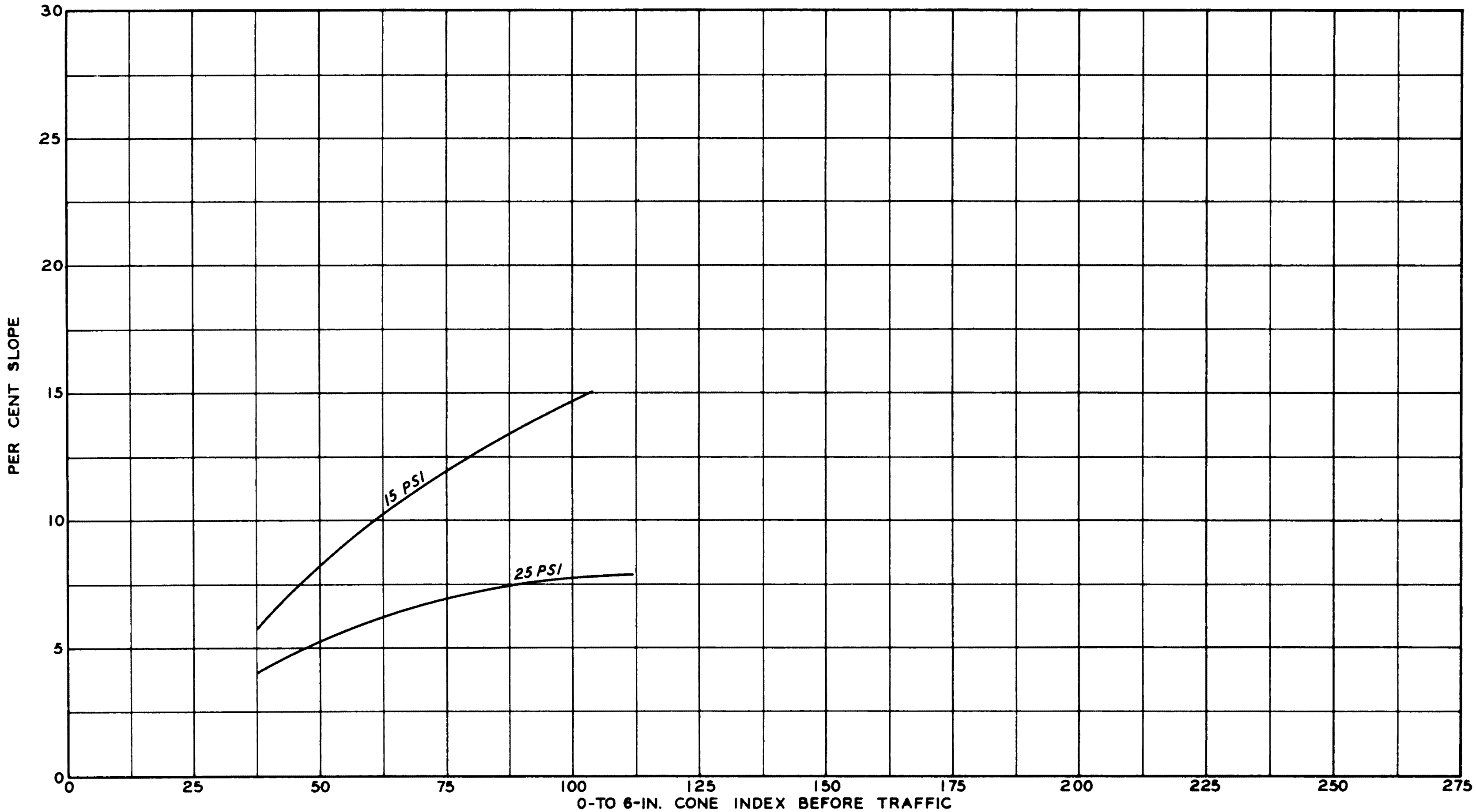
BEFORE TRAFFIC

PER CENT SLOPE VS CONE INDEX

3/4-TON TRUCK 9.00X16 TIRES

ON SAND

PLATE 12



NOTE: TIRE PRESSURE INDICATED IN PSI.

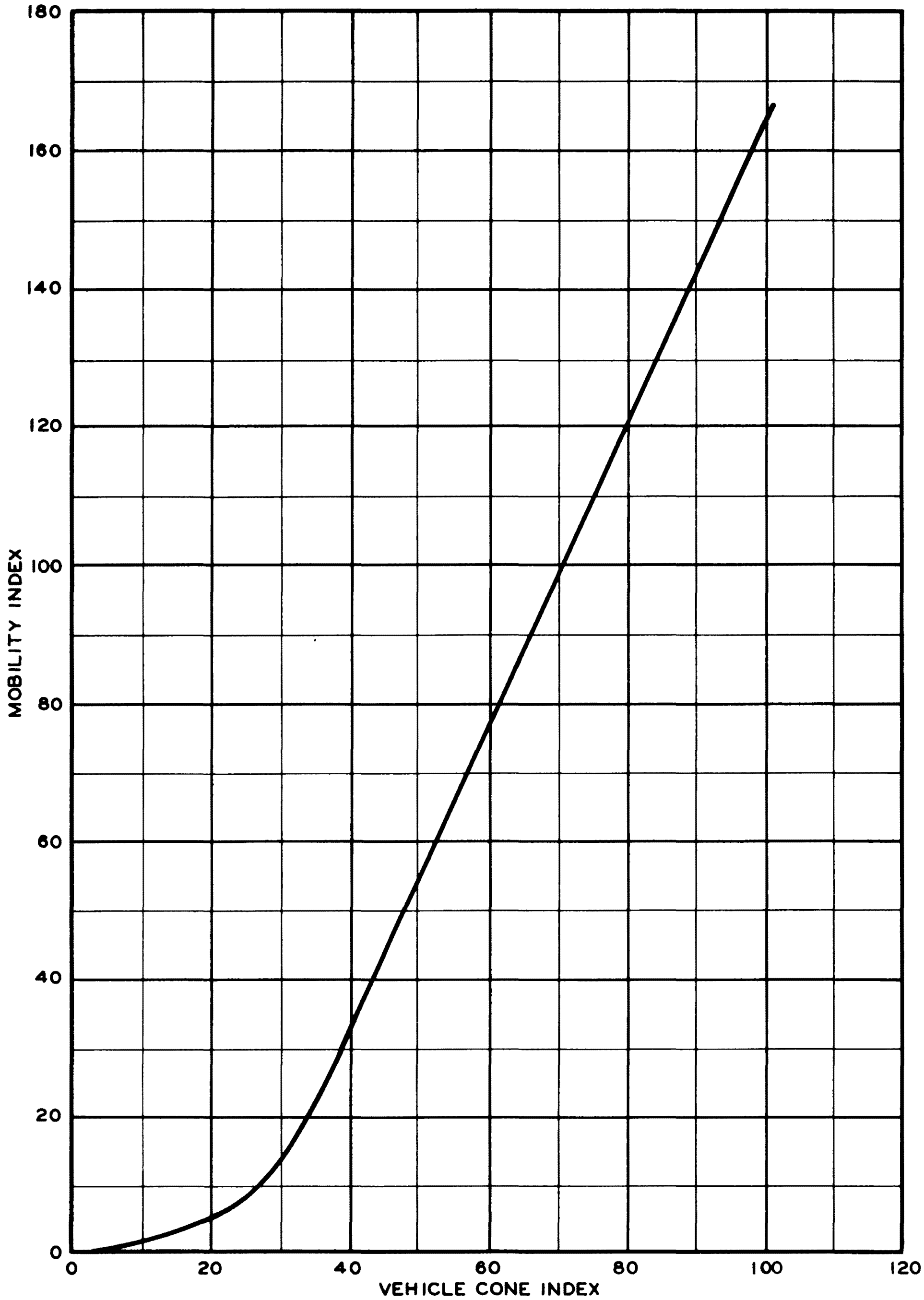
VEHICLE PERFORMANCE

BEFORE TRAFFIC

PER CENT SLOPE VS CONE INDEX

1/4-TON TRUCK 7.00 X16 TIRES

ON SAND



MOBILITY INDEX
VS
VEHICLE CONE INDEX

APPENDIX

APPENDIX A: CONE INDEX REQUIREMENTS ON LEVEL FINE-GRAINED SOILS AND SANDS WITH FINES, POORLY DRAINED

TM9-2800 Is Edition of Oct. 1947; TM9-2800-1 Is Edition of Feb. 1953.

Self-propelled Tracked Vehicles

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Amphibious vehicles					
Carrier, cargo, T46E1	TM9-2800-1	52	7	23	1
Carrier, cargo, M29C	TM9-2800	8	9	25	1
Vehicle, landing, tracked (unarmored), MK. 4, LVT (4)	TM9-2800	10	60	54	3
Vehicle, landing, tracked (armored), MK. 4, LVT (4)	TM9-2800	11	70	58	3
Cargo carriers (full-track)					
Carrier, cargo, M29	TM9-2800	25	14	29	1
Vehicle, armored, infantry, full track, T18E1	TM9-2800-1	282	38	43	2
Vehicle, armored, utility, M39	TM9-2800	26	102	73	5
Cranes					
Shovel, crawler-mounted, gasoline engine-driven, 3/4-cu-yd, with attachments, Buckeye model 70	TB5-9720-1	109	27	39	2
Crane, crawler-mounted, gasoline engine-driven, 3/4-cu-yd bucket, Koehring model 304	TB5-9720-1	11	34	42	2
Crane, revolving, crawler-mounted, gasoline engine-driven, 3/4-cu-yd, 7 to 10-ton, class III	TM9-2800	36	38	44	2
Shovel, power, crawler-mounted, gasoline engine-driven, 1/2-cu-yd, Osgood model 200	TB5-9720-1	133	41	45	2
Shovel, crawler-mounted, diesel engine-driven, 2-cu-yd, Thew model Lorain-82	TB5-9720-1	125	42	45	2
Crane, revolving, crawler-mounted, gasoline (and diesel) engine-driven, 1/2-cu-yd, 5- to 6-ton, class II	TM9-2800	35	44	46	2
Shovel, crawler-mounted, gasoline engine-driven, 1/2-cu-yd, with attachments, Bucyrus-Erie model 15B	TB5-9720-1	113	54	51	3

Self-propelled Tracked Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Cranes (cont'd)					
Crane, revolving, tractor-mounted, crawler-type, diesel engine-driven, 12,000-lb capacity at 8-ft radius	TM9-2800	40	64	55	3
Crane, revolving, tractor-mounting, crawler-type, diesel engine-driven, 5,000-lb capacity at 7-ft radius, 12- to 18-ft boom, telescopic	TM9-2800	38	65	56	3
Crane, revolving, tractor-mounting, crawler-type, diesel engine-driven, 10,000-lb capacity at 8-ft radius, 12-to 18-ft boom, telescopic	TM9-2800	39	66	56	3
Crane, revolving, crawler-mounted, diesel engine-driven, 1-3/4 to 2-cu-yd, 30- to 40-ton, class V	TM9-2800	37	76	61	4
Crane, revolving, tractor-mounting, crawler-type, diesel engine-driven, 12,000-lb capacity at 12-ft radius, 30-ft boom	TM9-2800	41	81	63	4
Shovel, crawler-mounted, diesel engine-driven, 2-cu-yd, Northwest model 78-D	TB5-9720-1	119	118	80	6
Gun and howitzer motor carriages (full-track)					
Carriage, motor, 90-mm gun, M36B2	TM9-2800	52	51	49	2
Carriage, motor, twin 40-mm gun, M19	TM9-2800	48	65	56	3
Carriage, motor, 8-in. howitzer, M43 and carriage, motcr, 155-mm gun, M40	TM9-2800	56	67	57	3
Carriage, motor, 105-mm howitzer, M7	TM9-2800	54	80	63	4
Carriage, motor, 105-mm howitzer, M7B1	TM9-2800	55	89	67	4
Carriage, motor, 90-mm gun, M36B1	TM9-2800	51	97	71	5

Self-propelled Tracked Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Gun and howitzer motor carriages (full-track) (cont'd)					
Carriage, motor, 76-mm gun, M18 (T70)	TM9-2800	49	98	71	5
Carriage, motor, 75-mm howitzer, M8	TM9-2800	53	115	79	5
Carriage, motor, 90-mm gun, M36 (T71)	TM9-2800	50	186	111	7
Half-track vehicles (see Self-propelled, Wheeled)					
Mine exploders and combat bulldozers					
Bulldozer, M1	TM9-2800	67	143	91	6
Road equipment					
Loader, aggregate, bucket, crawler-mounted, gasoline-driven, 3-cu-yd, 18-ft-10-in. boom	TM9-2800	92	52	50	3
Loader, aggregate, bucket, crawler-mounted, gasoline-driven, 3-cu-yd, 17-ft-4-in. boom	TM9-2800	91	62	54	3
Loader, aggregate, bucket, crawler-mounted, gasoline-driven, 3-cu-yd, 18-ft-10-in. boom, general purpose	TM9-2800	93	64	55	3
Loader, aggregate, bucket, crawler-mounted, gasoline-driven, 3-cu-yd, 19-ft-10-in. boom	TM9-2800	94	67	57	3
Ditching machine, ladder-type, crawler-mounted, gasoline engine-driven, digging depth 8 ft, width 18 to 24 in., Barber-Greene, model 44C	TB5-9720-1	27	75	61	4
Ditching machine, wheel-type, crawler-mounted, gasoline engine-driven, digging depth 5 ft 6 in., width 23 in., Cleveland model 110	TB5-9720-1	33	85	65	4
Tanks					
Tank, 76-mm gun, T41E1	TM9-2800-1	114	51	48	2
Tank, medium, T48	-------	---	53	49	2

