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Engineer Intelligence Guide 31, Production of Cross-Country Movement Studies, December 1959

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ENGINEER INTELLIGENCE

EIG 31

GUIDE

PRODUCTION OF CROSS-COUNTRY MOVEMENT STUDIES

A TECHNICAL SERVICE INTELLIGENCE DOCUMENT

PREPARED UNDER THE DIRECTION OF THE
CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C.

DEPARTMENT OF THE ARMY
OFFICE, CHIEF OF ENGINEERS
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PREFACE

Engineer Intelligence Guides (EIG's) are the media for the dissemination of intelligence collection, processing, production, and dissemination guidance by the Chief of Engineers to pertinent elements of the Corps of Engineers. EIG's are designed to provide orientation, direction, and instruction in the field of Engineer intelligence. Comments on this EIG and suggestions for additional EIG's are solicited from all recipients. Comments and suggestions should be addressed to:

Chief of Engineers
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Washington 25, D. C.
ATTN: Intelligence and Mapping Division

PRODUCTION OF CROSS-COUNTRY MOVEMENT STUDIES

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All figures and tables in this EIG have been taken from publications of the Waterways Experiment Station.

SUMMARY

1. Cross-country movement (CCM) refers to movement by military vehicles and foot troops away from roads.

2. The terrain factors that determine the suitability of terrain for such movement are slope, climate, soil (and snow), vegetation, streams and other water bodies, and cultural features.

a. Slopes of micro-relief features, such as small gullies and rock ledges, as well as those of macro-relief features, such as hills and mountains, are highly important. Steep slopes are perhaps the most common terrain feature limiting cross-country movement. Slopes of about 45 percent are considered to be the practicable upper limit for tracked vehicles; and 30 percent, for wheeled. For vertical slopes of hard features, such as rock ledges, heights between 2 1/2 and 4 feet are the practical upper limits for tracked vehicles; 1/2 to 1 foot, for wheeled.

b. Climate, although a highly important factor, exerts most of its significant effects indirectly. It determines to a large extent the moisture content of soils that in turn affects their strength for trafficability purposes; and it also influences condition of streams and small lakes and thereby affects their obstacle values.

c. Soils, when dry, will support vehicles almost without exception, but when wet their relationship to CCM is variable and difficult to evaluate. A test has been devised for determining the strength of soils. While this test to date has been used but little in the field of terrain evaluations, the research results have provided analysts with an invaluable tie between soils and vehicles that is essential background information for them. The cone index, remolding index, and rating cone index are measures of soil strength which have been related to soil classes in the Unified Soil Classification System. The vehicle cone index represents the minimum soil strength necessary for a given vehicle.

(1) The trafficability strength of soils varies with their moisture content. Soil moisture has been related to weather and climate and a method has been developed for predicting it.

(2) Snow behaves much like fine-grained soils.

d. Forests are the vegetation items of principal importance, but any vegetation high enough to obscure visibility has a slowing effect on vehicles. If trees are too big to push over, they need to be about 15 to 20 feet apart on the average in order to permit movement without much difficulty. If trees are so close together that they have to be pushed over, they may become serious obstacles to tanks if their diameter exceeds 6 inches and serious to trucks if their diameter exceeds about 1 inch.

e. Streams and other water bodies, like soils, may vary in their significance throughout the year, and like soils, their variability is closely related to climate. Narrow channels can be crossed without bridging or fording by tracked vehicles, but not by wheeled. As regards fording, depth of water, condition of bottom, and height, slope, and composition of banks are critical factors.

3. Sources of geographic information for evaluation of CCM conditions are many and varied. Reconnaissance provides the best source, but rarely, if ever, can enough reconnaissance be done to provide all the information needed. Maps and reports on a variety of subjects, including geology (especially topography and geomorphology), climate, soils, vegetation, hydrology, and other related subjects must be exploited fully. Airphotos should be used, especially for tactical studies.

4. Specialists commonly can do the best job of exploiting information sources in their respective fields; and small teams made up of relevant specialists are expected to produce the best CCM studies.

5. Cross-country movement studies, tactical as well as strategic, are intended to be used for planning. An overriding requirement is that they be simple and easy to understand. They should carry not only evaluation of terrain conditions but also facts about those conditions. On tactical maps, soil and slope commonly are evaluated together and shown by distinctive colors. Forest, another areal feature, is shown by a special overprint. Linear features, such as escarpments and streams, are shown by special linear symbols. On strategic maps, because of the limitations imposed by small scales, the significance of linear features commonly cannot be shown apart from the significance of areal features and all factors that affect movement must be combined into overall evaluations, which again are customarily shown by distinctive colors.

6. The steps in preparation of CCM studies entail first the collection and examination of all the available information needed for the analyses. Next a legend needs to be designed that meets the objective of the study and best accommodates the intelligence. Areas and features are then delimited on suitable base maps according to the established legend, and texts and other supporting materials prepared.

CHAPTER 1

INTRODUCTION

1. Purpose

The purpose of this Engineer Intelligence Guide (EIG) is to provide orientation, direction, and instruction in the preparation of cross-country movement (CCM) studies, primarily maps with supporting materials such as texts.

2. Scope

This guide deals with background information that analysts should know and understand before producing cross-country movement studies, either tactical or strategic; and it sets forth the procedure for making such studies beginning with exploitation of source information and ending with manuscripts ready for drafting and printing. Although kinds of source information are discussed, it is not a guide for the collection of such information; and although some comments are also included about cartography at the opposite end of the overall production process, details of drafting and reproduction are not covered.

3. General

a. This guide is intended for use of terrain specialists, or teams of such specialists, with training in earth sciences. The reason for this orientation is that the production of CCM studies, although relatively simple in theory, is rather complicated and difficult in actual practice. This situation is a result of the fact that analysts usually must interpret information from a variety of fields in order to determine the suitability of terrain treated in any particular CCM study. Important among these fields are geology (including geomorphology in particular), soil science, soil mechanics, climatology, hydrology, and botany (including forestry in particular). Elementary knowledge of these fields, at least enough to understand the literature relevant to CCM, therefore is a necessary qualification of analysts, or teams of analysts. It is also true that the greater their competence in these fields, the better able they are to exploit the source information, which commonly varies in both quality and quantity from area to area. Analysts also must know something about military vehicles, including the cross-country movement capabilities of vehicles for which interpretations are made.

b. This guide is oriented to the principal kinds of CCM studies being produced today. These studies reflect what has been learned from experience and research in the past and represent the present stage of development; but they do not represent the ultimate stage, particularly in map design. CCM studies, like vehicles, weapons, etc., are always susceptible to improvement. Moreover, terrain analysts, who are the principal designers of CCM studies, must be sensitive to new or additional needs and must have some freedom to exercise their ingenuity and imagination to meet those needs.

c. In the line with the nature to today's Army requirements, the term "CCM studies" is used instead of "CCM maps." Maps of course are essential, but more is required. Intelligence in the form of supporting texts, tables, graphs, or illustrations are essential too. Such items may appear on the margins of the front of maps, and/or on the back, or in reports that accompany the maps.

4. Definitions

a. Cross-country movement. This term, frequently abbreviated as CCM, means movement away from roads, movement without using roads. It usually refers to movement by military vehicles, most commonly by tanks, but actually the concept includes movement by all military vehicles that move on the ground, and foot troops, too.

b. Cross-country movement study. This is a study in which terrain information relevant to cross-country movement is ascertained and interpreted and in which the results are set forth on a map, or series of maps, with supporting texts, tables, etc. Interpretations on the map are for a specific vehicle, commonly the medium tank, or for a group of vehicles alike in their movement capacities, but the text and other materials may include interpretations for other vehicles and for foot troops.

c. Soil trafficability. This term means the capacity of soil to support traffic by military vehicles. It should not be used as a synonym for cross-country movement.

d. Trafficability. This term, which became widely used in World War II and has remained in the military jargon, is ambiguous. It has been and is still used loosely to mean cross-country movement at one extreme and soil trafficability at the other. It is used also to express the capacity of roads to support traffic, which is concerned only to a limited degree with soil trafficability and not at all with cross-country movement. It will be used in this guide to mean soil trafficability.

e. Other terms used in referring to CCM are going in British terminology, Befarbarkeit in German, and practicabilité in French. The British term going, like the American term, trafficability, has been used with a wide range in meaning; but, as applied to northern Germany at least, the term going reflects mainly an evaluation of soil conditions and is thus roughly equivalent to soil trafficability. The German and French terms are closer in meaning to the United States term, cross-country movement.

CHAPTER 2

TERRAIN FACTORS AND EVALUATION OF THEM

5. General

a. Terrain factors that affect movement. Slope is the most obvious factor, soil is another, vegetation a third, streams a fourth, and cultural features the fifth. Climate is the sixth factor, but unlike the others, the main effects of climate are exerted through soils, by causing them to be dry, moist, wet, frozen, or snow covered, and through streams, by causing them to be high or low, unfrozen or frozen.

b. Combinations of factors. In some places one factor alone determines whether an area is passable to vehicles, but more commonly it is the combination of two or more factors. Although the factors are discussed one at a time the reader should realize throughout that the effect of one factor commonly depends partly on the others; that it is the combination of factors that determines whether vehicles can move across terrain with ease, with difficulty, or not at all.

6. Slope

a. Definition. By slope is meant the inclined surface of a hill, mountain, ridge, or any other part of the surface of the earth. By slope is meant the inclination not only of macro-relief features, such as hills and mountains which are revealed on topographic maps, but also micro-relief features such as small gullies, mounds, low escarpments, small pinnacles and sinkholes which generally do not appear on topographic maps, even those of large scale. Some of the micro-relief features might appropriately be looked upon as constituting a roughness factor rather than a slope factor, but because the obstacel value of most of them is due to the steepness of their slopes they are included with the general factor of slope.

(1) The angle that the slope, or the inclined surface, makes with the horizontal is commonly expressed as percent of slope rather than degree of slope. Percent of slope is the rise in elevation per 100 feet of horizontal distance. A slope of 100 percent would be the hypotenuse of a right triangle 100 feet long on the base and 100 feet high on the side. The angle made by the hypotenuse and the base is 45 degrees. a 45-degree angle, therefore, is equivalent to a 100 percent slope.

(2) On a diagram of a right triangle the slope of the hypotenuse, which is 100 percent, does not appear to be particularly steep, but analysts should not be deceived by this. Actually slopes in nature greater than 80 or 90 percent are uncommon unless they are rock escarpments or vertical slopes in loess or volcanic ash.

b. Relationship to cross-country movement

(1) An ordnance requirement for most vehicles is that they be able to climb slopes of at least 60 percent. This holds for most wheeled vehicles as well as tracked. This limit, however, is too high for vehicles to negotiate under practical military operations.

(2) Slope has been related to soil strength and the generalized relationships are shown on Figure 1. The vertical scale represents slope expressed in percent; the horizontal scale represents the soil strength required over that needed for movement on flat ground. Note that on slopes above approximately 45 to 50 percent for tracked vehicles and 30 to 40 percent for wheeled vehicles, the curves flatten out. On steeper slopes there is but little gain in climbing capacity even if soil strength is increased substantially.

(3) In evaluating terrain for cross-country movement 45 percent is commonly used as the reasonable upper limit for tanks and 30 percent for trucks. If other factors are highly favorable these limits can be increased somewhat; if unfavorable, they need to be reduced slightly.

(4) Short vertical or near-vertical slopes, such as those associated with rock ledges and gullies, may be deterrents or obstacles on terrain with a general slope much below 30 to 45 percent. Vertical heights above 2 1/2 to 4 feet are generally considered to be the maximum for tanks and 1/2 to 1 foot the maximum for trucks.

(5) Foot troops can, of course, get over ground that is too steep and rough for either tanks or trucks. Slopes of 60 percent, however, are about the steepest that soldiers can climb by walking straight up slope. Above this limit they will normally have to zigzag and above 100 percent, the going is very difficult although not wholly impossible.

c. Information sources and interpretation of them.