Self-propelled Tracked Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Tanks (cont'd)					
Tank, medium, M46 and 46A1	TM9-2800-1	118	77	60	4
Tank, light, M24 (T24)	TM9-2800	138	76	61	4
Tank, medium, M26	TM9-2800	149	77	61	4
Tank, 90-mm gun, M47	TM9-2800-1	119	80	62	4
Tank, medium, M4 (75-mm gun)	TM9-2800	139	105	74	5
Tank, medium, M4A3 (75-mm gun)	TM9-2800	144	105	74	5
Tank, medium, M4A1 (75-mm gun)	TM9-2800	141	106	74	5
Tank, medium, M4A3E2 (75-mm gun, wet) assault	TM9-2800	148	108	75	5
Tank, medium, M4 (105-mm howitzer)	TM9-2800	140	109	76	5
Tank, medium, M4A3 (75-mm gun, wet)	TM9-2800	145	110	76	5
Tank, medium, M4A3 (105-mm howitzer)	TM9-2800	147	110	76	5
Tank, light, M5A1	TM9-2800	137	115	79	5
Tank, medium, M4A1 (76-mm gun, wet)	TM9-2800	142	129	85	6
Tank, medium, M4A3 (76-mm gun, wet)	TM9-2800	146	130	85	6
Tank, medium, M4A2 (76-mm gun, wet)	TM9-2800	143	134	87	6
Tank recovery vehicles					
Vehicle, tank recovery, M32 and M32A1 series	TM9-2800	153	97	71	5
Tractors					
Tractor, crawler-type, diesel engine-driven, 61 to 90 DBHP	TM9-2800	164	29	40	2
Tractor, earth-moving crawler, diesel engine-driven, 61 to 90 DBHP, No. 1	TM9-2800	165	29	40	2
Tractor, crawler-type, diesel engine-driven, 36 to 45 DBHP	TM9-2800	157	32	41	2
Tractor, crawler-type, diesel engine-driven, 46 to 60 DBHP	TM9-2800	159	36	43	2
Tractor, crawler-type, diesel engine-driven, 91 to 140 DBHP	TM9-2800	168	37	43	2
Tractor, crawler-type, diesel engine-driven, 46 to 60 DBHP, w/artillery towing attachments, winch, 1-drum, front-mounted	TM9-2800	160	38	44	2

Self-propelled Tracked Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Tractors (cont'd)					
Tractor, crawler-type, diesel engine-driven, 36 to 45 DBHP, w/artillery towing attachments, winch, 1-drum, front-mounted	TM9-2800	158	39	44	2
Tractor, crawler-type, diesel engine-driven, 46 to 60 DBHP, w/artillery towing attachments, winch, 1-drum, front-mounted	TM9-2800	162	40	45	2
Tractor, earth-moving crawler, diesel engine-driven, 46 to 60 DBHP, no. 1	TM9-2800	161	42	45	2
Tractor, crawler-type, diesel engine-driven, 46 to 60 DBHP, w/artillery towing attachments, winch, 1-drum, front-mounted	TM9-2800	163	42	45	2
Tractor, crawler, gasoline, 20 DBHP, Allis-Chalmers, WM	TB5-9720-11	9	46	47	2
Tractor, crawler-type, diesel engine-driven, 61 to 90 DBHP, w/artillery towing attachments, special high-speed gears, winch, 1-drum, front-mounted	TM9-2800	166	46	47	2
Tractor, high-speed, 18-ton, M4 and M4C	TM9-2800	171	46	47	2
Tractor, crawler, diesel, 70 to 90 DBHP, standard, Caterpillar D7, 74-in. gage	TB5-9720-11	25	46	47	2
Tractor, crawler-type, diesel engine-driven, 61 to 90 DBHP, w/artillery towing attachments, special high-speed gears, winch, 1-drum, front-mounted	TM9-2800	167	51	49	2
Tractor, crawler, diesel, 55 to 65 DBHP, standard, Allis-Chalmers, HD-7W	TB5-9720-11	19	50	49	2
Tractor, crawler, gasoline, 35 DBHP, Cleveland, BG	TB5-9720-11	15	51	49	2
Tractor, crawler, diesel, 55 to 65 DBHP, standard, Caterpillar, D6	TB5-9720-11	23	53	50	3

Self-propelled Tracked Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Tractors (cont'd)					
Tractor, crawler, diesel, 110 to 140 DBHP, Caterpillar, D8	TB5-9720-11	27	53	50	3
Tractor, crawler-type, diesel engine-driven, 36 to 45 DBHP	TM9-2800	155	55	51	3
Tractor, high-speed, 7-ton, M2	TM9-2800	169	59	53	3
Tractor, crawler-type, gasoline engine-driven, 20 DBHP (approx.), standard, w/bulldozer, hydraulic operated, power control unit, hydraulic operating, rear-mounted winch, single, drum, reversible	TM9-2800	154	63	55	3
Tractor, crawler, gasoline, 35 DBHP, standard, Caterpillar, R4	TB5-9720-11	11	65	56	3
Tractor, crawler, gasoline, 15 DBHP, standard, Clark CA-1, Clark-Air, 31-in. gage, with LaPlante-Choate BABX bulldozer, LaPlante-Choate power control unit and Braden towing winch	TB5-9720-11	13	65	56	3
Tractor, high-speed, 38-ton, M6	TM9-2800	172	66	56	3
Tractor, crawler, diesel, 35 to 40 DBHP, standard, International, TD-9	TB5-9720-11	29	65	56	3
Tractor, crawler, diesel, 35 to 40 DBHP, standard, Caterpillar, D4	TB5-9720-11	21	69	58	3
Tractor, crawler, gasoline, 20 DBHP, International, T-6	TB5-9720-11	17	79	62	4
Tractor, crawler-type, diesel engine-driven, 36 to 45 DBHP, w/angle-dozer	TM9-2800	156	80	63	4
Tractor, 13-ton, high-speed M5 and M5A1	TM9-2800	170	99	72	5

Self-propelled Wheeled Vehicles

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Ambulances					
Truck, 3/4-ton, 4 x 4, ambulance	TM9-2800	6	88	66	4
Truck, 3/4-ton, 4 x 4, ambulance, (K.D.)	TM9-2800	7	94	69	4
Truck, 1/2-ton, 4 x 4, ambulance	TM9-2800	5	104	73	5
*Ambulance, 3/4-ton, 4 x 2, metropolitan	TM9-2800	3	104	102	7
*Ambulance, field, 1-1/2-ton, 4 x 2	TM9-2800	4	126	118	7
Amphibious vehicles					
Truck, 2-1/2-ton, 6 x 6, amphibian	TM9-2800	9	102	73	5
Armored cars					
Car, armored, utility, M20	TM9-2800	13	102	73	5
Car, armored, light, M8	TM9-2800	12	115	79	5
Busses					
*Bus, 37-passenger, 4 x 2	TM9-2800	17	90	94	6
*Bus, 15-passenger, converted-type	TM9-2800	14	111	108	7
*Bus, 29-passenger, 4 x 2	TM9-2800	15	118	112	7
*Bus, 29-passenger	TM9-2800	16	135	123	7
Cranes					
Crane, revolving, truck-mounted, pneumatic-tired, 2-engine drive, 4- to 8-ton, class X	TM9-2800	29	81	63	4
Crane, truck-mounted, gasoline engine-driven, 3/8-cu-yd (mounted on Coleman 4 x 4 truck chassis)	TM9-2800	30	129	85	6
Crane, truck-mounted, gasoline engine-driven, 3/8-cu-yd, Quick-Way model-E	TB5-9720-1	19	135	88	6
*Hoist, mobile collapsible, 35,000-lb capacity, type B-1	TM9-2800	34	115	111	7
*Crane, truck-mounted, M2, and trailer, clamshell, M16	TM9-2800	33	132	120	7

* Not all-wheel drive.

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Cranes (cont'd)					
*Crane, truck-mounted (6 x 4 carrier), gasoline engine-driven, 3/4-cu-yd	TM9-2800	31	147	130	7
*Crane, truck-mounted (6 x 4 carrier), gasoline engine-driven, 3/4-cu-yd	TM9-2800	32	156	136	7
Half-track vehicles					
Carrier, 81-mm mortar, half-track, M4	TM9-2800	62	107	75	5
Car, half-track, M9A1	TM9-2800	59	123	82	6
Carrier, 81-mm mortar, half-track, M21	TM9-2800	64	126	84	6
Car, half-track, M2A1	TM9-2800	58	132	86	6
Car, half-track, M2	TM9-2800	57	133	87	6
Carrier, personnel, half-track, M3	TM9-2800	65	135	88	6
Carrier, 81-mm mortar, half-track, M4A1	TM9-2800	63	135	88	6
Carrier, personnel, half-track, M3A1	TM9-2800	66	137	89	6
Carriage, motor, combination gun, M15A1	TM9-2800	60	138	89	6
Carriage, motor, multiple gun, M16	TM9-2800	61	140	90	6
Passenger and scout cars					
Car, scout, 4 x 4, M3A1	TM9-2800	68	130	85	6
*Car, 7-passenger, 4 x 2, medium sedan	TM9-2800	74	81	88	6
*Car, 5-passenger, 4 x 2, light sedan	TM9-2800	71	97	99	6
*Car, 5-passenger, 4 x 2, light sedan	TM9-2800	69	100	101	7
*Car, 5-passenger, 4 x 2, medium sedan	TM9-2800	72	99	101	7
*Car, 5-passenger, 4 x 2, light sedan	TM9-2800	70	102	102	7
*Car, 5-passenger, 4 x 2, medium sedan	TM9-2800	73	103	102	7

* Not all-wheel drive.

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Road equipment					
*Grader, road, motorized, diesel engine-driven	TM9-2800	87	72	83	6
*Loader, shovel, tractor-mounted, hydraulic, 1/3-cu-yd	TM9-2800	95	75	85	6
Distributor, bituminous material, truck-mounted, 800 gal.	TM9-2800	84	141	90	6
*Loader, bucket, tractor-mounted, front end, hydraulic-operated, 1/3-cu-yd, Hough model SI	TB5-9720-1	71	118	112	7
*Grader, road, motorized, diesel engine-driven, 12-ft moldboard, Galion model 101D	TB5-9720-1	37	134	122	7
*Grader, road, motorized, gasoline engine-driven 12-ft moldboard, Galion model 101	TB5-9720-1	43	134	122	7
*Grader, road, motorized, diesel engine-driven, 12-ft moldboard, Caterpillar model 12	TB5-9720-1	49	148	130	7
Tank transporters and recovery vehicles					
Truck-tractor, M26 and M26A1	TM9-2800	152	166	102	7
*Truck, 12-ton, 6 x 4, M20; part of truck-trailer, 45-ton, tank transporter M19	TM9-2800	150	115	111	7
Tractors					
*Tractor, wheel-type, rubber tires, gasoline engine-driven, 10 to 35 DBHP	TM9-2800	173	52	70	5
*Tractor, wheel-type, rubber tires, gasoline engine-driven, 23 DBHP (approx.), standard, w/power control unit, hydraulic-operating, rear-mounted	TM9-2800	174	62	76	5
Trucks					
Truck, 2-1/2-ton, 6 x 6, van	Squier**	41	74	60	4

* Not all-wheel drive.

** Data on Specialized Mobile Equipment, prepared by Vehicle Branch, Squier Signal Laboratory, Signal Corps Engineering Laboratories, Bradley Beach, N. J.

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (Cont'd)					
Truck, cargo, 2-1/2-ton, 6 x 6, M135	TM9-2800-1	233	79	62	4
Truck, 3/4-ton, 4 x 4, light maintenance and installation, K-50	TM9-2800	238	78	62	4
Truck, 3/4-ton, 4 x 4 telephone maintenance and installation, K-50-B	TM9-2800	239	79	62	4
Compressor, air, truck-mounted, gasoline engine-driven, 105 CFM (truck, 2-1/2-ton, 6 x 6)	TM9-2800	277	79	62	4
Apparatus, decontaminating, power-driven, M3A1 (Chassis: truck, 2-1/2-ton, 6 x 6)	TM9-2800	267	80	63	4
Truck, dump, 2-1/2-ton, 6 x 6, M47	TM9-2800-1	237	80	63	4
Truck, 1/2-ton, 4 x 4, emergency repair	TM9-2800	229	82	64	4
Truck, 3/4-ton, 4 x 4, command reconnaissance	TM9-2800	235	83	64	4
Truck, cargo, 2-1/2-ton, 6 x 6, M34	TM9-2800-1	230	82	64	4
Truck, 1/4-ton, 4 x 4, command reconnaissance (Ford)	TM9-2800	220	84	65	4
Truck, 1/4-ton, 4 x 4, command reconnaissance (Willys)	TM9-2800	221	84	65	4
Truck, 1-1/2-ton, 6 x 6, personnel and cargo (w/winch)	TM9-2800	261	84	65	4
Truck, 7-1/2-ton, 6 x 6, prime mover	TM9-2800	308	85	65	4
Truck, 3/4-ton, 4 x 4, carryall	TM9-2800	234	86	65	4
Truck, 3/4-ton, 4 x 4, command reconnaissance (w/winch)	TM9-2800	236	86	65	4
Truck, 3/4-ton, 4 x 4, weapons carrier	TM9-2800	240	86	65	4
Truck, 1-1/2-ton, 4 x 4, turret trainer, type E-5	TM9-2800	260	86	65	4
Truck, cargo, 5-ton, 6 x 6, M41	TM9-2800-1	266	87	66	4

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (cont'd)					
Truck, 2-1/2-ton, 6 x 6, line maintenance and construction	Squier	46	87	66	4
Truck, 2-1/2-ton, 6 x 6, earth borer and pole setter	Squier	47	87	66	4
Truck, 3/4-ton, 4 x 4, emergency repair, M2	TM9-2800	237	88	66	4
Truck, 3/4-ton, 4 x 4, weapons carrier (w/winch)	TM9-2800	241	88	66	4
Truck, 1-1/2-ton, 4 x 4, panel delivery	TM9-2800	256	88	66	4
Truck, 1/2-ton, 4 x 4, panel delivery	TM9-2800	230	89	67	4
Truck, 1-1/2-ton, 4 x 4, cargo (w/winch)	TM9-2800	251	89	67	4
Truck, 1-1/2-ton, 4 x 4, stake and platform, K-33, C.O.E.	TM9-2800	257	89	67	4
Truck, 4-ton, 6 x 6, wrecker	TM9-2800	301	89	67	4
Truck, field lighting, type J-3	TM9-2800	314	89	67	4
Truck, field lighting, J-4 and AN2505	TM9-2800	315	89	67	4
Truck, field lighting, type J-5 and AN2525	TM9-2800	316	89	67	4
Truck, 1-1/2-ton, 4 x 4, C.O.E., stake	Squier	10	90	67	4
Truck, cargo, 2-1/2-ton, 6 x 6, M211	-------	---	77	60	4
Truck, 5-ton, 6 x 6, wrecker, M62	-------	---	91	68	4
Truck, 2-1/2-ton, 6 x 6, gasoline, tank, 750 gal.	TM9-2800	280	91	68	4
Shop equipment, motorized, welding (truck, 2-1/2-ton, 6 x 6, cargo	TM9-2800	285	91	68	4
Truck, 2-1/2-ton, 6 x 6, oil servicing, 660 gal., L-2	TM9-2800	286	91	68	4
Truck, 2-1/2-ton, 6 x 6, van, K-53	TM9-2800	290	91	68	4
Truck, 2-1/2-ton, 6 x 6, van, K-60	TM9-2800	291	91	68	4
Truck, 2-1/2-ton, 6 x 6, van	Squier	25	91	68	4
Truck, 2-1/2-ton, 6 x 6, van	Squier	30	91	68	4

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (cont'd)					
Truck, 1/2-ton, 4 x 4, pickup (open cab w/bucket and troop seats and w/o seats)	TM9-2800	232	92	68	4
Truck, 2-1/2-ton, 6 x 6, cargo, LWB	TM9-2800	273	92	68	4
Truck, 2-1/2-ton, 6 x 6, cargo, SWB	TM9-2800	275	92	68	4
Truck, cargo, 2-1/2-ton, 6 x 6, M35	TM9-2800-1	231	93	69	4
Auger, earth, skid-mounted, gasoline engine-driven	TM9-2800	218	93	69	4
Truck, 2-1/2-ton, 6 x 6, cargo, 15-ft body, C.O.E.	TM9-2800	269	93	69	4
Truck, 2-1/2-ton, 6 x 6, cargo, LWB (w/winch)	TM9-2800	274	94	69	4
Truck, 2-1/2-ton, 6 x 6, chemical service, M1	TM9-2800	276	94	69	4
Truck, 2-1/2-ton, 6 x 6, fuel or oil servicing, 750 gal., F-3	TM9-2800	279	94	69	4
Truck, 2-1/2-ton, 6 x 6, gasoline tank, 750 gal.	TM9-2800	281	94	69	4
Truck, surgical, 2-1/2-ton, 6 x 6	TM9-2800	289	94	69	4
Truck, 2-1/2-ton, 6 x 6, ordnance maintenance	TM9-2800	287	96	70	5
Water purification unit, gasoline engine-driven, truck-mounted, 75 gpm (truck, 2-1/2-ton, 6 x 6)	TM9-2800	292	96	70	5
Truck, 7-1/2-ton, 6 x 6, prime mover	TM9-2800	311	96	70	5
Truck, 1/2-ton, 4 x 4, weapons carrier	TM9-2800	233	97	71	5
Truck, 1-1/2-ton, 4 x 4, cargo, 15-ft body	TM9-2800	249	97	71	5
Shop equipment, motorized, general purpose repair (truck, 2-1/2-ton, 6 x 6, w/winch)	TM9-2800	284	97	71	5

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (cont'd)					
Truck, 2-1/2-ton, 6 x 6, pipeline equipment	TM9-2800	288	97	71	5
Truck, 6-ton, 6 x 6, cargo, (Treadway), (4DT)	TM9-2800	305	97	71	5
Truck, 1/2-ton, 4 x 4, carryall	TM9-2800	227	98	71	5
Truck, 1-1/2-ton, 4 x 4, cargo (w/winch)	TM9-2800	250	98	71	5
Truck, 2-1/2-ton, 6 x 6, cargo, 17-ft body, C.O.E.	TM9-2800	270	98	71	5
Truck, 2-1/2-ton, 6 x 6, cargo dump, LWB (w/winch)	TM9-2800	272	98	71	5
Truck, 2-1/2-ton, 6 x 6, LWB, high-lift, w/van-type body	TM9-2800	282	98	71	5
Truck, 2-1/2-ton, 6 x 6, w/van-type body, map reproduction equipment	TM9-2800	283	98	71	5
Truck, 1-1/2-ton, 4 x 4, cargo	TM9-2800	248	99	72	5
Truck, 2-1/2-ton, 6 x 6, water tank, 700 gal.	TM9-2800	293	99	72	5
Truck, 1-1/2-ton, 4 x 4, combination stake and platform, C.O.E.	TM9-2800	252	100	72	5
Truck, 1-1/2-ton, 4 x 4, stake and platform, K-54, C.O.E.	TM9-2800	258	100	72	5
Truck, 6-ton, 6 x 6, prime mover	TM9-2800	306	101	72	5
Truck, 6-ton, 6 x 6, prime mover	TM9-2800	307	102	73	5
Truck, 1-1/2-ton, 4 x 4, C.O.E., stake	Squier	26	102	73	5
Truck, 1-1/2-ton, 4 x 4, air compressor	TM9-2800	246	103	73	5
Truck, 1-1/2-ton, 4 x 4, dump	TM9-2800	253	103	73	5
Truck, 1-1/2-ton, 4 x 4. telephone construction and maintenance, K-42 and K-43	TM9-2800	259	103	73	5
Truck, 1-1/2-ton, 4 x 4, bomb service, M6	TM9-2800	247	104	73	5
Truck, 1-1/2-ton, 4 x 4, dump	TM9-2800	254	104	73	5
Truck, 1-1/2-ton, 4 x 4, earth auger	TM9-2800	255	104	73	5

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (cont'd)					
Truck, 4-ton, 6 x 6, cargo	TM9-2800	294	104	73	5
Truck, wrecking, heavy, M1 and M1A1	TM9-2800	313	104	73	5
Truck, fire, powered, crash, class 155, 6 x 6, high-pressure fog foam	TM9-2800	321	104	73	5
Truck, 5-6-ton, 4 x 4, van	Squier	8	104	73	5
Truck, 1-1/2-ton, 4 x 4, telephone maintenance and construction	Squier	18	104	73	5
Truck, 2-1/2-ton, 6 x 6, bomb service, M27 and M27B1	TM9-2800	268	106	74	5
Truck, 1-1/2-ton, 4 x 4, earth borer and pole setter	Squier	19	106	74	5
Truck, 1/2-ton, 4 x 4, pickup (closed cab w/seats and w/o seats)	TM9-2800	231	107	75	5
Truck, 4-ton, 6 x 6, crane, swinging boom, M1	TM9-2800	295	108	75	5
Truck, 4-ton, 6 x 6, dump	TM9-2800	297	108	75	5
Tank, asphalt, steel, truck-mounted w/heating flues, 800 gal. (truck, 4-ton, 6 x 6)	TM9-2800	299	108	75	5
Truck, 3/4-ton, 4 x 4, telephone installation and maintenance	Squier	21	108	75	5
Distributor, water, truck-mounted, 1,000 gal. (truck, 4-ton, 6 x 6)	TM9-2800	296	109	76	5
Truck, 5-6-ton, 4 x 4, van	TM9-2800	304	109	76	5
Truck, fire, powered, brush, class 300, 4 x 4	TM9-2800	323	109	76	5
Truck, flat bed, 4-ton 6 x 6, 4DT, 172-in. wheel-base, with "A" frame, cab protector and winch, rear-mounted	TM9-2800	298	111	77	5
Reproduction equipment, press section, 22 in. x 29 in., motorized (truck, 4-ton, 6 x 6, w/van-type body)	TM9-2800	300	111	77	5
Truck, fire, powered, crash, class 135, 4 x 4, high-pressure fog foam	TM9-2800	319	115	79	5

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (cont'd)					
Truck, dental-operating, 2-1/2-ton, 6 x 6	TM9-2800	278	116	79	5
Truck, 2-1/2-ton, 6 x 6, dump	TM9-2800	271	118	80	6
Truck, fire, powered, pumper, class 325, 4 x 4, 300 gpm	TM9-2800	325	121	81	6
Truck, fire, powered, pumper, class 525, 4 x 4, 500 gpm	TM9-2800	328	121	81	6
Plow, snow, rotary, gasoline engine-driven, truck-mounted (truck, 7-1/2-ton, 4 x 4)	TM9-2800	309	125	83	6
Truck, 7-1/2-ton, 6 x 6, crane-mounted, model P1	TM9-2800	310	125	83	6
*Truck, 1/2-ton, 4 x 2, pickup	TM9-2800	225	79	87	6
*Truck, 1-1/2-ton, 4 x 2, combination stake and platform	TM9-2800	243	80	88	6
Truck, fire, powered, class 150, 6 x 6, low-pressure carbon dioxide	TM9-2800	320	136	88	6
*Truck, dump body, 10-cu-yd, 4 x 2, 2DT, 157-in. wheelbase	TM9-2800	312	86	91	6
*Truck, 1-1/2-ton, 4 x 2, combination stake and platform	TM9-2800	242	87	92	6
Truck, 1/2-ton, 4 x 4, command reconnaissance	TM9-2800	228	150	94	6
*Truck, 1/2-ton, 4 x 2, pickup	TM9-2800	226	92	95	6
*Truck, 2-1/2-ton, 4 x 2, dump	TM9-2800	263	92	95	6
*Truck, 2-1/2-ton, 4 x 2, dump	TM9-2800	264	92	95	6
*Truck, 1/2-ton, 4 x 2, pickup	TM9-2800	224	94	97	6
*Truck, 1-1/2-ton, 4 x 2, combination stake and platform	TM9-2800	244	94	97	6
*Truck, 2-1/2-ton, 4 x 2, dump	TM9-2800	262	95	98	6

* Not all-wheel drive.

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trucks (cont'd)					
*Truck, 1/2-ton, 4 x 2, light maintenance and installation, K50	TM9-2800	223	102	102	7
*Truck, 1-1/2-ton, 4 x 2, dump	TM9-2800	245	102	102	7
*Truck, 1/2-ton, 4 x 2, carryall	TM9-2800	222	106	104	7
*Truck, fire, powered, pumper, class 525, 4 x 2, 500 gpm	TM9-2800	327	106	104	7
*Truck, fire, powered, pumper, class 750, 4 x 2, 750 gpm	TM9-2800	330	106	104	7
Truck, fire, powered, pumper, class 530, 6 x 6, 500 gpm, overseas-type	TM9-2800	329	177	107	7
*Truck, fire, powered, crash, class 125, 4 x 2, high-pressure fog foam	TM9-2800	317	111	108	7
*Truck, fire, powered, pumper, class 500, 4 x 2, 500 gpm	TM9-2800	326	112	108	7
*Truck, 2-1/2-ton, 6 x 4, cargo	TM9-2800	266	113	109	7
*Truck, fire, powered, pumper, class 325, 4 x 2, 300 gpm	TM9-2800	324	113	109	7
*Truck, 2-1/2-ton, 4 x 2, telephone construction and maintenance	TM9-2800	265	115	111	7
*Truck, fire, powered, crash, class 135, 4 x 2, high-pressure fog foam	TM9-2800	318	118	112	7
*Truck, 5-ton, 4 x 2, dump	TM9-2800	303	119	112	7
*Truck, fire, powered, brush, class 300, 4 x 2	TM9-2800	322	120	113	7
*Truck, 5-ton, 4 x 2, cargo	TM9-2800	302	129	119	7
*Shop, motorized, aviation battalion, type A and B	TM9-2800	219	133	122	7
Truck-tractors					
Truck, 1-1/2-ton, 4 x 4, tractor	TM9-2800	335	95	70	5
Truck-tractor, 4-ton, 6 x 6, (4DT), 172-in. wheelbase, with "A" frame, cab protector and front-mounted winch	TM9-2800	337	103	73	5

* Not all-wheel drive.

Self-propelled Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Truck-tractors (cont'd)					
Truck, 5-6-ton, 4 x 4, ponton tractor, C.O.E.	TM9-2800	344	108	75	5
Truck-tractor, wrecking, type C2, 7-1/2-ton, 6 x 6, (4DT)	TM9-2800	346	123	82	6
Truck, 4-5-ton, 4 x 4, tractor, C.O.E.	TM9-2800	340	130	85	6
Truck, 4-5-ton, 4 x 4, tractor, C.O.E.	TM9-2800	338	132	86	6
Truck, 4-5-ton, 4 x 4, tractor, C.O.E.	TM9-2800	339	132	86	6
Truck-tractor, 7-1/2-ton, 6 x 6, fuel-servicing, type F1	TM9-2800	345	139	90	6
Truck, 1-1/2-ton, 4 x 4, tractor	Squier	34	149	94	6
*Truck, 1-1/2-ton, 4 x 2, tractor	TM9-2800	332	89	94	6
*Truck, 1-1/2-ton, 4 x 2, tractor	TM9-2800	334	89	94	6
*Truck, 1-1/2-ton, 4 x 2, tractor	TM9-2800	333	91	95	6
*Truck, 2-1/2-ton, 6 x 4, tractor	TM9-2800	336	100	101	7
*Truck, 5-ton, 4 x 2, tractor, C.O.E., M426	TM9-2800	343	110	106	7
*Truck, 5-ton, 4 x 2, tractor, C.O.E., M425	TM9-2800	342	112	108	7
*Truck, 5-ton, 4 x 2, tractor	TM9-2800	341	130	119	7
*Truck-tractor, 20-ton, 6 x 4, diesel	TM9-2800	347	137	125	7

* Not all-wheel drive.