(1) Reconnaissance. The most reliable information about slopes, particularly short steep ones, is obtained by reconnaissance. In conducting reconnaissance, an instrument, such as an Abney level or clinometer, for measuring slope should always be used because slopes tend to appear, particularly to the untrained eye, much steeper than they actually are. At best, slope can be determined only on a small proportion of the area by this procedure; therefore, heavy reliance must be placed upon other sources, particularly topographic maps and airphotos.

(2) Maps and reports.

(a) Topographic maps are one of the most important sources of published information and always should be consulted. To those skilled in reading them, topographic maps are exceedingly

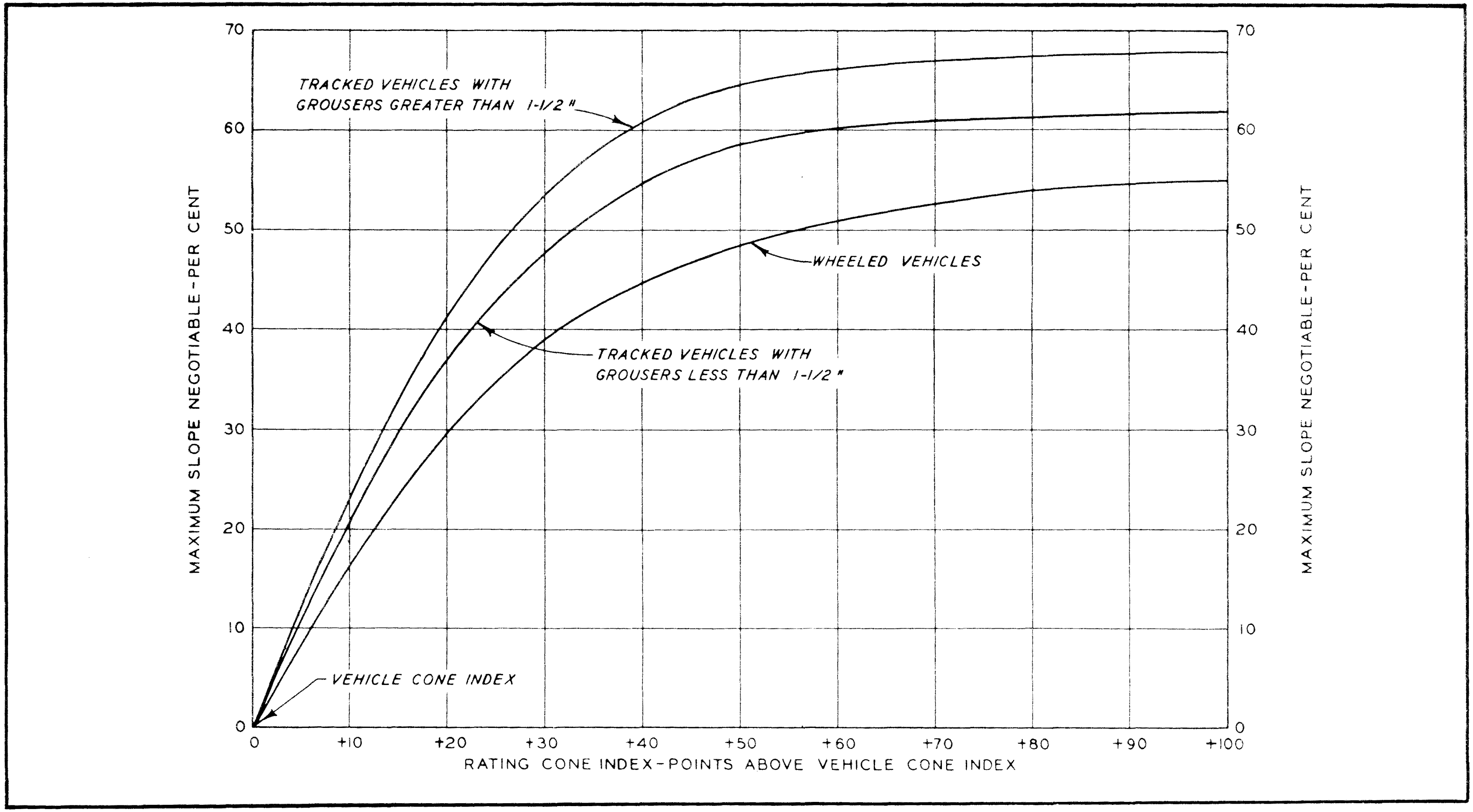

Figure 1. Criteria for self-propelled vehicles on fine-grained soils and sand with fines, poorly drained.

useful for the purpose of revealing the slope and landform. The percent of slope of a mountainside or a hillside can be determined by dividing the contour intervals by the horizontal distance between the contour lines and multiplying by 100. In fact, devices have been developed for quickly determining slope by measurement of the distance between contour lines.

(b) There is one particular danger in relying on the distance between contour lines for determining the slopes that tanks or other vehicles must actually traverse. Much micro-relief, or roughness, may be hidden, figuratively speaking, between the contour lines. If the contour interval is 100 feet, for example, hills or depressions say 75 feet below or above the general land surface will not be shown. If contour lines reveal a ridge with a general side slope of 20 percent, for example, it is still possible for the side of this ridge to be dissected by ravines or gullies which might make the actual slope that tanks would have to traverse on the order of 50 or 60 percent. The larger the interval between contour lines and the smaller the scale of the map, the greater are the amounts of micro-relief that may be hidden by the contour lines, and conversely, the smaller the contour intervals and the larger the scale of the map the less micro-relief will be hidden; but there is always the possibility that even on topographic maps at the large scale of 1:25,000 and a contour interval of 10 feet that some micro-relief relevant to cross-country movement may not be revealed.

(c) Topographic maps, therefore, need to be interpreted with caution and supplemented, if possible, by other information. Topographic maps can be interpreted best by analysts who also have a good knowledge of geomorphic processes—who understand how landforms got to be the way they are. Such understanding enhances substantially the reliability of slope interpretations that are made from topographic maps.

(d) Other sources of information about slope include geologic, geographic, and soil reports. Many of these contain landform descriptions, which not only reveal terrain characteristics but are helpful for interpreting topographic maps as well. Many soil maps, and some other kinds of maps too, carry information on slope and serve as useful supplements to topographic maps.

(3) Airphotos.

(a) Airphotos are admirably suited for interpreting slope. They are perhaps the best source of information on this factor. From them, it is generally possible to obtain information about not only macro-relief features but, perhaps more important, micro-relief features too. Small gullies, for example, which are not shown on topographic maps but which can drastically slow movement, usually appear plainly on airphotos.

(b) Stereo pairs and a stereoscope are needed for making slope interpretations; for good results the airphotos themselves need to be of high quality and reasonably large scale, 1:20,000 or larger.

(c) Slope interpretations from airphotos must be done carefully. There is a danger of interpreting slopes to be steeper than they actually are, and it must be recognized that even airphotos may not reveal correctly all relevant micro-features.

7. Climate

a. Climate, which has been defined as statistical meteorology, is the generalization or summation of the manifold weather conditions throughout the year.

b. Relationship to cross-country movement.

(1) Climate has a unique relationship to cross-country movement. Although highly important, most of the significant effects of climate are indirect. To a large extent, climate controls the moisture and temperature in soils and thus greatly affects their strength; climate also controls the water level and temperature of streams and thus affects their obstacle value. The indirect effects of climate on soils and streams are treated under these topical headings.

(2) Climate also has some direct effects. Fog, a rather common weather phenomenon in some places, may obscure visibility enough to retard movement or even prevent it. Dust storms and snow storms may have the same effect. Also, there are places where temperatures get high enough or low enough to affect adversely the performance of men as well as vehicles. In practice, areas are not downgraded in their suitability for CCM because of such direct weather effects, but such phenomena are brought to the user's attention in the text or other supporting material.

c. Information sources.

(1) There perhaps is greater international uniformity in weather records and reports than in any other field. Climatic summaries in which weather data are summarized by months and years are generally available for most countries of the world and daily weather records are available for many. Maps showing annual, seasonal or monthly distribution of rainfall or temperature are commonly available. Reconnaissance is of little or no value in obtaining climatic information; neither are airphotos, although some deductions about the general climate can be made from them.

(2) In dealing with climatic summaries, it must be recognized that these are statistical summaries with the shortcomings as well as the advantages inherent in the statistical procedures used. Some knowledge of statistical theory as well as climatology is

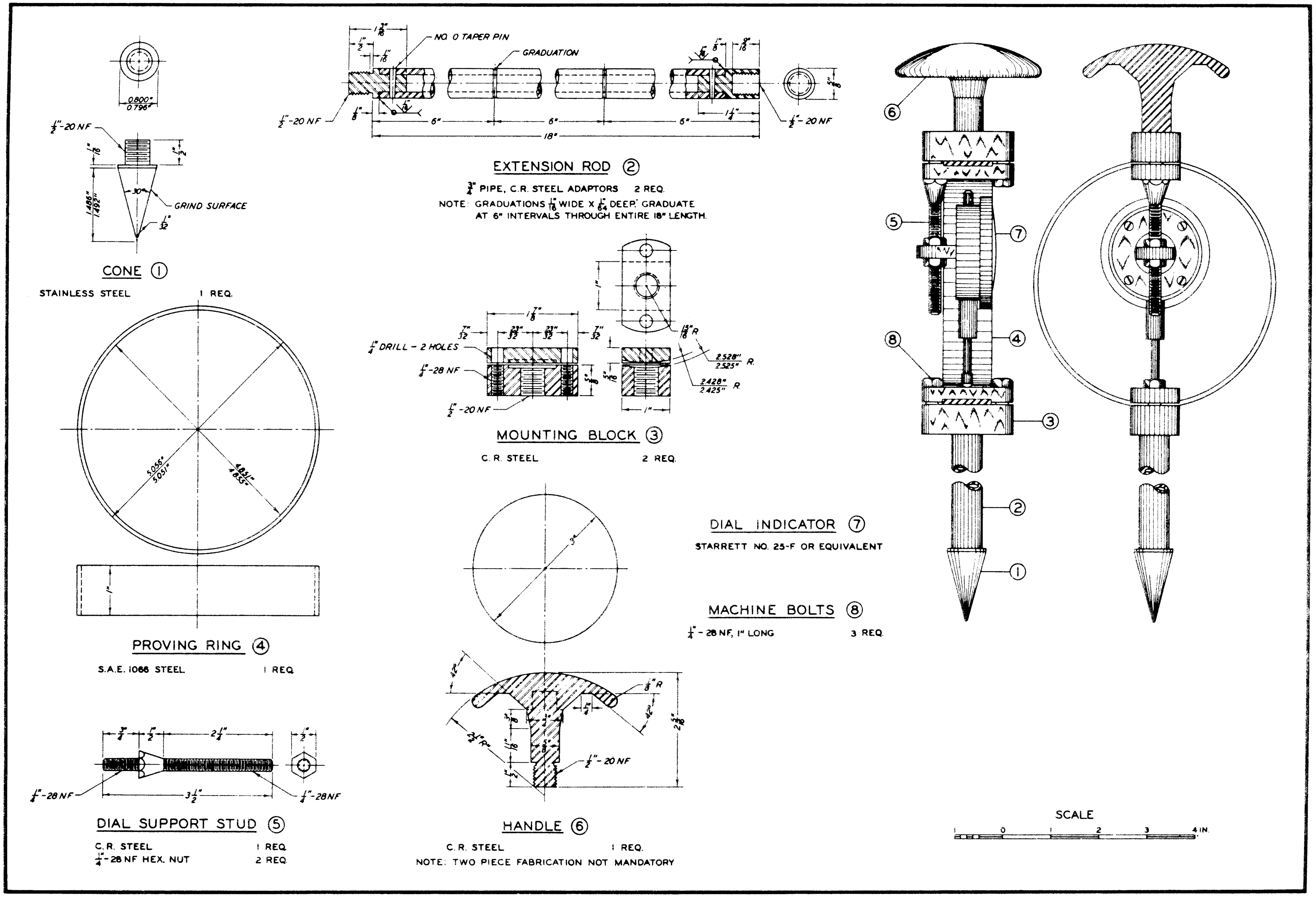

Figure 2. Cone penetrometer

essential to the proper interpretation of climatic data.

8. Soil (and snow)

a. General.

(1) Soil is perhaps the most difficult factor to deal with. To obtain the proper information about it is commonly difficult and time consuming, and to evaluate the trafficability strength of soils is rather complicated. More guidance is provided about this factor, therefore, than about the other factors that are relevant to cross-country movement; but this factor is not exhaustively treated and analysts should familiarize themselves with appropriate research reports (1,2,3,4,)[1] and manuals (7,8,9).

(2) The part of the soil most important to vehicles is the topmost foot, particularly the 6 to 12 inch depth, although the soil to the depth of about 2 feet or even deeper may be of some consequence. Whenever soils are mentioned in this guide only the surface foot or two is meant.

b. Relationship to cross-country movement.

(1) Soil trafficability testing.

(a) The relationship between the tread or track of a vehicle and the soil is not yet well understood and theoretical explanations, although useful, are inadequate and too complicated for general use by terrain analysts. Fortunately, the Corps of Engineers has developed an empirical method for determining whether a soil will in fact support passage of any vehicle; analysts should have available the technical memorandum (see reference 2) which describes this method and the application of it.

(b) The key item in this method is the cone penetrometer. This simple instrument (Fig. 2) consists of a 30-degree cone with a 1/2-square-inch base area mounted on one end of a 36-inch shaft, and a proving ring with dial gage and handle mounted on the other end. The force required to move the cone slowly through the soil is indicated on the dial inside the proving ring (Fig. 3). This force is considered to be an index of the shearing resistance of the soil and is termed the cone index. The capacity load of 150 pounds deflects the ring 1/10 of an inch and gives a cone index of 300, the maximum possible on this instrument and well above the minimum soil strength required by any Army vehicle.

(c) By making traffic tests with many vehicles, it was determined that the cone penetrometer is a reliable device for quantitatively measuring the trafficability strength of soils except for one unfortunate behavior characteristic of soils. This

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[1]Numbers in parentheses refer to Appendix IV.

characteristic is that soil strength may change under traffic. A soil may support three passes by a vehicle, for example, but will give way on the fourth. This change in strength is called remolding.

(d) Remolding may be positive as well as negative. That is, one soil may gain strength under traffic whereas another may lose; or the same soil may gain strength if its moisture content is low and may lose strength if its moisture content is high.

(e) In order to obtain a measure of the degree of remolding that a soil would undergo, one step was added to the method for testing soils for trafficability; unfortunately, this step takes more time and equipment than the simple cone penetrometer test. The second step is intended to simulate somewhat the action of vehicles in inducing remolding. To make the test, a sample of soil is taken with piston-type trafficability sampler and extruded directly into cylinder. First the cone index of the sample is determined, next, 100 blows are applied to the sample with an appropriate hammer and the cone index of the sample is again determined. Figure 4 illustrates the steps involved.

(f) Now that the cone index measurements have been made before and after remolding--before and after simulated traffic--how are the results interpreted? Here another term is introduced, the remolding index, which is simply the ratio obtained by dividing the cone index after remolding by the cone index obtained in the field before remolding.

$$\text{Remolding index} = \frac{\text{Cone index after remolding}}{\text{Cone index before remolding}}$$

From this formula, it is apparent that if the soil loses strength upon remolding, the remolding index will be less than 1; if it gains strength, the remolding index will be greater than 1.

(g) At this point a third index needs to be introduced. This is the rating cone index, which is simply the product of the measured cone index in the field and the remolding index for the same layer of soil.

$$\text{Rating Cone Index} = \text{Measured cone index (in the natural soil)} \times \text{Remolding index.}$$

The rating cone index correlates with vehicles in such a way that it provides a reliable guide for predicting whether a soil will sustain repeated traffic.

(h) Finally, there is the vehicle cone index, which is the minimum soil strength that will permit a given vehicle to complete about 50 passes. The vehicle cone index for the M-48 tank, for example, is 49. This means that if the rating cone index is less than 49 this tank will become mired to the point of immobilization before it has

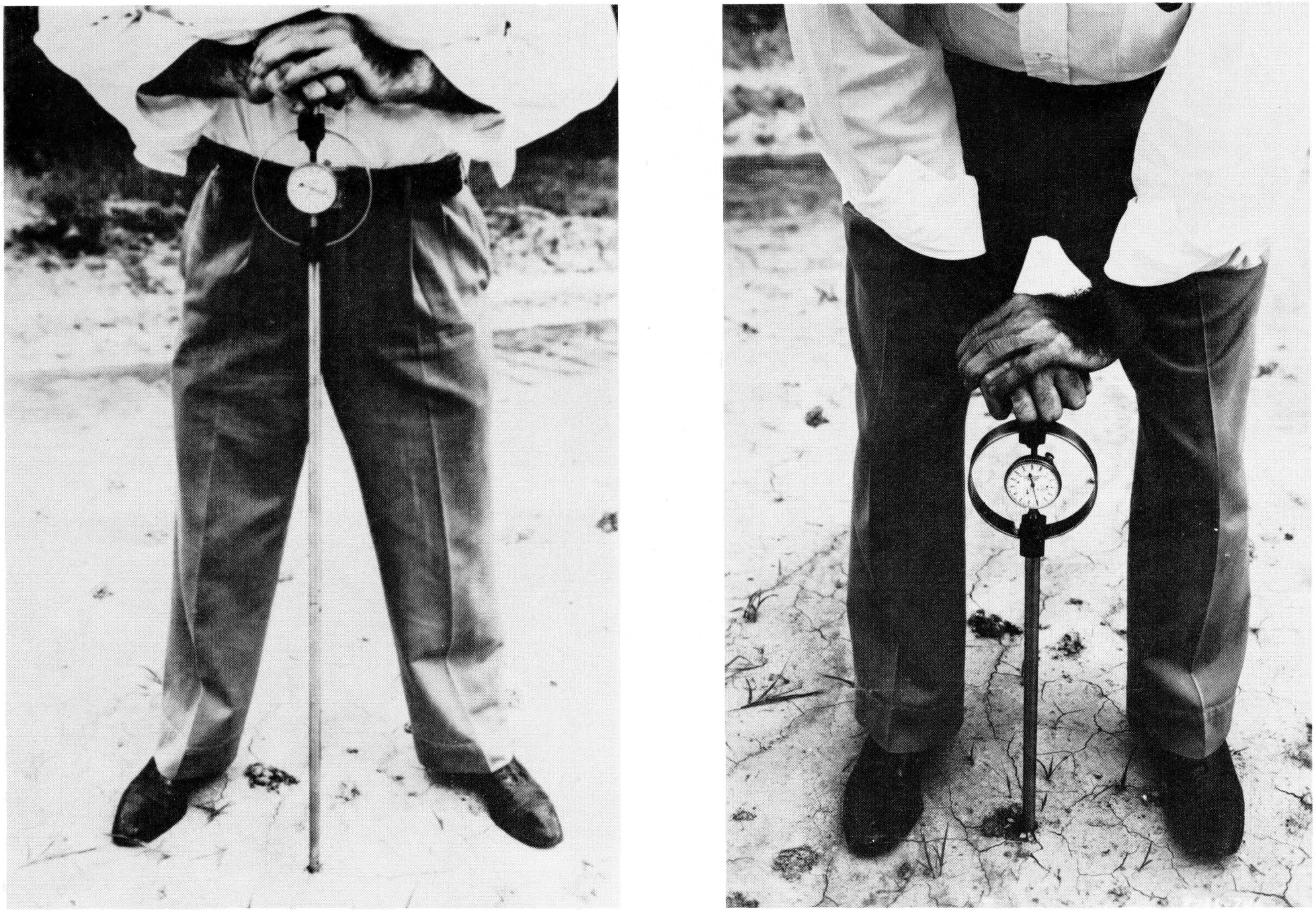

Figure 3. Cone penetrometer in use.

Figure 4. The remolding test.

completed 50 passes; and if the cone index is more than 49, the tank can make more than 50 passes, usually many more. Some other vehicle cone index values in round numbers are as follows: for foot soldiers, about 20; for M-29C, about 25; D-7 Engineer tractor, about 45; 2 1/2-ton 6x6 cargo truck, about 65; field ambulance 4x2, about 120. Vehicle cone indices for nearly all Army vehicles are listed in Reference 2 and should be consulted for further details.

(i) It is necessary to become familiar with one more term, the critical layer. This is the layer of soil that is most pertinent to the establishment of relationships between soil strength and vehicle performance. This is usually the 6- to 12-inch layer (lower half of topmost foot), but may vary with weight of vehicle and the soil strength profile (2). Unless otherwise specified, the critical layer in this guide means the 6- to 12-inch layer, and all index values, including the rating cone index and vehicle cone index, apply to this layer.

(j) Slipperiness and stickiness of soils may be troublesome, but they seldom cause immobilization of military vehicles, particularly tracked vehicles. Nearly all immobilizations in soils are caused by lack of enough traction capacity to allow development of the forward thrust necessary to overcome the rolling resistance. In simpler language, most vehicles get stuck in the mud because they sink in so deeply that they become high-centered.

(2) Soil moisture and climate.

(a) Soil moisture content varies with time. In order to predict the soil trafficability, it is first necessary to ascertain if the soils are likely to become wet and, if so, when.

(b) If today there is a heavy rainfall, say 3 inches, the soil becomes wet; but as soon as the rain stops the soil begins to dry. In summer it dries rapidly, in winter slowly. Thus it is apparent that weather and climate have highly important relationships to soil moisture. If the moisture content today is known, it is possible on the basis of weather forecasts, to predict what it will be tomorrow. The accuracy of soil moisture prediction depends on the accuracy of the weather forecasts. The weather can be forecasted fairly accurately for one day in advance and less accurately for a few days in advance. Although the weather cannot be forecasted accurately far into the future, it is possible on the basis of past records (climatology) to predict what is likely to happen in the distant future. Scientists and engineers reasoned that if the relationship between climate and soil moisture could be quantitatively established, it might be possible to predict soil moisture. Research on this problem revealed some helpful relationships. It showed that the moisture content of the surface foot of a given soil may frequently attain a certain level but will rarely exceed it.

(c) This moisture content which the soil may frequently reach but rarely exceed is called the field maximum moisture content (1). This field maximum is related not only to soil classes, such as ML and CL in the Unified Soil Classification System (8), but also to the way soils occur in nature. A soil class, ML for example, may have a higher field maximum at one site than at another, depending upon topographic position, presence or absence of impermeable layers below the surface foot, etc. One cannot, therefore, assign to a soil class a specific field maximum value, although a range could perhaps be given. However, techniques, still in the research stage, are being developed for predicting field maximum values.

(d) In addition to discovering the behavior represented by the field maximum, research has revealed some relationships between precipitation and temperature on the one hand and soil moisture on the other. This kind of relationship is illustrated by Figure 5. It gives the moisture content at the critical layer ((1) (i) above) of a fine-grained soil near Vicksburg, Mississippi. The precipitation amounts are shown in the companion graph at the bottom. The upper graph gives the moisture content in terms of inches of water within the critical layer. Note that in the spring the moisture content began to decrease at a rapid rate. In the summer when heavy rains occurred, the moisture content rose to a high level but quickly dropped again. The same pattern occurred in autumn. With the onset of weather cold enough to prevent any more growth by plants, the rate of moisture loss in the critical layer became very slow. The rather heavy rains, which in this particular year occurred in early December, brought the moisture content to a high level. Note that thereafter the moisture content decreased at a rate so slow that no deficit (storage capacity) of consequence was created before the next rain occurred. Hence, after the early part of December, light rains brought the soil to a moisture level that, in summer, would require very heavy ones. In fact, from early December to the time when plants resumed growth in spring, the moisture content remained close to the field maximum.

(e) From this kind of evidence, it is concluded that when the weather is warm enough to support plant growth, soil moisture becomes depleted so rapidly that the soil remains wet for short spells only. When the weather is so cold that plants do not grow, soil moisture is depleted slowly--so slowly that with successive rains it accumulates to the field maximum and seldom, if ever, drops far below this level. It is apparent, therefore, that in winter light rains may produce muddiness that in summer only heavy rains, say more than 2 inches, can do. It is apparent also that soil moisture does not relate to rainfall amounts alone but to temperature as well.