Towed Tracked Vehicles

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trailers					
Trailer, Athey, 6-ton, BT898-4	TM9-2800	181	83	64	4
Trailer, Athey, 6-ton, BT898-1	TM9-2800	181	111	77	5
Wagon, dirt or rock, crawler-mounted, bottom dump, 11-cu-yd	TM9-2800	182	152	95	6
Trailer, Athey, 20-ton, ET1076-1	TM9-2800	182	164	101	7

Towed Wheeled Vehicles

Name	T.M. or T.B.	Page	Mo-bility Index	Vehi-cle Cone Index	Cate-gory
Cranes					
Crane, mobile, 30,000-lb capacity	TM9-2800	27	82	64	4
Crane, non-revolving, pneumatic-tired, wheel-mounted, tractor-operated, 20,000-lb at 10-ft radius, 30-ft boom	TM9-2800	28	87	66	4
Crane, non-revolving, pneumatic-tired, wheel-mounted, tractor-operated, 40,000-lb capacity at 3-ft-6-in. radius, 20-ft boom	TM9-2800	28	101	72	5
Dollies					
Dolly, 4W tandem, 4DT, M1	TM9-2800	46	48	48	2
Dolly, propeller, type C-1A	TM9-2800	47	105	74	5
Dolly, 2W, 7-ton payload	TM9-2800	42	116	79	5
Dolly, 2W, 2 dual tires, 4-1/2-ton capacity	TM9-2800	42	132	86	6
Limber, carriage, heavy, M5	TM9-2800	47	150	94	6
Dolly, 2W, trailer-converter, wrecking, type C-2	TM9-2800	43	159	98	6
Dolly, 2W, trailer-converter, fuel-servicing, type F-1 or F-1A	TM9-2800	44	159	98	6
Dolly, 2W, trailer-converter, K-83	TM9-2800	45	164	101	7
Dolly, 10-ton, 2W, trailer-converter, M365	TM9-2800	43	166	102	7
Dolly, trailer-converter, type A-3, for technical supply, field shop, and instrument shop	TM9-2800	46	166	102	7
Dolly, 2W, trailer-converter, fuel-servicing, type F-2 or F-2A	TM9-2800	44	177	107	7
Hand carts					
Cart, hand, M3A4	TM9-2200	69	118	80	6
Cart, hand, M4A1	TM9-2200	70	118	80	6

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Hand carts (cont'd)					
Cart, hand, M6A1	TM9-2200	70	118	80	6
Road equipment					
Scraper, road, towed-type, cable-operated, 12-cu-yd, LeTourneau model LP	TB5-9720-1	83	68	57	3
Roller, road, towed, rubber-tired, 2 axle, 13W	TM9-2800	102	85	65	4
Mixer, rotary tiller, soil stabilization, power take-off, trailer-mounted	TM9-2800	97	89	67	4
Scraper, road, towed-type, cable-operated, 12-cu-yd	TM9-2800	104	89	67	4
Scraper, road, motorized, cable-operated, 12-cu-yd	TM9-2800	105	91	68	4
Heater, asphalt, trailer-mounted, 3-car, 42 HP	TM9-2800	89	93	69	4
Kettle, asphalt, repair, trailer-mounted, w/motor-driven hand spray, 165-gal capacity	TM9-2800	90	99	72	5
Pump, water, trailer-mounted, w/distributor attachments	TM9-2800	98	99	72	5
Asphalt & soil aggregate mixing plant, gasoline engine-driven, 25 ton per hour; unit no. 2, dryer, aggregate, semitrailer-mounted	TM9-2800	76	100	72	5
Scraper, road, motorized, cable-operated, 12-cu-yd, LeTourneau model LP with super C Tournapull	TB5-9720-1	79	102	73	5
Scraper, road, towed-type, cable-operated, 8-cu-yd	TM9-2800	104	104	73	5
Scraper, road, towed-type, cable-operated, 8-cu-yd, LeTourneau model LS	TB5-9720-1	91	108	75	5
Asphalt & soil aggregate mixing plant, gasoline engine-driven, 25 ton per hour; unit no. 3, stabilizer, soil, semitrailer-mounted, w/dolly	TM9-2800	77	115	79	5

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Road equipment (cont'd)					
Heater, asphalt, trailer-mounted, 2-car, 28 HP	TM9-2800	89	119	80	6
Scraper, road, motorized, diesel, cable-operated, 8-cu-yd, LeTourneau model LS with model C Tournapull	TB5-9720-1	87	126	84	6
Asphalt plant, gasoline-driven, 10 to 30 ton per hour; unit no. 2, dryer, aggregate, trailer-mounted, complete	TM9-2800	79	126	84	6
Pump, asphalt, trailer-mounted, w/distributor attachments	TM9-2800	98	127	84	6
Asphalt plant, gasoline-driven, 10 to 30 ton per hour; unit no. 1, mixer, bituminous, trailer-mounted, complete	TM9-2800	78	130	85	6
Kettle, asphalt, repair, trailer-mounted, w/motor-driven hand spray, 110-gal. capacity	TM9-2800	90	132	86	6
Mixer, rotary tiller, soil stabilization, gasoline engine-driven, self-powered, trailer-mounted	TM9-2800	97	132	86	6
Scraper, road, towed-type, hydraulic-operated, 1-1/2-cu-yd	TM9-2800	102	133	87	6
Scraper, road, towed-type, hydraulic-operated, 1-1/2-cu-yd, LaPlante-Choate model-cab	TB5-9720-1	103	133	87	6
Asphalt and soil aggregate mixing plant, gasoline engine-driven, 25 ton per hour; unit no. 1, mixer, pugmill, semitrailer	TM9-2800	75	134	87	6
Crushing and screening plant, 2-unit gasoline engine-driven, semitrailer-mounted, w/dolly, 25 cu yd per hour; unit no. 2, roll crusher	TM9-2800	82	139	90	6

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Road equipment (cont'd)					
Crushing and screening plant, 2-unit gasoline engine-driven, semitrailer-mounted, w/dolly, 25 cu yd per hour; unit no. 1, jaw-crusher	TM9-2800	81	140	90	6
Asphalt and soil aggregate mixing plant, gasoline engine-driven, 25 ton per hour; unit no. 4, elevator, bucket, trailer-mounted	TM9-2800	77	142	91	6
Distributor, bituminous material, trailer-mounted, 1,250 gal.	TM9-2800	83	148	93	6
Gradation control unit, aggregate gasoline-driven, trailer-mounted, 4 x 8 ft, vibrating screen, 3-compartment bin	TM9-2800	88	172	104	7
Tank, asphalt, steel, trailer-mounted, w/steam coils, 1,500 gal.	TM9-2800	109	178	108	7
Scraper, road, towed-type, cable-operated, 3-1/2-cu-yd	TM9-2800	103	195	115	7
Mixer, asphalt, diesel engine-driven, travel or central plant, trailer-mounted	TM9-2800	96	198	116	7
Scraper, road, towed-type, cable-operated, 6-cu-yd	TM9-2800	103	206	120	7
Scraper, road, towed-type, cable-operated, 6-cu-yd, LeTourneau model M	TB5-9720-1	95	212	123	7
Dryer, aggregate, dual-drum, 80 to 150 ton per hour, trailer-mounted	TM9-2800	85	213	123	7
Scraper, road, towed-type, cable-operated, 3-1/2-cu-yd, LeTourneau model D	TB5-9720-1	99	254	142	7
Conveyor, belt, transfer, gasoline-driven, 24 in. x 57 ft (dolly governs cone index)	TM9-2800	80	414	200	7

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Semitrailers					
Semitrailer, 10-ton, 2 W, stake and platform	TM9-2800	127	88	66	4
Semitrailer, special, drop-frame, 10-ton ponton	TM9-2800	118	89	67	4
Semitrailer, 10-ton gross, technical supply	TM9-2800	128	95	70	5
Semitrailer, 6-ton gross, 2W, antenna-mount, K-67	TM9-2800	110	100	72	5
Semitrailer, 3-1/2-ton, 2W, combination stake and platform	TM9-2800	126	100	72	5
Semitrailer, 3-ton, 2W, van	TM9-2800	129	100	72	5
Semitrailer, 25-ton, 2W, ponton	TM9-2800	118	107	75	5
Semitrailer, 8-ton gross, instrument shop	TM9-2800	123	112	77	5
Semitrailer, 12-ton gross, 2W, van, K-78	TM9-2800	132	112	77	5
Semitrailer, 10-ton gross, field shop repair, type A-3A	TM9-2800	121	113	78	5
Generator and charging plant, acetylene gas, semitrailer-mounted, van-type w/dolly, 750 cu ft per hour	TM9-2800	114	115	79	5
Semitrailer, 8-ton gross, 2W, antenna-mount	Squier	5	124	83	6
Semitrailer, 8-ton gross, 2W, antenna-mount, K-22 and K-64	TM9-2800	110	125	83	6
Semitrailer, 12-1/2-ton, 4W, wrecking, 40-ft, type C2	TM9-2800	135	127	84	6
Semitrailer, 5-ton, 2W, stake and platform, 16-ft	TM9-2800	126	128	84	6
Generator and charging plant, oxygen-nitrogen gas, semitrailer-mounted, van-type, 500 cu yd per hour	TM9-2800	115	129	85	6
Semitrailer, 2W, fuel-servicing, 2,000 gal. type F-2B	TM9-2800	113	130	85	6
Semitrailer, 6-ton, 2W, sterilizer and bath	TM9-2800	122	130	85	6
Semitrailer, 12-ton gross, 2W, van	Squier	37	130	85	6

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Semitrailers (cont'd)					
Semitrailer, 2W, 10-ton, refrigerator (Lightweight)	TM10-1673	5	130	85	6
Semitrailer, 6-ton payload, 10-ton gross, 2W, combination animal and cargo	TM9-2800	111	131	86	6
Semitrailer, 2W, fuel-servicing, 2,000 gal., type F-2	TM9-2800	112	131	86	6
Semitrailer, 2W, fuel-servicing, 2,000 gal., type F-2A	TM9-2800	112	131	86	6
Semitrailer, 10-ton gross, 2W, refrigerator body (Lightweight)	TM9-2800	120	131	86	6
Semitrailer, 10-ton gross, 2W, refrigerator body	TM9-2800	119	132	86	6
Semitrailer, 6-ton, 2W, clothing repair	TM9-2800	120	132	86	6
Semitrailer, 6-ton, 2W, textile repairs	TM9-2800	123	132	86	6
Semitrailer, 12-1/2-ton payload, 4W, tandem van	TM9-2800	134	132	86	6
Semitrailer, 4W, fuel-servicing, 4,000 gal., type F-1	TM9-2800	113	141	90	6
Semitrailer, 4W, fuel-servicing, 4,000 gal., type F-1A	TM9-2800	114	142	91	6
Semitrailer, 6-ton gross, 4W, van, K-55	TM9-2800	130	142	91	6
Semitrailer, 12-1/2-ton, 4W, wrecking, 25-ft, type C2	TM9-2800	135	142	91	6
Semitrailer, 15-ton,gross, 4W, van, with dolly	Squier	43	145	92	6
Semitrailer, low-bed, front-loading, 20-ton (Long gooseneck)	TM9-2800	117	146	93	6
Semitrailer, 6-ton gross, 4W, van	Squier	27	147	93	6
Semitrailer, 6-ton, 2W, laundry	TM9-2800	115	148	93	6
Semitrailer, 10-ton gross, 2W, oxygen generator, type A1	TM9-2800	117	148	93	6

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Semitrailers (cont'd)					
Semitrailer, 6-ton, 2W, van, mobile records	TM9-2800	130	148	93	6
Semitrailer, 6-ton, 2W, van	TM9-2800	131	148	93	6
Semitrailer, 7-ton, 4W, w/dolly, 2W, van, M26	TM9-2800	132	151	95	6
Semitrailer, 15-ton gross, 4W, w/dolly, 2W, V-9/MPG-1	TM9-2800	133	151	95	6
Semitrailer, w/dolly, 20-ton, low-bed	TM9-2800	116	153	96	6
Reproduction equipment, camera section, 24 in. x 30 in., semitrailer-mounted, (10-ton, w/van-type body)	TM9-2800	124	156	97	6
Semitrailer, 11-ton payload, 15-ton gross, 2W, van, 28-ft	TM9-2800	134	161	99	6
Semitrailer, 10-ton gross, laboratory, photographic, type N-2, N-3	TM9-2800	125	163	100	7
Semitrailer, 7-ton, 2W, stake and platform	TM9-2800	127	182	109	7
Semitrailer, 6-ton, 2W, shoe repair	TM9-2800	122	194	115	7
Semitrailer, 15-ton, 4W, carryall	TM9-2800	111	215	124	7
Tanks					
Tank, water, steel, semitrailer-mounted, 1,500 gal.	TM9-2800	136	102	73	6
Tank transporters and recovery vehicles					
Semitrailer, 40-ton, tank transporter, M15 and M15A1	TM9-2800	151	217	125	7
Trailer, 45-ton, 12W, M9, part of truck-trailer, 45-ton, tank transporter M19	TM9-2800	151	307	160	7
Trailers					
Trailer, 2W, airborne equipment, type H-1	TM9-2800	175	52	50	3

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trailers (cont'd)					
Howitzer, 240-mm, M1; carriage, howitzer, 240-mm, M1, M2A1 cannon transport wagon	TM9-2300	74	55	51	3
Howitzer, 240-mm, M1; carriage, howitzer, 240-mm, M1, M3A1 carriage transport wagon	TM9-2300	74	55	51	3
Gun, 8-in., M1; carriage, gun, 8-in., M2, M3A1 carriage transport wagon	TM9-2300	70	55	51	3
Gun, 8-in., M1; carriage, gun, 8-in., M2, M2A1 cannon transport wagon	TM9-2300	70	56	52	3
Trailer, 4W, pole-type, flat-bed, 7-ton, 3/8-cu-yd, truck-crane attachments	TM9-2800	217	65	56	3
Howitzer, pack, 75-mm, M1A1; carriage, howitzer (Pack), 75-mm, M8	TM9-2300	58	68	57	3
Gun, 57-mm, M1; carriage, gun, 57-mm, M1A3 and M2	TM9-2300	22	77	61	4
Trailer, ammunition, M10	TM9-2800	176	82	64	4
Howitzer, 105-mm, M2A1; carriage, M2A1	TM9-2300	62	88	66	4
Trailer, 2-1/2-ton, 2W, utility, pole-type	TM9-2800	215	89	67	4
Howitzer, 105-mm, M2A1; carriage, M2A2	TM9-2300	62	89	67	4
Trailer, 2-1/2-ton payload, 2W, cargo (amphibian)	TM9-2800	188	96	70	5
Oven Trailer of bakery unit, mobile, M-1945	TM10-1699C	3	98	71	5
Trailer, 7-ton gross, 4W, antenna-mount, K-28B and K-28C	TM9-2800	178	99	72	5
Trailer, 1/4-ton, 2W, cargo (amphibian)	TM9-2800	186	99	72	5
Trailer, 7-ton gross, 4W, van, K72	TM9-2800	214	99	72	5
Trailer, 3-ton gross, 2W, house, K-29	TM9-2800	201	100	72	5
Trailer, 1-ton, 2W, house	Squier	7	100	72	5
Trailer, 7-ton gross, 4W, van	Squier	33	100	72	5