(f) It has already been mentioned that the field maximum is a characteristic of a given kind of soil as it occurs in nature. The graphs in Figure 5 are for Commerce silty clay. Although other areas of Commerce silty clay would be expected to have curves nearly identical

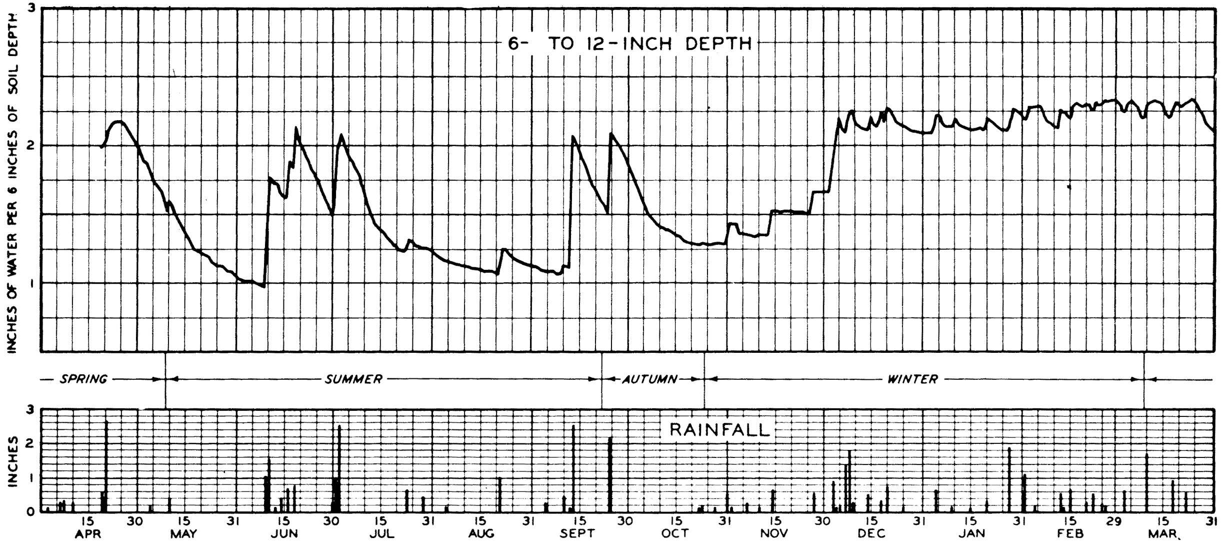

Figure 5. Daily soil-moisture record and concurrent rainfall for Commerce silty clay at Mound, Louisana, 1951-1952.

to this one, other kinds of soils might have different curves, but the general shape of them, particularly as related to seasons, would be similar if the climate were similar to that at Vicksburg, Mississippi.

(g) One can imagine situations in which these relationships do not hold, as for example in places where the soils become frozen for long periods or where the soils are naturally poorly drained and wet most of the year. Even with such exceptions, however, knowledge of this general relationship between climate and soil moisture is helpful in estimating soil trafficability.

(h) A method has now been developed for predicting the moisture content in the surface foot of soil. This method is a sort of bookkeeping system. For every day without rain a certain moisture loss is deducted to obtain the new balance; for every day with rain the moisture gain is added to obtain the new balance. If the kind of soil and its field maximum moisture content are known, it is possible with this method to know today what the moisture content is without making a field test, and to predict what the moisture content will be tomorrow and the next day on the assumption that the weather forecast is accurate.

(i) This method of predicting soil moisture will not be discussed in more detail in this guide. It is still undergoing testing and refinement. Terrain analysts responsible for predicting soil trafficability should avail themselves of the latest research report on soil moisture prediction (1).

(3) Soil moisture-strength relationships.

(a) Ability to predict soil moisture is of little or no value for trafficability purposes until another relationship is established; the relationship between soil moisture and soil strength. All soils, when dry, are trafficable to tracked vehicles, and also to wheeled vehicles if they are equipped with high-flotation, low-pressure tires. Wheeled vehicles not thus equipped may become stuck in sands that are dry and loose.

(b) Moisture added to a soil immediately changes its strength and, unfortunately for prediction purposes, different soils are affected differently by moisture changes. Dry sands, for example, improve when they receive some moisture. The same can be said for almost all other dry soils but with most of them a point is reached beyond which addition of moisture reduces their strength, sometimes drastically.

(c) This loss in strength does not become critical, however, until the moisture content becomes high--until it comes close to or equal to the field maximum for some soils, and until it exceeds this value for others. The soil moisture graph (Figure 5) for a soil near Vicksburg, Mississippi shows that the moisture content fluctuated close to the field maximum during the winter there. If the strength of this particular soil at its field maximum were too low for the support of vehicles, then the soil would be untrafficable most of the winter. If the strength were not too low, which happens to be the case, the soil will support vehicles throughout the winter, albeit with some difficulty.

(d) The relationship between soil moisture and soil strength is not simple, yet some useful generalizations have been made. These are set forth in Table 1. This table gives the trafficability characteristics of soils in the wet season. It is limited to the wet season because only then do the soils differ enough in their trafficability to be of consequence to military vehicles, except those soils which because of poor drainage remain wet far into or even throughout the entire dry season. Two facts should be kept in mind in considering this table: one, that the soils are wet and two, that the table sets forth gross generalizations to which there may be occasional exceptions.

(e) This table sets forth a grouping of soil classes of the Unified Soil Classification System. The soils in any one group are much alike in their relationship to moving vehicles. Note that Group "A" consists of GW, GP, SW, and SP. These are the sands and gravels without fines. The probable cone index range for these is from 80 to 300; the cone index of 80 is greater than that required for many vehicles and is just on the threshold of being strong enough for many others. A cone index of 300 is well above that required for any military vehicle. The remolding index range for these soils is greater than one. It will be recalled that by multiplying the cone index obtained in the field by the remolding index, the so-called rating cone index is obtained which is a measure of the strength that the soil will have after it has undergone 40 to 50 passes by a vehicle. The probable rating cone index for soils of Group "A" ranges from 80 to 300; and again these values are in the range within which traffic can be supported. While low cone index values may on occasion be obtained in some of these soils when wet, really when completely saturated, it is more common to obtain the lowest cone index rating in them when they are very dry. This low cone index rating when dry stands in contrast to the behavior of nearly all other soils.

(f) The second group, "B", is made up of only one soil class, CH, clay of high plasticity. This is the kind of soil that with certain moisture contents may become exceedingly slippery or sticky but it needs to be recalled here that military vehicles are not commonly immobilized by either slipperiness or stickiness alone. Slipperiness, however, may contribute substantially to immobilization on steep slopes. CH soils usually, but probably not always, will support more than 50 passes but the going will be difficult at times, perhaps most of the time.

(g) The third group, "C", is made up of GC, SC, and CL soils. This group includes the clayey gravels and clayey sands, both of which are coarse-grained soils, as well as lean clays which are

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 1. Trafficability characteristics of soils in wet season.

fine grained. Note that the probable cone index range, 85-175, is rather high. The probable remolding index, however, is lower than for the preceding two groups. Consequently, the probable rating cone index, which is the expected strength after traffic, is relatively low. The soil strength required by many vehicles is approximately in the middle of this range. Although these soils may become just as slippery as those in group "B", they will not become as sticky. Soils of group "C" usually will support limited traffic but in many places will not support as many as 40 to 50 passes and the risk of immobilization in these soils will be considerable.

(h) Group "D", the fourth group, includes all the soils high in silt and also those high in organic matter. In Group "D" are the silty gravels and silty sands, both of which are coarse-grained soils, as well as the various kinds of silts, which are fine-grained soils. Silt and organic matter induce weakness when soils containing them are wet. Note again that for the soils of Group "D" the cone index range is relatively high but note also that the remolding index ranges from the very low figure of 0.25 to the upper figure of 0.85, which while not especially low, is still well below the figure of 1. The low remolding index values indicate that soils high in silt or organic matter, or both, lose a great deal of strength when subjected to traffic. The probable rating cone index for the soils of Group "D" start at the very low figure of 25, which is too low for nearly all military vehicles, and range to the upper limit of about 120, which is adequate for nearly all vehicles. Stickness effects are only slight; a reflection of the behavior characteristic of soils that are high in silt or organic matter, or both. Soils of Group "D", when wet, usually will not support 40 to 50 passes of military vehicles; in fact they may not permit even a single pass. Going will nearly always be difficult, if it is possible at all.

(i) Observe that in this table the trafficability strength of wet soils is not neatly separated according to whether they are coarse grained or fine grained. While no fine-grained soils appear in Group "A", Group "B" is made up exclusively of fine-grained soils and Groups "C" and "D" are made up of some of both. Two coarse-grained soils, GM and SM, appear in the poorest group. Although these two coarse-grained soils may become exceedingly weak when wet, they nevertheless do tend to be more permeable than the fine-grained soils. Hence they usually reach critical moisture contents less often and remain in that condition for shorter periods than the fine-grained soils. Generally, therefore, they are more trafficable than the companion soils in this group. But if saturated or nearly saturated with water, they become just as weak as the others.

(j) This table, plus the conclusion that all soils when dry are trafficable, with the possible exception of sands, summarizes the general criteria for evaluating trafficability of soils.

c. Information sources and interpretation of them. Geographic information about kinds of soils and when they are wet, or in the case of sands, when they are dry, is needed. Terrain reconnaissance, maps and reports, and airphotos are the three principal sources of information. Seldom will one source be used to the exclusion of the others. Instead, the best combination of reconnaissance, maps and reports, and airphotos should be used. This combination will vary from region to region depending upon how much reconnaissance, if any, is possible, the nature and quality of maps, reports, and airphotos, the nature of the terrain, and the amount of time available to the terrain analysts.

(1) Terrain reconnaissance.

(a) There is no substitute for field examination of soils as a way to learn whether or not they are trafficable. Reconnaissance permits on-the-spot determination of their trafficability characteristics. Obviously terrain reconnaissance should be conducted whenever possible; yet, the probability of being able to conduct enough reconnaissance to collect all the needed information is unlikely. In fact, the usual situation is that, at best, only a little reconnaissance is possible; at worst, no reconnaissance is possible. Thorough reconnaissance takes much time, and usually such time is not available. Moreover, areas that are under study frequently may be difficult to reach or may be completely denied to the analysts for purposes of reconnaissance, at least for strategic studies.

(b) In doing reconnaissance for soil trafficability interpretations, the analysts, armed with the knowledge already set forth about soils should know what to look for. If the traffic is to take place immediately after reconnaissance, they merely need to determine if the soil is strong enough to support the vehicles that are to be used. In many places this determination can be made by simple inspection; in others, mainly in wet places, some soil trafficability testing will be necessary.

(c) If reconnaissance done today, however, is for interpretations of trafficability conditions some time in the future, then the analysts need to determine the kind of soil and its natural drainage condition. Information about drainage is needed in order to predict if and when the soil may be wet. Does the soil lie on sloping terrain so that excess water runs off, or is it in depressions where water will not only remain but may also flow in from the adjacent slope? Is there evidence of seepage from upslope, or drainage impedence downslope, such as can result from fills and embankments built by man? Is the soil permeable? Is there an impermeable layer below the surface foot? Is there evidence of a high water table? The analyst uses the answers to these questions, along with climatic data, to predict if and when the soil is likely to be wet.

(2) Maps and reports. If analysts themselves are unable to examine the soils in the field, then the next best step is to find out if some one else has done just that. This inquiry leads to maps and reports, the second principal source of information and always an important one. Analysts should particularly seek soil maps and

accompanying reports, even though such items are unavailable for many areas. Analysts must not limit themselves to items with the label "soils" on them. Frequently there is information about soils, or at least clues to their characteristics, on maps and in reports that carry the label of geology, geography, ecology, forestry, agriculture, climate, vegetation, and even other subject-matter names.

(a) Soil surveys. If soil surveys exist the probability is high that these are pedological soil surveys. Pedology means soil science, and pedological soil surveys, which are also referred to as agricultural soil surveys, are made by soil scientists according to the system of classifying and mapping soils developed by them. Unfortunately most pedological soil surveys are difficult to use unless the analysts have an understanding of pedology. Inasmuch as such surveys constitute one of the very best sources of information for interpreting soil trafficability, analysts need to acquaint themselves with the general characteristics of them.

(1) Analysts need to learn what is meant by the soil profile (8, par. 11) because soil scientists classify soils on the basis of characteristics of soil profiles. If one examines the soil on a ditch bank or on a cut of some kind, he commonly will find several layers within a depth of just a few feet, say 4 or 5 feet. These layers taken collectively make up the pedologist's soil profile and when he classifies soils he puts like profiles together.

(2) Pedologists have discovered that various kinds of soil profiles are distributed in nature in such a way that areas can be mapped on that basis. In fact, it is the only way in which soils can be effectively mapped. In an area mapped as a particular kind of pedological soil, a person should find anywhere within that area the same sequence of layers at approximately the same depth as in the representative profile.

(3) In descriptions of soil profiles one of the characteristics routinely recorded is the soil texture, which is approximately equivalent to grain-size distribution in the engineering vernacular. In fact, from knowledge of the soil texture, one can estimate what the equivalent class is likely to be in the Unified Soil Classification System. Without going into detail about the characteristics of individual textural classes, reference is made to Table 2, which shows the general relationships between textural classes as used in the U. S. Department of Agriculture and classes in the Unified Soil Classification System used by the Army. (The size limits and textural classification chart in TM 5-541 (Ref. 8)p.55, are obsolete and incorrect.)

(4) Note first of all that in the pedological system used by the U. S. Department of Agriculture there are no equivalents for GW and GP. The reason is, that for purposes of textural classification only that soil material less than 2 mm. in

diameter is considered. If soils are gravelly, for example, modifiers are used to indicate that fact, but the resulting terms do not correlate well with the Unified System.

(5) There is considerable similarity between some of the textural names in the pedological system and some of the typical names in the Unified System but the name in one classification does not mean exactly the same in the other classification. Caution must be exercised therefore in the interpretation of pedological textural terms. Almost every textural class in the U. S. Department of Agriculture system generally includes soils representative of more than one class in the Unified System, and the opposite is also true. The reason for this is that the criteria and limits used in one system are different from those in the other. Yet the correlation is good enough to be of considerable value in trafficability interpretations.

(6) Table 2 has the soils of the Unified System grouped according to their trafficability behavior just as in Table 1. Note that the correlation of textural classes with the trafficability groups is reasonably good, considerably better than the correlation with individual classes of the Unified System. In utilizing pedological soil surveys, therefore, one can interpret pedological textural classes directly into the trafficability classes without going through the intermediate step of estimating what the most likely equivalent is in the Unified Soil Classification System.

(7) Another caution needs to be mentioned at this point. In pedological soil surveys, it is a practice to indicate the texture of the surface layer only in the name of the soil type. Below this surface layer, which is commonly between 5 and 10 inches thick, the soil may be, and usually is, different in texture. In order to determine the soil characteristics necessary for proper trafficability interpretations, the analyst must read the soil profile descriptions and determine from them the soil texture (grain size) in the 6 - 12 inch depth, and also look for other evidence such as hardpans and claypans, which may have relevance to soil moisture relationship and hence to soil trafficability.

(8) In addition to obtaining information on texture from pedological soil surveys, one can generally obtain other kinds of information of considerable value for trafficability predictions. Perhaps most important is information about the natural drainage and moisture content of the soils. This condition is reflected in the pedological soil classification and is also generally described in some detail in the reports. From this information, one can determine where the soils are well drained and will follow the general relationship between soil moisture and climate already set forth in paragraph 8 b (2). One can also determine where the soils are poorly drained and will remain wet far into or throughout the dry season and one can also determine the intermediate conditions. From pedological soil surveys one can determine whether strong soil layers occur within the depth that can be

Trafficability Classification	Corps of Engineers Unified Soil Classification System		U. S. Department of Agriculture Soil Textural Classification											
	Symbol	Typical Names	Basic Soil Textural Class Names and Symbols*											
			Sand	Clay	Silty Clay	Silty Clay Loam	Clay Loam	Sandy Clay	Sandy Clay Loam	Sandy Loam	Loamy Sand	Loam	Silt Loam	Silt
			S	C	SiC	SiCL	CL	SC	SCL	SL	LS	L	SiL	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												
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.

○ 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%.

Table 2. Comparison of engineer and agricultural grouping of soil classes.

reached by tracks and wheels so that soils may remain trafficable even though the surface layer may become too weak to support vehicles. Pedological soil surveys also generally contain information on slope and landforms that is sometimes useful in supplementing other sources of information on the factor of slope; and they also generally contain information on land use which may supplement other sources of information on vegetation.

(9) Soil scientists, like engineers and others, do not yet completely agree in detail how soils should be classified and mapped and analysts therefore will find variations among soil surveys. Within a given country the modern soil survey may differ from the old. Perhaps more important is the fact that the soil classification scheme, including the classification of textures, will differ somewhat from country to country although the practice of classifying soils on the basis of soil profile is almost universal. Therefore, in exploiting pedological soil surveys, particularly of foreign countries, analysts need to examine in considerable detail the classification scheme used and establish correlations between the classification used in the foreign country and trafficability groups set forth in Table 2.

(b) Other surveys. Before leaving the matter of maps and reports, it needs to be mentioned again that, for many areas, information about soils is contained in publications on geology, geography, ecology, and other subjects. If soil surveys are not available, the common situation for many parts of the world, information from these other sources should then be sought and used but such information needs to be very carefully evaluated and interpreted.

(3) Airphotos

(a) Airphotos make up the third principal source of information about soils. If possible, they should always be considered, particularly in preparation of tactical cross-country movement maps.

(b) In utilizing airphotos, analysts need to be aware of the fact that they cannot see soils revealed by geometric shapes as they can other structures that rest upon or protrude above the general level of the ground. Analysts therefore are limited in their interpretation of soils to what can be deduced from clues that can be seen.

(c) The degree to which soils information can be interpreted from airphotos varies according to many factors, such as quality and scale of the airphotos, the nature of plant cover, the nature of the soils themselves, and last but not least, the skill of the photo interpreter himself. Skill is used here to connote knowledge not only of airphoto interpretation techniques but also of soils and how they occur in nature.

(d) The first requirement in airphoto interpretation of soils is to determine, insofar as possible, in which of the four trafficability groups, shown on both Tables 1 and 2, the surface soils of a given area belong. The second requirement is to determine the soil drainage conditions. For part of the second requirement, airphotos frequently are very useful because from them the skilled interpreter generally can determine where the soils have good drainage and where they do not. It must be remembered that airphotos reveal conditions at the time that the photography was done. Hence, for moisture prediction purposes, airphotos made months or years ago can serve only to indicate the general drainage conditions, but such information alone is important. It becomes especially important when used along with knowledge about the kinds of soil and knowledge of moisture-climate relationships.

d. Snow

(1) Snow (4) is being considered along with soil because when there is snow on the ground it substitutes partly or entirely for the soil and because its trafficability behavior is similar to that of soils. Its strength, like that of soils, can be measured with the cone penetrometer and through such measurements its trafficability can be determined. Most snow behaves more like fine-grained soils than coarse-grained, although snow that is granular and behaves somewhat like sand does occur.

(2) Snow is seldom a critical obstacle for tracked vehicles although it frequently may be a hindrance, especially on slopes. Snow, because of its slipperiness, reduces the steepness of slopes that vehicles can climb. On level or gently sloping terrain, tracked vehicles such as tanks apparently can function reasonably well in snow as much as 3 feet deep and perhaps even a little deeper; and it happens that relatively few places in the world suitable for cross-country movement accumulate snow to depths greater than 3 feet. Although there are many places where snow does accumulate to depths greater than 3 feet, such places are commonly forested or mountainous or both and hence generally unsuited for movement for reasons other than deep snow.

(3) Snow is considerably more of a hindrance and hazard to wheeled vehicles. Snow just covering the ground surface may create slipperiness that makes movement of wheeled vehicles difficult although their capability under such circumstances can be enhanced considerably by tire chains and by reduction of tire pressures. If the depth of snow exceeds approximately 8 to 10 inches, most wheeled vehicles are likely to become immobilized. Exceptions, of course, can occur if the snow is quite dense and hard, and again the use of high-flotation, low-pressure tires enhances the capability of wheeled vehicles on snow just as on sand.

e. Summary. The factor of soils has been discussed at considerable length, not because it is more important than other factors but because it is a difficult factor to evaluate and because considerable research has been done on soil trafficability. Reconnaissance, maps and reports, and airphotos are the principal sources of information. The strength of soils can and usually does change under traffic; such a change in strength is called remolding. An instrument, called the cone penetrometer, has been developed for determining the trafficability of soils and a test also has been devised for approximating the extent of remolding likely to occur under traffic. The terms, cone index, remolding index, rating cone index have been introduced, all of which relate to soil strength, and the term vehicle cone index, which expresses the minimum soil strength that will permit vehicles to operate. The term critical layer, which usually is the layer at the 6 to 12-inch depth, has been added to the vocabulary. A technique has been developed for predicting soil moisture content on the basis of the relationship between climate and soil and in this connection the parameter called field maximum moisture content has been introduced. The trafficability characteristics of soil classes as defined in the Unified Soil Classification System and the exploitation of pedological soil surveys for trafficability interpretations were discussed briefly. Finally, it was mentioned that snow behaves much like soil in its relationship to vehicles.

9. Streams and other drainage features (canals, ditches, ponds, and small lakes).

a. Relationship to cross-country movement.

(1) Streams, ditches, and canals are linear features. They may and frequently do constitute elongated obstacles in terrain that is otherwise suitable for movement. They therefore have an important effect on direction of movement; in many areas, they make long detours necessary. Ponds and lakes, on the other hand, and also marshes, swamps, and bogs are areal obstacles rather than linear obstacles; and while they impose circuitous routing, a single pond or small lake commonly does not make long detours necessary.

(2) Water bodies vary in their characteristics from time to time depending upon weather and climate. Streams tend to be relatively low and slow during periods of low precipitation and high and rapid during periods of high precipitation, but the relationship is not always this simple. Melting snow, for example, may cause high water downstream even in arid regions where rainfall is always low. High rainfall or excessive snowmelt may cause streams to flood and become temporary barriers, even to the extent of destroying existing bridges or preventing construction of new ones. Continuous below-freezing weather may cause stream flow to decrease even though precipitation may be high. Low temperatures may cause water bodies to freeze over, to form ice strong enough to carry military vehicles; water bodies then, instead of being obstacles, may become the preferred avenues for movement.

(3) How thick does the ice need to be? Infantry moving in single file at a 2-pace interval requires ice at least 3 inches thick; lightly loaded 2 1/2-ton trucks require ice at least 10 inches thick; and 45-ton vehicles, 2 feet thick (7). Analysts should recognize however that the moving of troops and vehicles on ice may entail considerable risk because weak places due to water issuing from springs, or due to other causes, may prevent uniformly strong ice from forming. They should advise reconnaissance before heavy vehicles are taken onto the ice.

(4) Stream channels also may become the preferred avenues for movement during periods of little or no flow. Some stream channels, in Korea for example, were used for this purpose during the dry season. Even then, however, there may be traps, such as quicksand or other soft places, where vehicles would bog down, and vulnerability to damage from flash floods may exist. Appropriate caution therefore should be advised if analysts conclude that travel on stream beds is feasible.

(5) In CCM studies, the ease of crossing streams commonly is evaluated in terms of fordability. This depends upon the characteristics of the vehicles and of the drainage features themselves. The significant characteristics of drainage features are width of channel, depth and velocity of water, nature of bottom, and height, slope, and strength of banks. These characteristics may vary independently; fording, even of the smallest streams, requires selection of sites where favorable conditions coincide.

(6) Drainage features are considered no hindrance where fords are common and usable with little or no improvement; they are a hindrance if difficult to cross because suitable fords are lacking or rare, or fording would require considerable preparation of approaches, reinforcement of bottoms, or the use of special equipment on the vehicle.