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trailers (cont'd)					
Trailer, bomb, 3/4-ton payload, 2W, M29	TM9-2800	183	102	72	5
Trailer, 3/8-ton payload, 2W, telephone cable splicer, K-38-A	TM9-2800	185	102	73	5
Trailer, 1-1/4-ton, 2W, arc-welder	TM9-2800	180	107	75	5
Trailer, 1-ton, 2W, 2-horse, van	TM9-2800	212	107	75	5
Trailer, dump, towed-type, 1/2-ton, 2W	TM9-2800	192	114	78	5
Trailer, bomb, 1-ton, 4W, T53	TM9-2800	183	116	79	5
Trailer, 3-1/2-ton payload, 2W, pole-hauling and cargo, V-13/GT	TM9-2800	208	116	79	5
Howitzer, 155-mm, M1; carriage, howitzer, 155-mm, M1A1 and M1A2	TM9-2300	64	122	82	6
Trailer, antenna, 8-ton gross, 4W, K-64-C	TM9-2800	179	123	82	6
Trailer, fuel-servicing, 2W, 600 gal., type A-1	TM9-2800	196	125	83	6
Trailer, fuel-servicing, 2W, 600 gal., type A-1A	TM9-2800	196	125	83	6
Trailer, fuel-servicing, 2W, 600 gal., type A-3	TM9-2800	197	125	83	6
Trailer, 12-ton gross, 4W, van	Squier	42	125	83	6
Trailer, fire-pumper, 2W, 500 gpm, class 1000	TM9-2800	195	130	85	6
Semitrailer, 12-ton gross, 2W, van	Squier	37	130	85	6
Trailer, 5-ton payload, 4W, van, K-34	TM9-2800	213	133	87	6
Mixing and make-up machinery trailer of the bakery unit, mobile, M-1945	TM10-1699A	4	133	87	6
Gun, 90-mm, T8; carriage, gun, 90-mm, T5E2	TM9-2300	24	140	90	6
Trailer, mount, M20	TM9-2800	206	141	90	6
Trailer, 1-ton, 2W, cargo	TM9-2800	187	143	91	6
Trailer, 1-ton, 2W, tire-repair, load B, M25	TM9-2800	211	143	91	6
Trailer, 1-ton, 2W, water-tank, 250 gal.	TM9-2800	216	143	91	6

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trailers (cont'd)					
Gun, 120-mm, M1; mount, gun, antiaircraft, 120-mm, M1 and M1A1	TM9-2300	18	143	91	6
Trailer, 1-ton, 2W	Squier	23	143	91	6
Trailer, 1-ton, 2W, K-63 and K-63A	Squier	24	143	91	6
Trailer, 1-ton, 2W, K-52	Squier	24	143	91	6
Trailer, 1-ton, 2W, antenna-mount	Squier	45	143	91	6
Trailer, 1-ton, 2W, tire-repair, load A, M25	TM9-2800	211	144	92	6
Trailer, 4W, special tandem, 7 to 14 ton (4DT)	TM9-2800	216	144	92	6
Trailer, 5-ton, 4W, antenna-mount, K-76 and K-77	TM9-2800	178	145	92	6
Trailer, 7-ton gross, 4W, special	Squier	40	145	92	6
Trailer, 1-ton payload, 2W, antenna-mount, V-15/T	TM9-2800	177	146	93	6
Trailer, 7-ton gross, 4W, low-bed, tandem-axle, antenna-mount, K-84	TM9-2800	179	146	93	6
Trailer, generator, M7	TM9-2800	197	146	93	6
Trailer, M18	TM9-2800	198	146	93	6
Trailer, mount, M17	TM9-2800	206	146	93	6
Trailer, 12-ton gross, 4W, van, V-5/MPN-1	TM9-2800	214	146	93	6
Pump, gasoline-dispensing, mobile, gasoline engine-driven, 100 gal. per minute (Habhegger - "PM-100")	TM10-1660	9	146	93	6
Trailer, bomb, M5	TM9-2800	184	147	93	6
Trailer, 8-ton, full, low-bed	TM9-2800	202	147	93	6
Gun, automatic, 40-mm, M1; carriage, gun, 40-mm, M2A1	TM9-2300	10	147	93	6
Trailer, 5-ton, 4W, van	Squier	38	147	93	6
Trailer, chemical handling, M2	TM9-2800	189	148	93	6
Trailer, chemical service, M1	TM9-2800	190	148	93	6
Trailer, director, M13	TM9-2800	191	148	93	6
Trailer, director, M14	TM9-2800	191	148	93	6
Trailer, director, M22	TM9-2800	192	148	93	6
Trailer, 2-ton, 4W, w/smoke generator, M7	TM9-2800	198	148	93	6

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trailers (cont'd)					
Trailer, 1-1/2-ton payload, 6-ton gross, 4W, house, K-35 and K-65	TM9-2800	200	148	93	6
Trailer, tilting-type, searchlight, 60-in., 4W, M1	TM9-2800	209	149	94	6
Trailer, 1/4-ton payload, 2W, telephone cable splicer, K-38	TM9-2800	185	150	94	6
Trailer, 20-ton, full, low-bed	TM9-2800	204	153	96	6
Gun, automatic, 40-mm, M1; mount, gun, 40-mm, M3 and M5 (7.25 x 22 tires)	TM9-2300	12	154	96	6
Trailer, 2-ton payload, 2W, pole-hauling and cargo, K-36	TM9-2800	208	155	97	6
Bath unit, field, mobile, 24-shower head	TM10-1696	3	157	98	6
Bath unit, field, mobile, 24-shower head (Orr and Sembower-2B-24 and 3B-24)	TM10-1616	4	157	98	6
Gun, 155-mm, M2; carriage, gun, 155-mm, M1	TM9-2300	66	159	98	6
Howitzer, 8-in., M2, carriage, howitzer, 8-in., M1	TM9-2300	68	159	98	6
Trailer, 4-ton, 2W, ammunition, M21	TM9-2800	176	164	101	7
Gun, 90-mm, M1 and M1A1; mount, gun, antiaircraft, 90-mm, M1 and M1A1	TM9-2300	14	164	101	7
Trailer, 14-ton gross, 4W, antenna-mount, K-75	TM9-2800	180	165	101	7
Trailer, 8-ton, ammunition, 4W, M23	TM9-2800	177	170	104	7
Trailer, 4-ton gross, 4W, special	Squier	36	171	104	7
Trailer, 1-ton, snow, M19	TM9-2800	210	176	106	7
Trailer, 5-ton, 4W, van, K-80	Squier	38	176	106	7
Trailer, 5-ton, 2W, cable reel and pole trailer	Squier	15	180	108	7
Gun, 90-mm, M2; mount, gun, antiaircraft, 90-mm, M2	TM9-2300	16	181	109	7

Towed Wheeled Vehicles (Cont'd)

Name	T.M. or T.B.	Page	Mobility Index	Vehicle Cone Index	Category
Trailers (cont'd)					
Generator and charging plant, hydrogen and carbon dioxide, methanol water type, low-pressure; 4,000 CFH hydrogen; 156 lb per hour, carbon dioxide; trailer-mounted	TM9-2800	199	182	109	7
Trailer, 2W, oxygen-servicing, type E-1	TM9-2800	207	182	109	7
Trailer, 2W, oxygen-servicing, type E-2	TM9-2800	207	182	109	7
Trailer, 4W, airdrome utility, type F-2	TM9-2800	175	183	110	7
Trailer, 60-ton, full, low-bed	TM9-2800	205	186	111	7
Trailer, 16-ton, full, low-bed	TM9-2800	203	187	111	7
Trailer, 2W, clothing and textile repair	TM9-2800	188	194	115	7
Trailer, 4W, 6-ton gross, van	Squier	12	194	115	7
Trailer, 4W, 4-ton gross, special, K-77-A	Squier	36	194	115	7
Trailer, 2W, shoe-repair	TM9-2800	209	195	115	7
Trailer, 2W, shower-bath	TM9-2800	210	197	116	7
Trailer, laundry, mobile, 2-trailer type, trailer no. 2	TM9-2800	202	199	117	7
Trailer, 5-ton payload, 2W, cable-hauler, K-37	TM9-2800	184	214	124	7
Trailer, tractor-crane, 7-ton M6	TM9-2800	212	214	124	7
Trailer, laundry, mobile, no. 1	TM10-1680	279	221	127	7
Trailer, laundry, mobile, no. 2	TM10-1680	279	221	127	7
Trailer, laundry, mobile, 2-trailer type, trailer no. 1	TM9-2800	201	231	132	7
Trailer, 22-ton, 6W, low-bed	TM9-2800	204	285	156	7
Trucks					
Truck, bomb-lift, M1	TM9-2800	331	144	92	6
Truck, lift, M22	TM9-2800	331	166	102	7

Table 3

Trafficability Characteristics of Soils and Land Areas 1/

Group	Soils	Unified Soil Classification System	Probable Cone Index Range	Probable Remolding Index Range	Probable Rating Cone Index Range	Slipperiness Effects	Stickiness Effects	Soil Trafficability 2/ or Bearing Strength: Wet Period	Soil Trafficability 2/ or Bearing Strength: Dry Period
Well-drained Soils:									
A	Coarse-grained, cohesionless sands and gravels	GW, GP, SW, SP	80 to 300	>1	80 to 300	Slight to none	None	Will support continuous traffic of military vehicles with tracks or with high-flotation tires. Moist sands are good, dry sands only fair. Wheeled vehicles with standard tires may be immobilized in dry sands.	Good
B	Inorganic clays of high plasticity, fat clays	CH	55 to 165	0.75 to 1.35	65 to 140	Severe to slight	Severe to slight	Usually will support more than 50 4/ passes of military vehicles. Going will be difficult at times.	Good
C	Lateritic clays of low plasticity	MH	- - - - -	- - -	- - - - -	Slight to moderate	None	Will support 40 to 50 passes of military vehicles except during and for a few hours after heavy rains.	Good
D	Clayey gravels, gravel-sand-clay mixtures Clayey sands, sand-clay mixtures Gravelly clays, sandy clays, inorganic clays of low to medium plasticity, lean clays, silty clays	GC SC CL	85 to 175	0.45 to 0.75	45 to 125	Severe to slight	Moderate to slight	Often will not support 40 to 50 passes of military vehicles, but usually will support limited traffic. Going will be difficult in most cases.	Good
E	Silty gravels, gravel-sand-silt Silty sands, sand-silt mixtures Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity Organic silts and organic clays	GM SM ML and CL-ML OL, OH	85 to 180	0.25 to 0.85	25 to 120	Moderate to slight	Slight	Usually will not support 40 to 50 passes of military vehicles. Often will not permit even a single pass. Going will be difficult in most cases.	Good
Poorly drained soils:									
F	Soils having impeded drainage sands silts clays organic silts and organic clays	 SP, SW, SM, SC ML CL, CH OL, OH				Variable	Variable	Will not support even a single pass of military vehicle.	Will not support military vehicles for the first 1 to 3 months; then, when dry, will support continuous traffic.
Trafficability based on site characteristics 3/									
G	Marshes and swamps (perennially wet soils)							Untrafficable	Generally untrafficable
H	Bouldery land and rough mountains							Untrafficable	Untrafficable

1/ Modification of Table 3 from Trafficability of Soils, Waterways Experiment Station, Technical Memorandum No. 3-240 Fourteenth Supplement. Dec. 1956, Vicksburg, Miss.