(7) Tracked vehicles have the ability of bridging gaps that are not more than a few feet in width. The medium tank can bridge gaps of as much as approximately 8 feet and hence stream channels no wider than 8 feet are no obstacle to them. Wheeled vehicles, however, do not have this kind of capability. Once the self-bridging capability of vehicles is exceeded, streams can then be crossed only by bridging, ferrying, or fording. The significance of the width of the stream although important to bridging, is of relatively little significance to ferrying and fording except that the wider the stream the greater the hazard involved.

(8) For fording, the maximum depth of water permissible is between 3 and 4 feet for most tanks and between 2 and 3 feet for most trucks (9). There are devices with which vehicles can be equipped so that they can cross water bodies considerably deeper than 4 feet; but vehicles usually are not so equipped and conversion kits are time-consuming to put on. Unless otherwise instructed, analysts, in evaluating streams, should assume that water-proofing kits are not used.

(9) Stream velocities should be less than 5 feet per second for reasonably safe fording.

(10) The bottom of stream channels must be firm enough to support the vehicles if fording is to be successful. This limitation largely prevents the fording of streams in which the bottoms are made up of fine-grained material even though the water may be no more than a few inches deep. Suitable bottoms, therefore, are restricted to those that are sandy, gravelly, or rocky but even sandy bottoms may give way locally to the weight of vehicles, and in some places the bottoms may be so bouldery that vehicles cannot move over them.

(11) The banks are important, too. If they are vertical and hard, they will be obstacles for tanks if their height exceeds 4 feet and for trucks if their height exceeds about 1 foot. If the banks are sloping, greater heights can be tolerated; if the bank slopes are less than 45 percent the height is then immaterial, provided the vehicles can get adequate traction.

(12) The strength of the material composing the banks may be important. It is possible for banks, particularly if made up of fine-grained soils, to be so weak that they give way under the weight of vehicles. The sandy and gravelly materials, on the other hand, are likely to provide adequate strength, although with these,exceptions can occur.

(13) In summary, it is apparent that depth of water, the nature of the bottom, and the nature of banks are all important in fording. Stream velocity may be important also.

b. Information sources and interpretation of them.

(1) Reasonably adequate information about the big streams is commonly available, but not for the small. As every stream is a potential obstacle and as there are many more miles of small streams than of large, the problem of obtaining adequate information pertains mainly to the small streams, and to ditches and canals. Reconnaissance is the best source of information, and for many areas is the only conpletely reliable source. Yet, much can be gotten from maps, reports, and airphotos. There are, of course, maps and reports of hydrologic surveys which are useful. Such reports are available only for large rivers for the most part,although some on small streams are available. Topographic maps, and geographic maps and reports, along with airphotos, are perhaps the best sources of information generally available but occasionally there is useful information in publications on geology, agriculture, soils, and forestry. With a knowledge of geology, geomorphology, hydrology and climatology, considerable information about stream characteristics can be deduced from topographic maps and airphotos by competent analysts. Nevertheless, reliable information of the kind needed for interpreting cross-country movement conditions generally is difficult to get; especially for the smaller streams and also frequently for ditches and canals.

10. Vegetation

Vegetation includes not only the so-called natural vegetation but also crops being grown by farmers and others.

a. Relationship to cross-country movement.

(1) The principal concern is with forest vegetation as trees are the principal obstacles or deterrents to movement. Although it is true that other kinds of vegetation, such as grass and brush, also have some effect, their effect in most places is of relatively low significance.

(2) Nearly all forests will have a slowing effect on movement. The problem in interpretation therefore is not whether forests will slow movement but whether they will slow movement slightly, drastically, or make movement altogether impracticable.

(3) Fully dependable criteria pertaining to size of trees have not been established. The significance of species of trees or of the kinds of root systems has not been determined. Medium tanks, for example, reportedly can push over single trees as much as 12 inches in diameter, but this diameter is too large as a practical one for evaluation of forests. The overturning of trees within stands can create complications. It is likely, for example, if several trees are pushed over, some will not fall clear but instead will interlock with other trees to form a new obstacle to movement. Another difficulty can arise from the protruding root system of overturned shallow-rooted trees.

(4) Trees with trunk diameter less than 3 inches are only a slight hindrance to medium tanks. The maximum diameter of trees practical for medium tanks to push over is considered to be between 6 and 8 inches although trees somewhat less than 6 inches in diameter may cause unsuited conditions if they are very close together. On cross-country movement maps produced by the U. S. Army in Europe (5,6) the practical limiting diameter for single trees to be overturned is 15 cm. (about 6 inches) for deeper rooted trees like oaks, and 20 cm. (about 8 inches) for shallow-rooted trees like spruce. In interior Alaska, on the other hand, tanks apparently have but little difficulty moving through forests in which the trees common to that area are 6 to 8 inches in diameter. The maximum diameter of trees feasible for 2 1/2-ton trucks to push over is considered to be between 1 and 2 inches.

(5) The critical average distance between trees in forests where the trees are too big to be pushed over is considered to be between 15 and 20 feet for both tanks and trucks. This distance admittedly is greater than the width of the vehicle but some allowance must be made for turning. In some managed forests where trees grow in rows the permissible distance between them may be considerably less than 20 feet but cannot be much less than 15 feet. The M48 tank is about 11 1/2 feet wide.

(6) Brush or tall grass may impair visibility for drivers of tanks and trucks and may obscure obstacles such as stumps and boulders. Brush hinders and may even stop trucks but will have little or no deterring effect on tanks. In fact, brush may enhance conditions for tanks by spreading the load over a greater ground surface.

(7) Low-growing vegetation, say less than 3 feet tall, has no significant effect on movement except where it obscures obstacles such as boulders and stumps or except where there is a firm grass sod. On sod, the surface may be slippery enough to cause trouble, particularly where the slope is steep. Grassy sod does not add enough strength to the surface of weak soils to be of consequence because most military vehicles are so heavy that they simply cut through sod if the soil below is soft.

(8) In some places vegetation gives rise to unusual difficulties such as tire punctures by cacti needles in some desert areas.

c. <u>Information sources and interpretation of them</u>.

(1) Reconnaissance is especially important as a source of information about vegetation because two of the characteristics essential to sound evaluation, namely, the size of trees and the distance between them, are seldom recorded and frequently are difficult to determine from airphotos. However, as for the factors of soil and slope, maps and reports and airphotos are the sources upon which analysts commonly will have to rely for information about the factor of vegetation.

(2) Obviously maps and reports that are likely to be of the most value are those which deal with vegetation, particularly forests; but information on vegetation also may occur in many publications that do not carry the words "vegetation" or "forest" in their titles. Among these are agricultural reports of various kinds and also reports on soils, geology, and geography.

(3) Maps and reports commonly provide information about kinds of vegetation, including usually the principal species of trees, grasses, etc. Less commonly do they provide information on diameter of trees, although such information is not unusual, but rarely do they provide information on the distance between trees. Foresters, botanists and ecologists who know a great deal about growth habits and ecological relationships of trees are professionally best prepared to interpret the probable spacing as well as the size of trees. In some countries, such as Germany, where nearly all forests are carefully managed, reasonably good information is likely to exist from which reliable deductions can be made; but for most countries information on diameter and spacing is inadequate.

(4) Airphotos are very useful for deducing information about vegetation but even on airphotos the determination of spacing between trees is very difficult and in many places impossible. Again, the best interpretations can be made by foresters, ecologists, and botanists who not only know how to interpret airphotos but also know the ecological relationships of the kinds of vegetation with which they are dealing.

(5) The problem of ascertaining size and spacing, particularly spacing, from the literature and airphotos is obviously difficult and for many areas cannot be done reliably without some reconnaissance. Forests also may be, and frequently are, altered by man through thinning or cutting. Forests also may be altered by burning. Because of these conditions, the information on forests, particularly for populated regions, needs to be recent if it is to be highly reliable.

11. Cultural features.

a. Definition. By cultural features is meant the works of man such as stone walls, hedge rows, dikes, canals, cuts, fills, built-up areas, etc. Some of these features have been considered under the factor of slope and some under the factor of streams; and some, such as built-up areas, are usually not evaluated in cross-country movement studies. Nevertheless cultural features are treated as a factor so as to remind the analysts that the effect of works of man must not be overlooked in evaluating terrain for cross-country movement.

b. Relationship to cross-country movement. Cultural features considered here are those that are deterrents or obstacles to movement. Vehicles must climb over stone walls, unless the sheer weight of the vehicles pushes them over, and hence the height and thickness of such walls may determine whether or not they are serious obstacles. The height of embankments as well as the slope on either side determines their obstacle value. Embankments more than 10 feet high with side slopes of more than 45 percent are likely to be serious obstacles. Cuts of similar dimensions have similar significance. The critical values cited for streams apply to ditches and canals as well, but in addition, embankments of various heights may occur alongside these features and, if so, they increase the obstacle value of the ditches or canals. In some places there may be large gravel pits or other areas where strip mining has taken place and left features that are obstacles or traps for vehicles. These too must be evaluated on the basis of factors already discussed, including particularly the present slope and soil characteristics of such disturbed areas.

c. Information sources and interpretation of them. Information on cultural features that may be highly relevant to cross-country movement is frequently difficult to obtain unless, of course, reconnaissance can be conducted. Some of the features can be interpreted from airphotos and some are also shown on topographic maps, but dimensions, which are highly important to cross-country movement, are frequently difficult to find or to estimate. Geographic reports may be helpful but no single kind of publication is likely to have the data needed as a consistent characteristic. Considerable resourcefulness is required in seeking out relevant information on cultural features.

CHAPTER 3

MILITARY CHARACTERISTICS OF CROSS-COUNTRY MOVEMENT STUDIES

12. General

While the military characteristics of cross-country movement studies have not been established formally, some general characteristics nevertheless have evolved from research and experience in the last decade, and these today can be considered as military design requirements. In meeting these requirements two general formats have evolved; one for tactical (large-scale) maps, with supporting materials, and the other for strategic (small-scale) maps, with supporting materials. Intermediate-scale studies to a large extent follow the format of either the tactical or strategic studies, whichever is the more appropriate in the particular study.

<u>a.</u> These formats are not the only ones that conceivably meet the requirements but they are acceptable formats that represent solutions to a difficult problem, and most CCM studies produced in recent years resemble one or the other.

<u>b.</u> In the interest of keeping to a reasonable minimum the kinds of maps military personnel are asked to use, it is suggested that the basic features of either format, whichever is appropriate, be followed. At the same time it is recognized that minor variations will nearly always be necessary because of peculiarities of any area under study and the quality and amount of source information available. Variations also may be necessary because of limitations of time or reproduction facilities. Moreover variations, or even completely new designs, may be necessary because of special requirements of the requestor.

<u>c.</u> Last but not least, cross-country movement studies, like vehicles, weapons, etc., are susceptible to improvement. The formats presented in this guide therefore represent today's stage in development. As development progresses, improvements are to be expected.

13. Intended use

<u>a.</u> Cross-country movement studies are designed for use mainly in <u>planning</u>. The strategic studies are intended for use at high echelons of command such as the Department of Defense, Department of the Army, theater commands, and field armies. Tactical studies are intended for use at one or more echelons of command from corps to battalion.

b. It is envisaged that CCM studies will be used as one among several sources of information from which the total intelligence for a given plan of operation is derived. These studies, therefore, are intended to supplement importantly, but not replace, topographic maps as the principal operational map at nearly all echelons of command.

14. Design requirements

a. An overriding requirement is that the maps and supporting materials be simple and easy to read; this requirement is difficult to meet when effort is made to produce accurate studies that meet the other requirements, too.

b. Unless otherwise specified by the requestor, the terrain evaluations shown on the cross-country movement map should be for tracked vehicles only, using the capability of the medium tank as a standard. To have the map show evaluations for both tracked and wheeled vehicles, and perhaps for foot troops as well, although highly desirable, would tend to make the map too complicated; hence the restriction to tracked vehicles. Evaluations, or at least comments, about wheeled vehicles and foot troops should be included in the supporting materials.

c. The map should symbolize interpretations of the effect of terrain on capabilities of tanks to move across country and it should also show facts about the terrain important to movement. In other words, the map should show both the interpretations and, insofar as feasible, the terrain conditions that are interpreted.

d. Terrain elements that need to be evaluated and on which relevant facts need to be presented are slope, climate, soil, streams, vegetation, and cultural features.

e. Unless otherwise specified, the map should show the interpreted conditions for the entire year. In other words, the expectable effects of climate on soils and water bodies are somehow to be accounted for and shown.

f. The preferred scale for tactical maps is 1:100,000 although other scales, particularly 1:50,000, are acceptable. The preferred scales for strategic maps are 1:1,000,000 and smaller.

g. For tactical maps the intelligence should be overprinted on standard topographic maps modified as little as possible to accommodate the new information. It is especially important that roads show clearly on CCM maps. For strategic maps the intelligence should be overprinted on standard base maps, again modified as little as possible to accommodate the new information.

h. The maps, both tactical and strategic, should be supported by brief legend explanations, texts, tables, diagrams, and perhaps other illustrations necessary to the proper and complete exploitation of the available cross-country movement intelligence for the study area.

15. Tactical cross-country movement study -- an example

a. The CCM studies (6) covering the British Zone of Germany represent the current stage of development of tactical CCM studies. Sheet P-5 (Halberstadt) of this area is attached as Appendix I and is described in some detail in the following paragraphs.

(1) Note first of all that the base map is of the series published by the British War Office and its design is different from that of topographic maps published by the Army Map Service of the Corps of Engineers. The changes in the base map are perhaps greater than would have been necessary on the standard U. S. Army type topographic base maps.

(2) Under "Map Explanation" the first part is entitled "Evaluation of Terrain for Cross-Country Movement." In this, CCM is defined, the fact that the evaluations are oriented to the medium tank is set forth, and some additional information that the user needs to know is given.

(3) The second major division of the "Map Explanation" is the table entitled "Areal Slope-Soil Evaluation." This table sets forth the evaluation of slope and soil, taken together.

(a) The evaluation of slope and soil together represents a practical compromise between two less desirable alternatives. One would be to have the map show the overall, integrated evaluation of areas, an alternative, which while highly desirable, makes exceedingly difficult the display of terrain facts along with the interpretation of them. The other alternative would be to show the evaluation of slope and soil separately which, while displaying each factor fairly well, has the undesirable feature of leaving for the user the task of putting together all the independent evaluations to come up with an integrated evaluation.

(b) For terrain free of forests, the evaluations of slope and soil commonly do represent the overall evaluation for areas, and there are many such areas in the world. In nature, many slope boundaries and soil boundaries occur at the same place; therefore the slope-soil combinations require fewer boundaries than would be needed if the two factors occurred entirely independent of each other.

(c) Where forests occur, the user must integrate the slope-soil evaluation with the forest evaluation in order to arrive at the overall evaluation for such areas. While this step, admittedly, is a shortcoming, it also has the compensatory effect of making him aware of the location and nature of the forest hindrances or obstacles.

(d) In the left-hand column of the table giving slope-soil evaluations there are four major classes in which evaluations are expressed by the rating terms "PASSABLE", "DOUBTFUL", and "IMPRACTICABLE"; these are defined immediately under the table. The fact that the number of classes is no more than 4 and the rating terms no more than 3, represents a practical compromise between simplicity and legibility on the one hand and maximum detail which analysts could provide on the other.

(e) The second column, labelled "Map Unit", indicates the color and pattern for nine map units, which are described in the third column. Note that information on slope and soil is provided. The columns headed "Map Unit" and "Description" represent the partial answer to the requirement that the maps provide terrain facts as well as interpretation of them. In the table as a whole, the nine map units are assembled into four groups on the basis of their similarity in terrain conditions affecting movement; and they are arranged in a descending order of relative suitability for movement.

(f) In the first column some cognizance is taken of the effect of climate upon movement conditions. The first class for example is labelled "PASSABLE at all times," whereas the second is labelled "PASSABLE most of time, DOUBTFUL or IMPRACTICABLE part of time." This particular label does not state <u>when</u> the passable or the impracticable conditions occur but some related information is given in the third column and more information is provided on the back of the map sheet.

(g) Note the selection of colors, green for "PASSABLE" and red for "IMPRACTICABLE." As this selection parallels the traffic-light colors, the significance of the map colors is easy to remember. "PASSABLE at all times" is shown as dark green. The second class, "PASSABLE most of time, DOUBTFUL or IMPRACTICABLE part of time" is shown as light green. The third class, "IMPRACTICABLE most of time, PASSABLE or DOUBTFUL part of time," is shown as green with red lines and the fourth class "IMPRACTICABLE at all times" is all red.

(h) Map units 1 and 2 which designate the terrain types that are "PASSABLE at all times" have identical color patterns; these map units are distinguished from one another by number symbol only. The same holds for other groups of map units that make up any one of the major evaluative classes. This feature admittedly subdues the visual display of selected terrain facts; it represents another compromise with the requirement that the map must be simple and easy to read. It permits the map to carry selected terrain facts without seriously hindering display of the evaluations.

(4) Moving downward to the next table, the user will note that evaluations of embankments and escarpments are set forth. Here again some facts about these features are revealed by both symbols and descriptions.

(5) The third table, which is entitled "Evaluation of Forests," sets forth evaluations in terms of "Minimum Hindrance " and "Maximum Hindrance" and again provides some descriptive material. The forest

patterns are in green -- the conventional color used for vegetation -- and this fact makes their meaning easier to remember, but along with this advantage is a probable disadvantage or risk of misinterpretation. The user must remember that these green forest patterns represent conditions bad for movement, whereas the green slope-soil colors represent conditions good for movement. Moreover, the user must mentally integrate the two in order to visualize the overall evaluation.

(a) Note that the symbol box for maximum hindrance has in it a black arrow which indicates the orientation of lanes in forests where such lanes occur. This is a special feature relevant to Germany, where nearly all forests are managed, and illustrates another characteristic of this map design. This characteristic is that of enough flexibility to accommodate special features of an area while still preserving the basic structure of the study. The note at the bottom of this table about forests tells the map user that in rugged areas the two forest types are not distinguished, but all are shown by the maximum hindrance symbol.

(b) There may be studies for which information is inadequate for classifying forests according to "Minimum Hindrance" and "Maximum Hindrance." In such studies, the distribution of forests nevertheless should be shown on the CCM map so as to indicate where forests are hindrances of undetermined degree.

(6) The last table under "Map Explanation" deals with drainage. This table sets forth an evaluation of the streams and provides some descriptive material of the three evaluative classes. Note that, as with slope-soil evaluations, cognizance is taken again of the fact that streams, like soils, are affected by climate. Thus streams that are a seasonal hindrance are shown by a symbol different from those that are a hindrance all the time.

(7) Note that on this sheet linear features, such as embankments, escarpments, and streams, are shown by symbols different from those which are used to show the evaluation of features that distribute themselves areally such as slope-soil combinations and forests. Escarpment symbols and special stream symbols are used to connote linear features rather than areas because such symbols make the map more expressive of the terrain conditions affecting movement.

(8) Note that the title of this particular study is "Cross-country Movement and Terrain." In examining the map explanation, one finds that it contains considerable information about the terrain, and more is provided on the back of the map. On the back there is, on the left half, a description of the criteria for evaluation of cross-country movement conditions. Much that has been stated in this guide is summarized there. It also includes the evaluation of the different kinds of trafficability of soils according to summer, autumn, winter, and spring. This evaluation, of course, is for northern Germany; it might be different for another area.

(9) On the right half of the back is a summary of terrain discussed with special reference to cross-country movement. This discussion pertains to the terrain represented by this particular sheet, but it also shows on the small inset map the setting of the area covered by the sheet with regard to the physical geography of the surrounding region. While the discussion is oriented to cross-country movement, the information obviously may have many other applications.

16. Strategic cross-country movement study -- an example

a. Like tactical maps, the strategic maps reflect evaluations of all the relevant terrain factors, including variations in their significance due to climate, but there are some important differences in method of presentation.

(1) Because the scale of strategic maps is small, it is impossible to show by symbol the distribution of linear obstacles such as escarpments and rivers, except perhaps the very big and prominent ones; and it is also impossible, or at least impracticable, to show the distribution of forests apart from the distribution of slope-soil conditions. On strategic maps therefore the map units must of necessity reflect the integrated evaluation of all factors.

(a) An area with favorable slope and soil conditions, for example, will be down-graded if it has a lot of streams even though the conditions between the streams are favorable; or an area with favorable slope-soil conditions will be down-graded if it is partly or wholly covered with trees.

(2) Another difference is that the strategic maps are of necessity highly generalized. When one generalizes on maps one has to "permit many little lies in order to preserve the big truths." In order to set forth the big truths on strategic maps, many exceptions, "little lies," must be ignored with the expectation, or at least the hope, that the user of such maps will be aware of this unavoidable shortcoming.

(3) Appendix II is an example of a legend for a strategic cross-country movement map and Appendix III is an example of the kind of supporting table that accompanies such a map. The complete cross-country movement study also has a brief text.

(a) Note on the legend illustrated by Appendix II that the evaluations are expressed in terms of "GOOD," "FAIR," "POOR," and "UNSUITED;" these are defined at the bottom of the legend. These definitions, or the parts of these definitions referring to restrictions in direction of movement, accommodate the linear obstacles which on tactical maps are shown by special symbol and are given their own unique obstacle rating.

(b) Note also that green again is the color used for areas that are generally passable, the areas classed as "GOOD" and "FAIR." Red is used for areas "UNSUITED" for movement and brown is used for the intermediate areas. Each map unit of the same color commonly is given a unique pattern; for example, all map units classed as "UNSUITED" are red, but each one is given a distinctive pattern.

(c) Observe that in the legend terrain facts as well as evaluations are provided.

(d) Observe also that climatic effects are recognized where significant, as in map unit 3.

(4) On strategic maps the composition of the map units as well as the total number necessarily varies somewhat from study area to study area; but ordinarily the total number of map units is less than 10. Usually the map units are arranged in descending order of ease of movement. Wherever a militarily significant grouping can be achieved, the map units are grouped under appropriate headings, such as "GOOD," "FAIR," "POOR," and "UNSUITED."

(5) Considerably more information about the terrain conditions and also climatic effects than is in the legend is given in the supporting table of which Appendix III is an example. Under the column headed "General Terrain Conditions" those terrain characteristics particularly relevant to movement are set forth. Under the column headed "Movement of Tracked Vehicles" the significance of these terrain characteristics is interpreted for tanks and other vehicles with similar movement capabilities. The remaining two columns provide interpretations for wheeled vehicles and foot troops. This arrangement represents the compromise between the desirability of having the map provide cross-country movement evaluations for all types of vehicles,and foot troops too, and the necessity for keeping the map reasonably simple and easy to read. The evaluations on the map therefore are oriented specifically to tanks without regard to other vehicles or foot troops; but information relevant to wheeled vehicles and foot troops is provided in this table.

(6) In addition to the table, a brief text is commonly provided, which discusses the overall characteristics of CCM conditions for the study area as a whole. Its length commonly is between 4 and 8 triple-spaced, legal-size pages of typed manuscript. It is made up of two parts, the introduction and the main text.

(a) The introductory statement is an overall summary of the most significant aspects about the cross-country movement conditions in the study area as a whole. It usually consists of a brief statement of the geographic distribution of and relationships between the major groups of map units so as to provide the framework for the main body of the text.

(b) The main body of the text usually is organized according to the major groups of map units that appear on the legend. The outstanding characteristics of each group are discussed briefly and significant relationships between groups may be pointed out.

(c) Illustrations, such as photographs of cross-country movement conditions, are helpful and should be included in the text if feasible. Ground photos or low oblique airphotos are among the most useful illustrations.

CHAPTER 4

PREPARATION OF CCM STUDIES

17. General

Preparation of the CCM study begins with the processing of collected source materials and culminates in the presentation of the CCM study in manuscript. During preparation, collection of data may be resumed and processing continues in conjunction with evaluation. Experience in preparation of CCM and related studies has shown that strict separation of collection, processing, and preparation is not efficacious. The research method is conditioned by the subject matter, and, in turn, the subject matter can be treated only by use of certain procedures that demand this method.