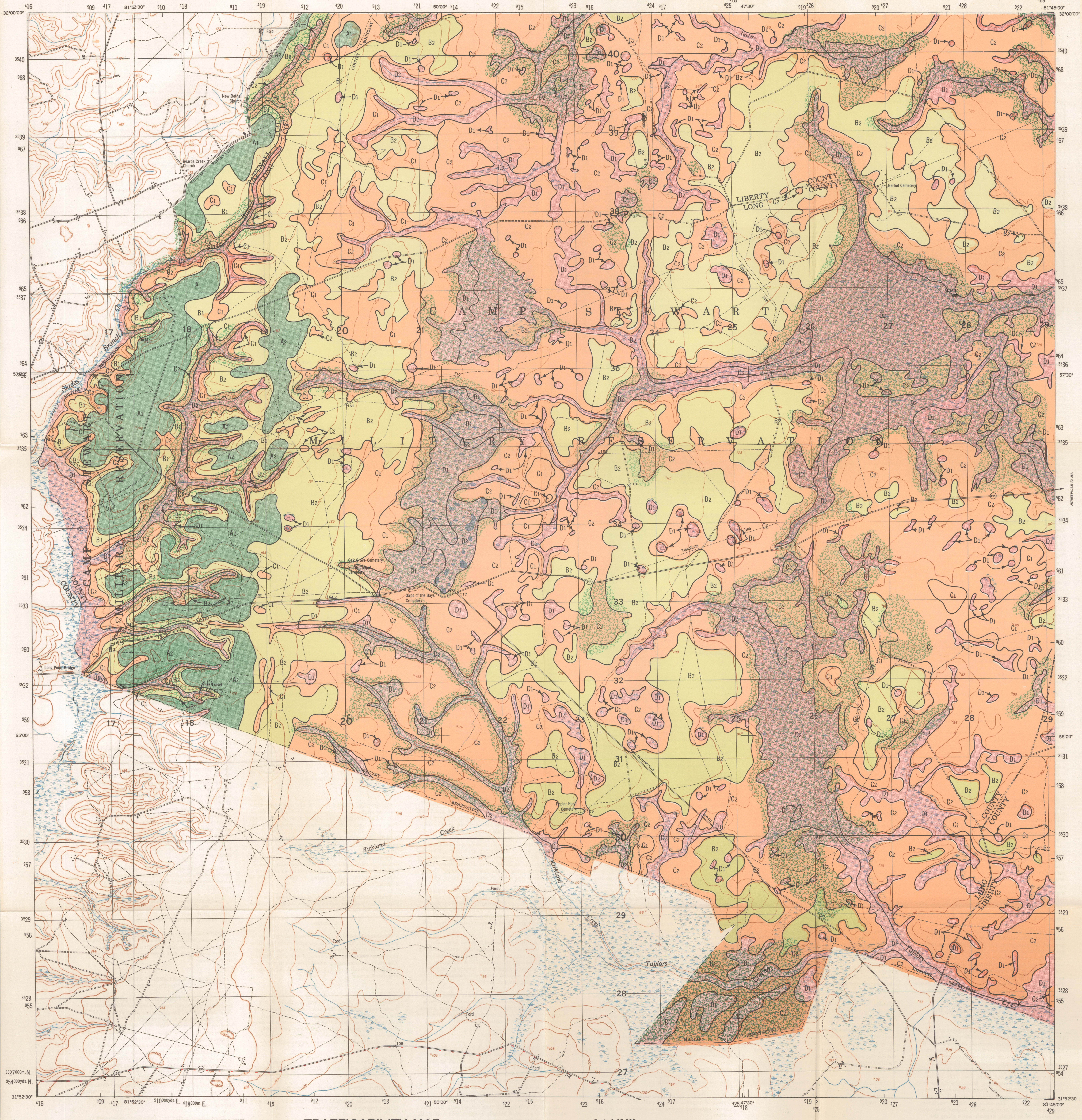
2/ Independent of slope, vegetation, and other terrain features which affect cross-country movement.

3/ Independent of soil.

4/ Soil that will support 40 to 50 passes of a military vehicle is considered to be firm enough for continuous traffic.

GLENNVILLE NE

EXPERIMENTAL SHEET



CROSS-COUNTRY MOVEMENT

This map shows intelligence on cross-country (off-road) movement generalized to correspond with the scale of the map. Evaluations different from those indicated hereon may occur in areas too small to delineate. Hence, this map does not preclude necessity for reconnaissance and other detailed intelligence for tactical operations. Evaluations are for the M-48 tanks now in use by American troops. The use of special vehicles or methods is not considered in the evaluations.

EXPLANATION OF COLORS

(Back of map contains more detail)

COLOR	General Soil-slope Evaluations	
	Dry Period 1/	Wet Period 2/
A_1, A_2	Passable	Passable
B_1, B_2	Passable	Doubtful to impassable
C_1, C_2	Passable	Impassable
D_1	Doubtful to impassable	Impassable
D_2	Impassable	Impassable
	Dense Tree Growth	

Passable—Soil-slope conditions will support 40 or more M-48 tanks in trace or permit maneuvering of an M-48 tank.

Doubtful—Soil-slope conditions make movement of an M-48 tank doubtful; may support a few tanks in trace, but probably will not permit maneuvering.

Impassable—Soil-slope conditions will not support one pass or maneuvering of an M-48 tank.

EXPLANATION OF DRY AND WET PERIODS

1/ Dry period is the period when climatic factors combine to produce soil moisture contents that are generally low. The period occurs from about 1 May to 1 November—roughly, the growing season. Dry periods may occur at other times of the year as a result of long spells of fair weather.

2/ Wet period is the period when climatic factors combine to produce soil moisture contents that are close to or at the maximum. The period extends from about 1 November to 1 May. Wet periods may occasionally occur in other seasons of the year as a result of unusually heavy or long-enduring rains, floods, or irrigations, but drying of soil thereafter will be rapid.

TRAFFICABILITY MAP

Prepared by Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi

Revised 15 June 1954

EXPLANATION OF LETTER-NUMBER SYMBOLS

(Back of map contains more detail.)

A_1 Top of nearly level hills and ridges and moderate (less than 10%) slopes near tops of hills and ridges on the Okefenokee terrace. Soils are silty to clayey sands with significant amounts of concretions or pebbles.

A_2 Areas resembling A_1 areas in topography and wegetation. Soils are silty sand with slightly more silt and slightly coarser and more poorly graded sand than the A_1 soils. Few concretions.

B_1 Usually moderately sloping areas surrounding the A_1 areas on the Okefenokee terrace. Soils are mainly silty sands and occasionally clayey sands with higher percentages of silt (or clay) than the A_1 soils. Some concretions.

B_2 Usually moderately sloping areas surrounding the A_2 areas on Okefenokee terrace and the crests and top slopes of low flat hills and swales on Wicomico and Penholoway terraces. The soils are silty sands with more silt than A_2 soils, with organic material in the top few inches. No concretions.

C_1 Usually moderate or slight slopes fringing drainageways on Okefenokee terrace and relatively level to gentle slopes on the Wicomico and Penholoway terraces. Soils on the Okefenokee terrace are silty and clayey sands with high organic content in heavily vegetated areas; silty and poorly graded sands with appreciable amounts of organic matter occur on Wicomico and Penholoway terraces.

C_2 Gentle slopes surrounding drainageways on Okefenokee terrace and relatively level areas on Wicomico and Penholoway terraces. Soils are usually organic silty sands or poorly graded organic sands.

D_1 Slightly sloping areas adjacent to streams on Okefenokee terrace and the swamps on Wicomico and Penholoway terraces. Soils are silty sands, organic sandy silts and organic silts.

D_2 Low-lying areas consisting of the lowest portion of drainageways on Okefenokee terrace and large swamps on Wicomico and Penholoway terraces. Soils are organic silts, organic silty sands, and some clays with appreciable amounts of organic matter.

Scale 1:25,000

1 ½ 0 1 Mile

1000 500 0 1000 2000 Meters

1000 500 0 1000 2000 Yards

CONTOUR INTERVAL 10 FEET

DATUM IS 1929 MEAN SEA LEVEL

TRANSVERSE MERCATOR PROJECTION

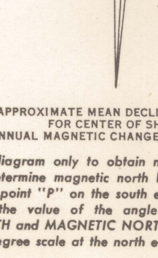
1927 NORTH AMERICAN DATUM

BLACK NUMBERED LINES INDICATE THE 1,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 17

TICKS INSIDE THE NEATLINE INDICATE THE 1,000 YARD U. S. POLYCONIC GRID, ZONE B

THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

GRID ZONE DESIGNATION: 17R	TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS		
100,000 M. SQUARE IDENTIFICATION	SAMPLE POINT: NEW BETHEL CHURCH		
MF	1. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself:	18	
	Estimate tenths from grid line to point:	7	
	2. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself:		39
	Estimate tenths from grid line to point:		4
IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 3527000	SAMPLE REFERENCE:	187394	
	If reporting beyond 100,000 meters or if sheet bears an overlapping grid, prefix 100,000 Meter Square Identification, as:	MF187394	
	If reporting beyond 18° in any direction, prefix Grid Zone Designation as:	17RMF187394	



APPROXIMATE MEAN DECLINATION 1951 FOR CENTER OF SHEET

ANNUAL MAGNETIC CHANGE 1′ EASTERLY

Use diagram only to obtain numerical values. To determine magnetic north line, connect the pivot point "P" on the south edge of the map with the value of the angle between GRID NORTH and MAGNETIC NORTH, as plotted on the degree scale at the north edge of the map.

AMS V845

Second Edition–AMS

BASE MAP

Prepared by the Army Map Service (AJAM), Corps of Engineers, U. S. Army, Washington, D. C. Compiled in 1948 by photogrammetric (multiplex) methods. Aerial photography Jan.-Feb., 1947. Horizontal and vertical control by Georgia Geodetic Survey, USC&GS and CE. This map complies with the national standard map accuracy requirements. Map field checked.

TERRAIN ANALYSIS CENTER
FILE COPY

LEGEND

ROAD DATA 1948

Hard surface, heavy duty road, four or more lanes wide — 4 LANES | 6 LANES

Hard surface, heavy duty road: Two lanes wide; Three lanes wide — 3 LANES

Hard surface, medium duty road, four or more lanes wide — 4 LANES | 6 LANES

Hard surface, medium duty road: Two lanes wide; Three lanes wide — 3 LANES

Buildings

School; Church

Standard gauge railroad — Single track; Double track

Narrow gauge railroad

Railroad in street

Carline

National boundary

State boundary (with monument)

County boundary

County subdivision boundary

Corporate limits

Reservation boundary

Loose surface, graded and drained, or narrow hard surface road

Improved dirt road or street

Unimproved dirt road; Trail

Route markers: Federal; State — 19 50

Horizontal control point

Bench mark, monumented — BM ×792

Bench mark, non-monumented — ×431

Spot elevation in feet: Checked; Unchecked — ×168 ×168

Intermittent lake

Intermittent stream; Dam

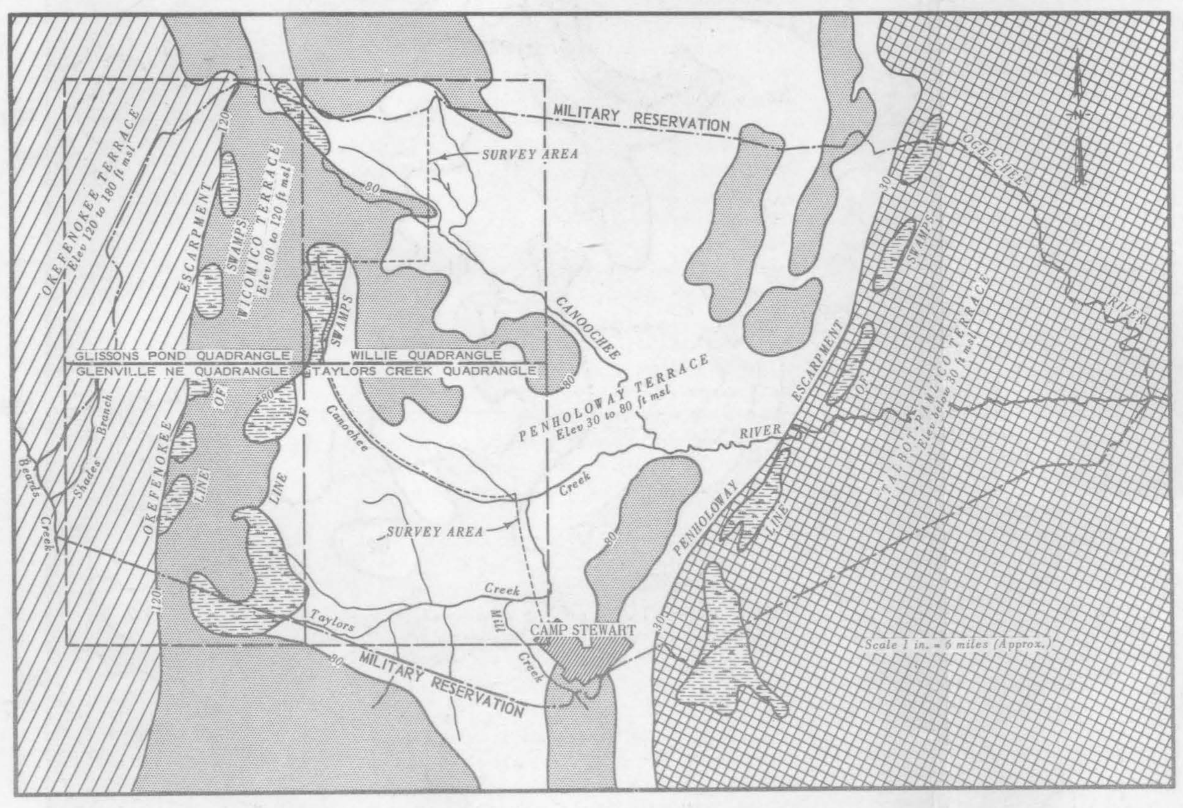
Swamp, marsh

Rapids; Falls

Large rapids and falls

TAC A 021905B ZZ +1 MAP

PLATE 14



GENERAL

This trafficability analysis of a portion of Camp Stewart (see above map) was prepared from airphotos (scale 1:18,000), geologic maps and literature, topographic maps, interrogation, field sampling, and observations of actual traffic of tanks. The study considered primarily soil types and slope, but obstacles such as dense forests are also discussed. The relative order of trafficability is shown by letter and subscript numbers, letter "A" areas being better for vehicle movement than "B" areas and within a letter group subscript "1" areas being slightly better for vehicle movement than subscript "2" areas.

The Camp Stewart reservation is approximately 35 miles long and 18 miles wide and comprises an area of approximately 440 square miles. It is situated in the Atlantic Coastal Plain, an area underlain by unconsolidated sands, clay sands, and clays. The surface materials of the Coastal Plain were eroded from inland areas, carried by rivers as sediments, and then deposited in shallow marine waters when the sea extended far to the west of its present shore line.

Three former shores appear within the 150 square miles in the mapped area: namely, the Okefenokee, Wicomico, and Penholoway terraces. The Okefenokee terrace slopes gently eastward. Relief consists of low, rounded hills, separated by generally east-flowing shallow streams. Stream erosion has deeply dissected the portion of the Okefenokee terrace in the southwest portion of the area mapped. The Okefenokee escarpment slopes very gently and cannot readily be detected from the ground. There is little relief on the Wicomico and Penholoway terraces, the smooth gentle easterly slope being broken only by shallow streams draining the centers of wide swamps.