18. Research and researchers

a. The research method is predicated on the need for examination of a number of terrain factors, which are known mainly through scientific identifications and evaluations. The procedures for the analysis of the scientific facts and the reinterpretation of scientific evaluations are varied. They are not all restricted to scientific research. However, a scientific background in earth sciences is essential to select the appropriate procedures for each case and to make judgements based on scientific evidence.

b. Terrain factors have been examined quantitatively only in part, so that the non-specialist has no criteria for identifying pertinent data and judging the meaning and validity of data. The research method required for terrain intelligence is, therefore, an adaptation of the scientific research method. It calls for the group activity of personnel qualified in the topics that are considered in the terrain--in this case, CCM--study. This means that the group for a CCM study should be composed of soil scientists, geologists, botanists or foresters, hydrologists, and climatologists. The first three types of specialists are used most and are, therefore, the more urgently needed. The number of each type of specialist will depend on the area being studied, the availability of data, the complexity of the analysis and evaluation, and other operating conditions of the project. Ideally, the composition of the group will be changed in response to the needs of the particular project. Correct staffing is the foundation of the research method.

c. A group leader should be designated from among the specialists to administer the project, supervise the research, and review the products for adherence to standards.

d. Criteria must be established or reaffirmed on which to base the entire study. Fundamentally they refer to the factors of terrain affecting the cross-country movement of the vehicle. Once the correlations between characteristics of the terrain elements and performance of the vehicle are determined, it is possible to proceed systematically through the various steps of the project. The criteria will give direction to the collection and interpretation of data and will control the evaluation of movement conditions in the map region.

e. The widest range of resources should be available for effective accomplishment of the CCM study. They include:

(1) Access to all significant published literature and maps on the problem, including topical and regional material. Intelligence reports and manuscript material should be considered also; but intelligence reports should be used with great caution, especially old ones.

(2) Complete coverage of the map region by aerial photography of recent date at a scale appropriate for terrain interpretation.

(3) Facilities for performance of ground and aerial reconnaissance of the map region, wherever a region is accessible for this purpose.

(4) Availability of field soil-trafficability testing equipment.

(5) Access to tank performance tests and military exercises involving use of tanks.

(6) Direct communication with representative users (or potential users) to determine specific needs and reactions as an aid to development of the product.

(7) Access to consultation with topical and regional experts wherever possible, including funds for payment of consultation.

f. Basic to the concept of the research method is flexibility to meet the actual demands of the investigation as it progresses. Professional judgment is essential to determining the appropriate changes in procedure to maintain standards of quality and quantity of output.

g. The types of procedures employed in preparation of CCM studies are orthodox scientific procedures that should be fully known to all research personnel of the project. Some comments on the procedures follow:

(1) Analysis of scientific maps and literature. This involves selection of pertinent data and preliminary compilation in a form for use in compilation of the CCM manuscript. It presumes familiarity with scientific terminology, English and foreign, used in sources, and ability to identify the data in other terms that have meaning for the CCM study.

(2) Interpretation of air photos. Emphasis is placed on obtaining data from the photos and making evaluations at the same time.

(3) Scientific field and aerial reconnaissance. A thorough knowledge of procedures for identifying terrain features rapidly and accurately on the ground and from the air is a prerequisite. Also involved are accurate recording of observation and immediate evaluation of observed features.

(4) Preparation of thematic maps. This involves a knowledge of the problems of special-purpose mapping, interpretive generalization of topical information, and procedures for transfer of data from various sources and at various scales to a base of selected scale.

(5) Preparation of CCM texts and tables. The communication of scientific and technical data to non-specialists requires a broad knowledge of special and general vocabularies, and experience in converting a variety of unrelated sources to a common purpose and expressing the data and interpretations in a uniform style.

19. Steps in preparing CCM maps

In listing the steps below it is assumed that individual analysts, or preferably, teams of analysts made up of several kinds of specialists, are qualified to deal with the various kinds of source information and have as a minimum the information about relevant terrain factors and their evaluation, the characteristics of CCM studies already given in this guide, and know the CCM capabilities of the vehicles concerned.

a. Tactical maps.

(1) The first step can be divided into three parts.

(a) Analysts need to select and assemble large-scale topographic maps, and reports and maps on soils, geology, vegetation, and other subject-matter items that contain information on the terrain factors for the entire study area. Such maps ought to be examined and studied along with airphotos and both, if possible, ought to be related to actual conditions on the ground through reconnaissance.

(b) From this preliminary investigation determine how best to exploit the combination of sources of information available.

(c) Develop a map explanation (legend) that will fit the entire study area. Follow the general structure of the example in Appendix I, but adjust it to the new area of concern. This legend must of necessity be considered preliminary until it has been tested for sample localities, after which it should be considered firm.

(2) The second step consists of evaluating the terrain conditions and delimiting both areal and linear features.

(a) Delimit the areas too steep for movement. Do this first so as not to waste time interpreting soils, vegetation, etc. for those areas in which slope alone is too steep for feasible movement.

(b) Delimit the slope-soil map units in those areas not too steep for movement. The legend already established sets forth the map units to be used for this purpose. The legend also sets forth the interpretation to be placed upon these map units. Awareness of these interpretations should be maintained throughout this step.

(c) In those areas not too steep for movement, delimit the forested areas, classified according to minimum hindrance and maximum hindrance. In those areas too steep for movement, merely classify all forests as maximum hindrance; do not waste time attempting to classify them.

(d) Classify and delimit streams according to the scheme required by the legend.

(e) Classify and delimit embankments, escarpments, and other features that are to be shown by special symbols. Do this only for areas outside of those too steep for feasible movement.

(3) Make a reconnaissance check of the delineations if possible and make necessary corrections.

(4) Prepare the supporting text and other material that goes on the back of the map.

(5) Submit the material for drafting and reproduction, maintain close liaison with cartographic units doing this work. Follow the job through.

(6) Several of the tasks listed above are particularly adaptable to the use of specialists in order to obtain the best possible product. Moreover, several can be working on the same area at the same time. While one is mapping the slope-soil combinations, another can be mapping the forest, and a third, the streams. This particular map design, therefore, is amenable to the division of labor and the utilization of specialists in the production process.

c. Strategic maps.

(1) As with tactical maps, the first step for strategic maps can also be divided into three parts.

(a) Analysts need to select and assemble all relevant source information. Since reconnaissance is almost never possible for strategic maps, greater reliance must be placed upon other sources of information particularly upon topographic maps and upon reports and maps on soils, geology, vegetation, and other subject-matter items that contain information needed for the analysis. Airphotos, if available, ought to be used, at least for spot checking if time does not permit examination of all of them.

(b) From this preliminary investigation determine how best to exploit the combination of sources of information and procede to study the relevant information for the area as a whole.

(c) Develop a legend that will fit the entire study area.

(2) Because cross-country movement evaluation for strategic studies requires the evaluation of all factors in many combinations, it is difficult to make a beginning. Two alternative approaches are suggested; the one to be followed depends upon the terrain characteristics of the study area and the relative quality and quantity of information available on the various factors. In using either of these approaches, or any other approach, the objective is the same--to end up with map units reasonably homogeneous in terrain characteristics affecting cross-country movement. Furthermore, the end result ought to be the same regardless of which approach is used.

(a) From a preliminary analysis ascertain if cross-country movement in the given study area happens to be controlled to a large extent by any single factor, such as slope, soil, or vegetation. If so, make the initial divisions on the basis of the particular factor. For example, if slope is the predominant factor, an initial breakdown of the terrain into areas of uniform slope characteristics could be attempted. Information on other factors could then be applied to this breakdown and the tentative map units established.

(b) Start with a basic (pedological) soil map. Place the basic soil map units into groups so as to form tentative CCM map units. Apply information on other factors, especially vegetation, and modify as required.

(3) Proceed with the evaluation of terrain factors and place the appropriate boundaries on the map. Avoid excessive cartographic detail. A map so detailed that it is difficult to read fails of its purpose. If the map turns out to be too detailed, the legend may have to be revised. Possibly two map units, intricately associated, may have to be combined into a new one to form a map unit depicting an association of two or more kinds of cross-country movement conditions.

(4) Prepare the supporting table, text, and illustrations, if any.

(5) Submit the material for drafting and reproduction. Maintain close liaison with personnel doing this work. Follow the job through.

APPENDIX I
Sample of tactical CCM study

system where known

th route numbers
nostly 6 m. wide 56

andstrassen 1. Ordnung) metalled
erage useful width

nd 4 m. average useful width

Not always motorable

Urban Areas

CONTOUR INTERVAL 10 METERS UP TO 50 METERS AND
25 METER INTERVAL THEREAFTER

HEIGHTS IN METERS

HALBERSTADT, GERMANY

APPENDIX II

SAMPLE LEGEND FOR STRATEGIC CCM STUDY

CROSS-COUNTRY MOVEMENT CONDITIONS FOR TRACKED VEHICLES

MAP UNIT			DESCRIPTION
			GOOD*
dark green	1		Good at all times on level to gently sloping surfaces.
			FAIR
light green	2		Fair at all times on moderately sloping surfaces with slightly incised drainage channels.
light green	3		Fair most of the time on moderately sloping surfaces with slightly incised drainage channels; poor June through October.
			POOR
brown	4		Poor at all times in forests.
brown	5		Poor at all times on steep slopes and on moderately sloping dissected surfaces.
			UNSUITED
red	6		Unsuited at all times on densely forested, level to sloping surfaces.
red	7		Unsuited at all times on permanently wet ground.
red	8		Unsuited at all times on rough, dissected, or very steeply sloping surfaces.

* RATING TERMS FOR CROSS-COUNTRY MOVEMENT CONDITIONS

Good -- Conditions permit free movement in any direction.

Fair -- Conditions moderately hinder progress or moderately restrict choices of direction for movement.

Poor -- Conditions severely hinder progress or greatly restrict choices of direction for movement.

Unsuited -- Conditions preclude all but local movement.

(Line patterns shown are for illustration only. Appropriate patterns should be chosen for each study.)

Cross–Country Movement

Evaluations of movement conditions on the map apply to self–propelled tracked vehicles that exert average ground pressures of about 12 pounds per square inch such as the medium tank, M48, and are not equipped with such aids as special lugs, grousers, or fording equipment. Evaluations of movement conditions for wheeled vehicles and foot troops are also presented below to give the overall picture, Evaluations of movement conditions for wheeled vehicles apply to vehicles having characteristics essentially the same as the 2½ ton, 6 x 6 truck not equipped with such aids as chains and high flotation tires or with special fording equipment.

MAP UNIT	GENERAL TERRAIN CONDITIONS	MOVEMENT OF TRACKED VEHICLES	MOVEMENT OF WHEELED VEHICLES	MOVEMENT OF FOOT TROOPS
1	Level to gently sloping surfaces; coastal plains, intermontane basins, narrow valley floors, and beaches. A few widely spaced large rivers and irrigation canals, and many small intermittently flooded depressions and steep–banked intermittent streams subject to flash floods, June through Oct. Locally sand dunes as high as 50 ft., stony surfaces, desert shrubs, and small lakes. Soils firm most of time; local areas of fine–grained soils muddy for brief periods after heavy rains.	Mostly free for long distances in any direction. Interrupted at 30– to 50–mile intervals by large perennial rivers and irrigation canals all of year, and at 3– to 10–mile intervals by all streams for very short periods June through Oct. Moderately hindered locally by such obstacles as sand dunes, steep–banked intermittent streams, small lakes, and temporarily flooded depressions, and stony surfaces, all of which could be bypassed.	Moderately restricted in choices of direction by the many small streams. Interrupted by streams and canals as for tracked vehicles. Local obstacles, especially areas of dense desert shrubs, could be bypassed.	Same as for tracked vehicles, although local areas of dense desert shrubs severely hinder movement.
8	Mostly forested rough, dissected, or very steeply sloping surfaces with many narrow valleys and a number of small basins. All streams subject to flooding, June through Oct.	Precluded in most places by rugged terrain and steep, forested slopes; possible locally on floors of some basins and narrow valleys except June through Oct., when movement precluded by floods and muddy soils.	Same as for tracked vehicles.	Possible in most places although seriously hindered by steep slopes; infeasible locally in very rugged areas. Seriously hindered in basins and on valley floors, June through Oct.

APPENDIX IV

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