The principal drainage artery on the reservation is the Canoochee River, an east-flowing stream bordered by swamps which drain the northeastern portion of the reservation. Canoochee Creek drains the lower northeastern and central sections, and Taylors Creek drains the southern portions of the mapped area. Both creeks flow eastward into the Canoochee River. The drainage areas of these creeks contain the old lagoon formed by the spit and bar of the Wicomico depositional terrace. Beards Creek flows southward and drains the southern portion of the western boundary.

Because the surface soils are primarily sandy, they are relatively permeable; however, the presence of silt and small percentages of clay particles gives the soil a greater capacity for retaining water than would normally be expected of sandy soils. The soils are characterized as poorly drained because of this condition and the high water table. The high water table exists even on the Okefenokee terrace during the wet season. This is probably due to the presence of a tighter clay-sand zone usually found a few feet below the surface. This relatively impermeable layer is also probably the cause of the development of spring heads on the terrace escarpment and in the swamps at the toe of the terrace.

The soils of the mapped area consist mainly of loose surface sands and silty sands, clay sands, clays, and organic silts and clays. The topsoils in the upland areas are generally light gray in color; the subsoils are generally yellow to brown and extend to much greater depths. The surface soils represent a residuum from the weathering of the clay sands which underlie most of the region. Along the northwestern and central west boundary of the reservation numerous iron concretions (limonite), or pebbles, are scattered throughout the upper soil layers. The remaining soils (on the Wicomico and Penholoway terraces) are all more or less organic and are found mainly in undrained depressions, stream valleys, and along the lower levels of slopes where the soil is saturated for much of the year. These soils consist largely of mixtures of sands, silts, and organic matter, and range from a few inches to several feet in thickness.

The vegetal cover of the reservation is closely associated with the soil drainage conditions. In general, longleaf pine, scrub oak, and broomsedge grass prevail over the better-drained soils of the Okefenokee and Wicomico terraces. The moderately well-drained areas support slash pine with an undergrowth of wire grass, palmettos, and gallberry bushes in locations where trees are sparse. The poorly drained areas are covered with a dense growth of cypress, black and sweet gum, water oak, pond pine, and bay and titi trees.

OKEFENOKEE TERRACE (A_1, A_2, B_1, B_2, C_1, C_2, D_1, D_2)

The Okefenokee terrace is the highest ground (120 to 180 ft msl) found within the reservation boundary. This terrace consists of rounded hills located along a narrow north-south belt that traverses the western part of the reservation. The eastern margin of this terrace is formed by a gentle sloping escarpment, roughly 40 ft in height, which represents an old shore line. The toe of this escarpment is swampy. Moderate slopes occur near tops of hills and along the stream with few deeply eroded drainageways along the southwestern boundary. The soils are highly variable, ranging from well drained in the higher topographical positions to highly organic soils along the drainageways. Because of the variations in soil types and moisture conditions, a wide range of seasonal trafficability also exists.

A Group

This group includes those areas having soil-slope conditions that will permit tank movement in normal wet weather and containing no obstacles to impede tank movement. Such areas occur only on the Okefenokee terrace.

A_1

Topography. The A_1 areas are nearly level hills and ridges and the moderate slopes (less than 10 per cent) near the tops of hills and ridges. These areas occur from the central to the northern part of the Okefenokee terrace. Vegetation is primarily broomsedge grass, but some pine trees are found along the edges of the fields and pecan orchards in some of the fields. Ground-water levels in the wet period are usually below 3 ft except during and after heavy rains.

Soils. The soils are silty to clayey sands with significant amounts of limonitic concretions or pebbles. The clayey soils usually occur on the level ridgetops and the silty soils along the slopes.

Trafficability—wet period. These areas are passable during the wet period. Deep rutting may occur under heavy repetitive traffic in the silty sands with probable immobilization occurring if old ruts are filled with water following heavy rains.

Trafficability—dry period. During this period the areas are passable.

A_2

Topography. Topographic features, vegetation, obstacles, and ground-water conditions are similar to A_1 areas, except that these areas occur in the south-central section of the Okefenokee terrace and scrub oak is the predominant type of tree growth.

Soils. The soils are silty sands with slightly more silt, coarser and more poorly-graded sands, and fewer concretions than the A_1 soils. The higher silt content permits these soils to retain water for longer periods than A_1 soils following heavy rains.

Trafficability—wet period. These areas are passable during the wet period except during and shortly after excessive rains (rainfall totalling greater than about 4 in. and occurring in a period of a few days), at which time these areas may be of doubtful trafficability. Deep rutting will occur under heavy repetitive traffic in normal wet weather.

Trafficability—dry period. These areas are passable during the dry period.

B Group

On the Okefenokee terrace the B group areas surround the A group and usually occur at lower elevations. The soils contain higher percentages of silts permitting them to hold water for longer periods following rains than the A group soil; therefore, trafficability conditions are rated slightly lower.

B_1

Topography. The topography of the large areas mapped as B_1 are usually gently to moderately sloped and the narrow areas parallel to the deeper dissected drainageways are usually moderately sloped. Vegetation consists of broomsedge grass and a sparse growth of pine trees and sometimes pecan orchards. The vegetal growth will not impede the movement of an M-48 tank. The water table during the wet season is usually below 2 ft.

Soils. The soils are mainly silty sand and occasionally clayey sands with higher percentages of silt (or clay) than the A_1 soils. Some concretions are to be found in these areas.

Trafficability—wet period. Although these areas are generally passable during the wet period, local spots may be doubtful to impassable especially during and following rains. Trafficability for the wet period is therefore rated as doubtful to impassable.

Trafficability—dry period. These areas are passable during the dry period.

B_2

Topography. The large B_2 areas occur as gentle slopes along the southeastern portion of the Okefenokee terrace. Smaller B_2 areas are located on moderately sloping ground along the southwestern boundary. The latter areas have been gullied somewhat by erosion and tank movement along a hill line will be impaired because of the gullies. Vegetation consists of broomsedge grass, scattered pine and scrub oak tree growth. A few small pecan orchards are found. The water table during the wet season is generally below 18 in.

Soils. The soils are silty sands with more silt than the A_2 soils, with organic material in the top few inches, and with no concretions.

Trafficability—wet period. The trafficability of most of the B_2 areas will permit 40 to 50 passes of the M-48 tank but other small depression-like areas (many too small to map) will be wet enough during the wet period to cause immobilization. Trafficability, in general, will be doubtful to impassable.

Trafficability—dry period. These areas will be passable. However, some of the shallow depression areas will remain untrafficable slightly later than 1 May.

C Group

The C group areas occupy intermediate drainage positions and occur along drainageways and swamps, and as poorly drained areas in upper topographical positions of the Okefenokee terrace. The areas in upper topographical positions may even occur on slopes; however, along the slopes of these areas subsurface spring heads exist, keeping the moisture content much higher than that of adjacent areas. A few depressions or sinks occur within these areas, particularly in the C areas along the eastern face of the Okefenokee terrace. The soils of these areas contain high percentages of silt and high organic contents in heavily vegetated spots. The soil types combined with the intermediate drainage result in areas untrafficable to tank movement for about 5 months during the year.

C_1

Topography. These areas usually contain moderate to slight slopes along the drainageways and near tops of ridges (slopes less than 10 per cent), and gentle slopes along the eastern section (slopes less than 4 per cent) of the Okefenokee terrace where they border swamps. Sinks occur in the areas along the eastern section and gullies along the southwestern parts of the terrace. Vegetation is highly variable. Broomsedge grass with a few pine trees occurs in higher topographical portions, wire grass and sparse tree growth on the eastern face of the terrace, and large and occasionally dense trees are to be found in some of the areas. (Dense tree growths are shown on the trafficability map.) The gullies may restrict movement along a hill line. Dense tree growth will restrict visibility and also provide a serious obstacle to tanks. Reconnaissance in these areas may sometimes reveal paths through which the trees do not present a serious obstacle. The wet-season water table is generally below 18 in.

Soils. The soils are silty and clayey sands with high organic content in heavily vegetated areas.

Trafficability—wet period. During the wet period these areas will be generally impassable; however, extended dry periods may cause improvement to the point where limited traffic is possible.

Trafficability—dry period. These areas will be passable during dry periods, but doubtful and impassable local spots (too small to map) will occur until after the new spring growth is well established.

C_2

Topography. The C_2 areas are gently sloped (less than 2 per cent) and occur primarily along the edges of swamps and wide drainageways. The areas are, in general, heavily wooded (slash pine) and contain an understory growth of gallberry bushes and palmettos and a heavy mat of wire grass. Reconnaissance may be required for route selection in the densely wooded areas. The wet-season water table is generally below 14 in. Heavy rains may cause the lower sections of these areas to be flooded.

Soils. The soils are usually organic silty sands or poorly graded organic sands. The low topographic position plus the presence of sufficient fine materials will permit these soils to hold moisture at high levels during most of the wet period.

Trafficability—wet period. These areas will be impassable during the wet period. The areas heavily wooded with small trees (5 in. in diameter or less) and heavy underbrush may provide adequate bridging (when the trees are knocked down) over the soft soil to permit the passage of a few tanks in trace, but will not permit maneuvering.

Trafficability—dry period. During the dry period these areas will be passable except at the beginning of the dry period (about 1 June) when numerous local spots will be impassable or of doubtful trafficability.

D Group

The D group consists of the low-lying areas that make up the drainageways, adjacent areas that have a high ground-water table, and the poorly-drained sinks and depressions such as cypress ponds scattered throughout the Okefenokee terrace. The stream banks are slightly sloped except for a few local areas in the southwestern portion of the Okefenokee terrace where the stream banks are vertical and several feet high. The slope along the drainageways is less than 2 per cent. Sandy bottoms are occasionally found along some of the narrow streams, and during the dry season these areas will permit limited fording. Several fords are shown on the map.

D_1

Topography. These areas are low lying compared to surrounding terrain. They lie adjacent to the main portion of streams, and occur as sinks and depressions within other mapped groups. Maximum slopes do not exceed 2 per cent. A dense growth of vegetation exists in these areas, consisting of a wide range of tree sizes and types (black and sweet gum, and slash pine are the predominant species, occasionally mixed with water oak, bay, pond pine, and cypress), gallberry bushes, and in some areas a heavy mat of wire grass with a few palmettos. The sinks usually contain some grasses and cypress trees. In some of the areas tree growth is large and dense enough to be impassable for straight-line routing, and reconnaissance is necessary for route selection. (Areas of large and dense tree growths are shown on the map by a special symbol.) The wet-season water table is generally below 6 in. except in the sinks where surface water is present. During and after heavy rains these areas will be flooded.

Soils. The soils are organic silty sands, organic sandy silts and organic silts that usually remain wet except in abnormally dry periods.

Trafficability—wet period. The soil types and wet condition of these areas make them impassable during the wet season.

Trafficability—dry period. The trafficability rating for this period is impassable to doubtful. During an average growing season or dry period, these areas will generally be impassable. Unusually dry weather during this period may decrease the normal water table to levels low enough to make some of the areas passable for at least short periods. The dense vegetal growth found in these areas usually provides sufficient bridging (particularly in areas of dense growth of small trees and heavy brush) over the soft impassable soil to permit one or two tanks traveling in trace at high speeds to cross some of the narrow areas or perhaps penetrate deeply into some of the larger areas before becoming immobilized.

D_2

Topography. The D_2 areas are low lying with slopes of 2 per cent or less and consist of the lowest portion of the drainageways on the Okefenokee terrace. A heavy tree growth of large and small trees (black and sweet gum, water oak, bay, pond pine, cypress, and titi) and an understory growth of brush (primarily gallberry) are found in these areas. The vegetal growth will restrict tank movement similar to the D_1 areas except the tree growth will be heavier and the frequency of occurrence of dense tree growth will be much greater. The wet-season water table is not usually more than a few inches below the surface; the streams maintain a slow but continuous discharge even in the dry periods.

Soils. These areas contain bog-like soils consisting of organic silts, organic silty sands, and some clays with appreciable amounts of organic matter.

Trafficability—wet period. The wet, bog-type soils make these areas impassable. During a large portion of the wet season these areas will be inundated with a foot or more of water.

Trafficability—dry period. During the dry period these areas will be impassable but like the D_1 areas a tank traveling at high speed may cross some of the narrow areas or penetrate deeply into a large area before becoming immobilized. The water levels of these areas will be increased considerably following heavy showers.

WICOMICO TERRACE (B_2, C_1, C_2, D_1, D_2)

The Wicomico terrace occurs between the 120- and 80-ft contours. This terrace represents a former sea bottom with spits (or sand bars) which were deposited by longshore currents when the surface of the Wicomico terrace was submerged under a shallow sea. Little relief is found. The terrace consists of large knolls sloping gently toward large swamps and drainageways. The Wicomico terrace is the largest within the mapped area, and is located on a north-south belt with large lobes projecting eastward along the north and south sections. This terrace is bounded on the east by a shallow escarpment not perceptible on the ground, on the west by the toe of the Okefenokee escarpment, and on the north by an abrupt escarpment which can easily be located on the ground. Large swamps also occur along the eastern edge and on the southwestern part of the terrace. The soils are highly variable, ranging from intermediate drained soils on top of knolls to poorly drained highly organic soils found along the shallow sloped drainageways and in the large perennial swamps. A wide range of trafficability conditions are to be found, even in the dry period.

B Group

The B_2 areas are the best group on the Wicomico terrace from the trafficability standpoint.

B_2

Topography. The topography of these areas consists of crests and upper slopes of low, flat hills and swells. On the Wicomico terrace, the B_2 areas appear as scattered island-like spots with the exception of several large areas appearing in the southern portion of the area. Sinks are found in the large B_2 areas. Vegetation is primarily broomsedge grass, pine and scrub oak trees. Occasionally these areas may include dense growths of pine trees large enough to impede tank movement. The wet-season water table is generally below 18 in.

Soils. The soils are silty sands, containing organic material in the top few inches and having no concretions. These soils contain more silt than the A_2 areas found on the Okefenokee terrace.

Trafficability—wet period. These areas are generally passable during the wet period except local spots consisting of depression-like areas (some too small to map) may be of doubtful to impassable trafficability especially during and after heavy rains. The trafficability rating for the wet period is doubtful to impassable.

Trafficability—dry period. These areas are passable. The small depression areas will remain untrafficable for short periods after 1 May.

C Group

The largest portion of the Wicomico terrace is mapped as C. The C group occupies level to gentle sloping topographic positions which are dissected by shallow drainageways. The soils contain a high percentage of silt and have a high organic content in heavily vegetated areas. The low relief combined with the high percentages of silt or organic materials permits these soils to hold sufficient amounts of water to make these areas impassable in normal wet weather. Many depressions and sinks usually mapped as D_1 occur within these areas.

C_1

Topography. The C_1 areas occur mainly as slight slopes (less than 4 per cent) along the northern border and as shallow knolls on the lower portion of the Wicomico terrace. Vegetation consists of wire and some broomsedge grasses, few palmettos, and a sparse growth of pine and some local spots of gum trees. Many large sinks are found within these areas. The wet-season water table is usually below 18 in.

Soils. The soils are silty sands and poorly graded sands with appreciable amounts of organic matter in the top 4 in.

Trafficability—wet period. During the wet period these areas will be generally impassable but extended dry periods may cause sufficient improvement to permit limited traffic.

Trafficability—dry period. These areas are passable during the dry periods. Local spots will remain doubtful to impassable for short periods after 1 May.

C_2

Topography. These areas are level or slightly sloped (less than 2 per cent) and surround the knolls and the low-lying sluggish drainageways which dissect these areas, and the large perennial swamps. On the southern portion of the terrace, some of these areas are gently undulating swells and swales. Many large and small sinks are found. Most of these areas are covered with a heavy mat of wire grass, scattered pine and gum trees, and palmettos. However, the areas which encroach along the swamps and drainageways are usually heavily wooded (primarily slash pine, black and sweet gum, and an understory growth of gallberry bushes). Reconnaissance may be required for route selection in these latter areas. Heavy rains will probably inundate the lower sections. The wet-season water table is generally below 14 in.

Soils. The soils are usually organic silty sands or poorly graded organic sands. Several rainy periods after the first killing frost will increase the moisture content of these soils to near their maximums. Thereafter the soils will remain wet until the new growth of grasses is well developed (about 1 June).

Trafficability—wet period. These areas are rated as impassable during the wet period. During periods of no rain (10 days or more) the shallow knolls may permit the passage of a few tanks traveling in trace without maneuvering, but the swales and low wooded areas will remain impassable during the wet period.

Trafficability—dry period. These areas are, in general, passable during the dry period beginning about 1 May. The trafficability of the lower areas adjacent to swamps and drainageways, and the swales will remain doubtful until about 1 June.

D Group

On the Wicomico terrace, this group consists of the low-lying level areas that make up the drainageways, adjacent areas that have a high groundwater table, the large perennial swamps found along the toe of the Okefenokee terrace, and the many large and small sinks or depressions scattered throughout the terrace. The stream banks along the small streams are slightly sloped; however, the large streams may contain near vertical sand banks which will impede tank movement. Some of the narrow streams contain sandy bottoms and will permit limited fording in the dry season. A few of the existing fords are shown on the map.

D_1

Topography. Little or no relief occurs in these areas. The D_1 areas are found adjacent to the streams, edges of swamps, and natural swell-like areas within the broad drainageways and large perennial swamps. The small shallow sinks or depressions occurring within other mapped areas are also mapped as D_1. A dense tree growth, some brush, and occasionally grasses and palmettos are found in these areas except in the small sinks where only a few trees may occur. Tree size and density are variable. The predominant tree growth is black and sweet gum, and slash pine usually mixed with some growth of water oak, bay, pond pine, and cypress. Portions of the D_1 areas along swamps and drainageways contain tree growths of sufficient size and density to be impassable to tank movement. Reconnaissance is necessary for route selection. (Areas of large, dense tree growths are shown on the map by a special symbol.) The wet-season water table is generally below 6 in. During and after heavy rains these areas will be flooded.

Soils. The soils are organic silty sands, organic sandy silts and organic silts that remain wet except in abnormal dry periods.

Trafficability—wet period. The soil types and wet conditions of these areas make them impassable during the wet period.

Trafficability—dry period. Impassable to doubtful trafficability conditions will prevail in these areas during the dry period. Extended dry periods will decrease the normal water table to levels low enough to make some of these areas passable. The dense vegetal growth found in these areas (except small sinks) usually provide sufficient bridging over the soft impassable soil to permit one or two tanks traveling in trace at high speeds to cross some of the narrow areas or perhaps penetrate deeply into some of the larger areas before becoming immobilized.

D_2

Topography. The D_2 areas are low-lying level areas with slight slopes found only along the sluggish streams. These areas consist of the lowest portion of the drainageways, swamps, and the large sinks that usually have water standing in them most of the year. A heavy tree growth of large and small trees (black and sweet gum, water oak, pond pine, cypress, and titi) and an understory growth of brush (primarily gallberry) are found in these areas. The dense vegetation will impede tank movement and some of the large tree areas are dense enough to be impassable. The wet-season water table is not usually lower than a few inches below the surface; the swamps and streams will contain free water even in the dry period. Heavy rain will increase the depth of water covering these areas.

Soils. These areas contain bog-like soils consisting of organic silts, organic silty sands, and some clays with appreciable amounts of organic matter.

Trafficability—wet period. The wet, bog-type soils make these areas impassable. During a large portion of the wet season they will be inundated with several feet or more of water.

Trafficability—dry period. During the dry period these areas will be impassable. The surface layers of local spots may dry sufficiently to look passable but the underlying soft layers will still make them impassable.

PENHOLOWAY TERRACE (B_2, C_1, C_2, D_1, D_2)

The Penholoway terrace is the lowest of the three terraces found within the mapped area. It occurs between the 80-ft and the 30-ft contours. This terrace has little or no relief and consists primarily of shallow depressions which make up the many marshes and swamps. The remaining terrain consists of a few knolls, and gently undulating swells and swales. The Penholoway terrace lies in a north-south direction with its central portion extending a few miles farther to the west than the north and south edges. It is bordered on the west by the toe of the Wicomico terrace with a line of large swamps which are part of the terrace surface. The eastern edge of this terrace is defined by a comparatively steep escarpment over 40 ft in height. Several broad drainageways cross the terrace surface, flowing in an easterly direction. The banks of Canoochee River, Canoochee Creek, and portions of Taylors Creek are steep and of sufficient height to be impassable to tank movement. The steepest slopes occur along the Canoochee River. The soils, in general, are poorly drained and are usually high in organic content as a result of the dense grass and tree growth. Heavy vegetal growth, steep banks along some of the main drainageways, and the poor soil conditions make this terrace the most undesirable from the seasonal trafficability standpoint.

B Group

The extent of the B group areas on the Penholoway terrace is very limited. A few areas consisting of portions of shallow knolls occur on the lower and upper parts of the terrace. These areas contain no obstacles to impede tank movement.

B_2

Topography. The topography of these areas consists of slight slopes (2 per cent or less). Vegetation is broomsedge grass with scattered pine trees. The wet-season water table is generally below 18 in.

Soils. The soils are silty sands containing organic material in the top few inches.

Trafficability—wet period. These areas are generally passable during the wet period except for a few local spots which may be doubtful to impassable. The trafficability rating for the wet period is doubtful to impassable.

Trafficability—dry period. These areas are passable. The lower areas will remain untrafficable for short periods after 1 May.

C Group

The largest portion of the Penholoway terrace is mapped as C. The C group occupies areas of little relief which are dissected by several broad drainageways. Numerous depressions and sinks occur. The soils contain high percentages of silt plus appreciable amounts of organic material in heavily vegetated areas.

C_1

Topography. A few C_1 areas are found on the Penholoway terrace. These areas are found along the floodplain of the Canoochee River and occur on slight slopes or swell-like areas. Vegetation consists of broomsedge grass, pine and gum trees. The wet-season water table is generally below 18 in. During flood periods these areas will be inundated.

Soils. The soils are silty sands and poorly graded sands with appreciable amounts of organic matter in the top 4 in.

Trafficability—wet period. During the wet period the soil condition of these areas will be generally impassable but extended dry periods may cause sufficient improvement to permit limited traffic.

Trafficability—dry period. These areas are passable during the dry periods. Local spots will remain doubtful to impassable for short periods after 1 May. If spring floods occur on the Canoochee River, these areas will remain impassable until after the water leaves the surface and the new growth is well established.

C_2

Topography. The major portion of the Penholoway terrace is mapped as C_2. These areas are level or slightly sloped (less than 2 per cent) or gently undulating swells and swales. Many large and small sinks are found. The principal vegetal cover is a heavy mat of wire grass, scattered pine and gum trees, and palmettos. However, the areas that encroach along the swamps and drainageways are usually heavily wooded (primarily slash pine, black and sweet gum, and an understory growth of gallberry bushes). Reconnaissance may be required for route selection in these latter areas. Heavy rains will flood this lower section. The wet-season water table is generally below 14 in.

Soils. The soils are usually organic silty sands or poorly graded organic sands. Several rainy periods after the first killing frost will increase the moisture content of these soils to near their maximum. Thereafter the soils will remain wet until the new growth of grasses is well developed (about 1 June.)

Trafficability—wet period. These areas are rated as impassable during the wet period. During periods of no rain (10 days or more) the shallow knolls and swells may permit the passage of a few tanks traveling in trace without maneuvering, but the swales and low wooded areas will remain impassable during the wet period.

Trafficability—dry period. These areas are, in general, passable during the dry periods beginning about 1 May. The trafficability of the lower areas adjacent to swamps and drainageways, and the swales will remain doubtful until about 1 June.

D Group

These areas are similar to the D group areas found on the Wicomico terrace. This group consists of the low-lying level areas that make up the drainageways, adjacent areas that have a high ground-water table, the large perennial swamps found along the toe of the Wicomico terrace, and the many large and small sinks or depressions scattered throughout the terrace. The banks along the small streams are slightly sloped; however, the major streams have nearly vertical sand banks that are impassable to tank movement. Adequate bridge structures over the main streams are very limited but passageways can be found by reconnaissance along the upper reaches of Taylors Creek; bridging and other engineering construction will probably be required for crossing the Canoochee Creek, Canoochee River, and the lower portion of Taylors Creek. A few of the existing crossings are shown on the map.

D_1

Topography. Little or no relief is found in these areas. The D_1 areas are found adjacent to the streams, edges of swamps, and natural swell-like areas within the broad drainageways and larger perennial swamps. The small shallow sinks or depressions occurring within other mapped areas are also mapped as D_1. A dense tree growth, some brush, and occasionally grasses and palmettos are found in these areas except in the small sinks where only a few trees may occur. Tree size and density are variable. The predominant tree growth is black and sweet gum, and slash pine usually mixed with some growth of water oak, bay, pond pine, and cypress. Portions of the D_1 areas along swamps and drainageways contain tree growths of sufficient size and density to be impassable to tank movement. Reconnaissance is necessary for route selection. (Areas of large, dense tree growths are shown on the map by a special symbol.) The wet-season water table is generally below 6 in. During and after heavy rains these areas will be flooded.

Soils. The soils are organic silty sands, organic sandy silts and organic silts that remain wet except in abnormally dry periods.

Trafficability—wet period. The soil types and wet conditions of these areas make them impassable during the wet period.

Trafficability—dry period. Impassable to doubtful trafficability conditions will prevail in these areas during the dry period. Extended dry periods will decrease the normal water table to levels low enough to make some of the areas passable for at least short periods during that period. The dense vegetal growth found in these areas (except small sinks) usually provides sufficient bridging (particularly in areas of dense growth of small trees and heavy underbrush) over the soft impassable soil to permit one or two tanks traveling in trace at high speeds to cross some of the narrow areas or perhaps penetrate deeply into some of the larger areas before becoming immobilized.

D_2

Topography. The D_2 areas are low-lying level areas with slight slopes found only along the sluggish streams. These areas consist of the lowest portions of the drainageways, swamps, and the large sinks that usually have water standing in them most of the year. A heavy tree growth of large and small trees (black and sweet gum, water oak, pond pine, cypress, and titi) and an understory growth of brush (primarily gallberry) are found in these areas. The dense vegetation will impede tank movement, and some of the large tree areas are dense enough to be impassable. The wet-season water table is not usually more than a few inches below the surface; the swamps and streams will contain free water even in the dry period. Heavy rain will increase the depth of water covering these areas.

Soils. These areas contain bog-like soils consisting of organic silts, organic silty sands, and some clays with appreciable amounts of organic matter.

Trafficability—wet period. The wet, bog-type soils make these areas impassable. During a large portion of the wet season they will be inundated with several feet or more of water.

Trafficability—dry period. During the dry period these areas will be impassable. The surface layers of local spots may dry sufficiently to look passable but the underlying soft layers will still make them impassable.

GENERAL WEATHER-TRAFFICABILITY RELATIONSHIPS

The climate of southeastern Georgia is semitropical. The mean annual range of temperature is only about 30° F, ranging from an average of 82° F in July and August to an average of 52° F in December and January. The first and last killing frosts usually occur about 1 November and 1 March, respectively. The duration of temperatures below 32° F are short and snow is uncommon during the winter period. Annual precipitation is approximately 48 in. with maximum rainfall occurring in July, August, and September and averaging more than 6 in. in each of these months. The high maximums for these months is due to hurricane rains which usually occur in this period. During the remaining months the rainfall is evenly distributed, averaging more than 2 in. per month, and occurs in several storm periods.

From about 1 May to 1 December, when temperatures are high and plants are growing vigorously, soil loses moisture rapidly. Several inches of rainfall occurring intermittently over a period of several days may temporarily (for 2 to 4 days) increase the ground-water levels of the low-lying areas to the point of doubtful trafficability. Because of the sandy nature of the soils, runoff will be insignificant even during heavy showers. From 1 December to 1 May, on the other hand, soil loses moisture slowly since plant life is dormant; and when the moisture content reaches a high level, it tends to remain high. Therefore, even light rains are likely to make the soils excessively wet for long periods.