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3-11.1B

Small-Unit Leader's Guide to Weather and Terrain

U.S. Marine Corps

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ERRATUM

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SMALL-UNIT LEADER'S GUIDE TO WEATHER AND TERRAIN

1. For administrative purposes, FMFRP 0-51 is reidentified as MCRP 3-11.1B.

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DEPARTMENT OF THE NAVY
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FOREWORD

1. PURPOSE

Fleet Marine Force Reference Publication (FMFRP) 0-51, Small-Unit Leader's Guide to Weather and Terrain, provides basic information on weather and terrain and their effects on military operations.

2. APPLICABILITY

This manual is applicable to small-unit leaders and commanders and to the staffs of small units. This manual is also a basis for instruction and for use by personnel developing equipment and doing studies for the Marine Corps.

3. SUPERSESSION

Operational Handbook 0-51, Small-Unit Leader's Guide to Weather and Terrain; however, the texts of FMFRP 0-51 and OH 0-51 are identical and OH 0-51 will continue to be used until the stock is exhausted..

4. RECOMMENDATIONS

Comments and recommendations on this manual are invited and are essential to its orderly development. Comments should be addressed to --

Commanding General
Marine Corps Combat Development Command (WF 12)
Quantico, VA 22134-5001

5. **CERTIFICATION**

Reviewed and approved this date.

BY DIRECTION OF THE COMMANDANT OF THE MARINE CORPS

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USER SUGGESTION FORM

From:

To: Commanding General, Marine Corps Combat Development Command (WF 12), Quantico, Virginia 22134-5001

Subj: RECOMMENDATIONS CONCERNING FMFRP 0-51, *Small-Unit Leader's Guide to Weather and Terrain*

1. In accordance with the Foreword to FMFRP 0-51, which invites individuals to submit suggestions concerning this FMFRP directly to the above addressee, the following unclassified recommendation is forwarded:

____	____	____	____
Page	Article/Paragraph No.	Line No.	Figure/Table No.

Nature of Change: ☐ Add ☐ Delete ☐ Change ☐ Correct

2. Proposed new verbatim text: (Verbatim, double spaced; continue on additional pages as necessary.)

3. Justification/source: (Need not be double spaced.)

NOTE: Only one recommendation per page.

Record of Changes

Change No.	Date of Change	Date of Entry	Organization	Signature

SMALL-UNIT LEADER'S GUIDE TO WEATHER AND TERRAIN

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SECTION 1

INTRODUCTION

"Within a single square mile a hundred different orders of battle can be formed. The clever general perceives the advantages of the terrain instantly; he gains advantage from the slightest hillock, from a tiny marsh; he advances or withdraws a wing to gain superiority; he strengthens either his right or left, moves ahead or to the rear, and profits from the merest bagatelles."

Frederick The Great: Instructions
for His Generals.

101. GENERAL

a. The successful commander maximizes his advantages. With the spread of technologically advanced weapons systems, Marines can expect to face opposing forces on the battlefield with combat power equal or greater than ours. The preparedness to deal with weather conditions, and the ability to read, understand, and exploit the terrain can mean the difference between victory and defeat.

b. The three components which support tactical decisions are (see fig. 1-1):

(1) Knowledge of weather, climate, and terrain and how to advantageously use them.

(2) Knowledge of the enemy.

(3) Knowledge of own forces.

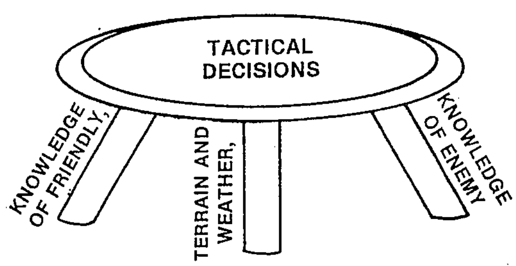


Figure 1-1. Three Components which Support Tactical Decisions

c. The purpose of this manual is to help field commanders, especially small unit leaders, understand the basic terminology and principles used to understand weather and terrain.

102. LESSONS FROM THE PAST

History is replete with campaigns where weather and terrain were not properly considered. Weather and terrain interact with the mission, armament, morale, supply, and comparative strength to confront the commander with a succession of unique situations in the execution of combat operations. This variety is not an excuse for inactivity or curtailed planning. Rather, it is the stimulus for planning with an "elasticity of mind", as opposed to rigid formula, that considers each factor in light of the fundamentals of war. Those who have understood terrain and weather and their effects on military operations have been able to develop plans which took advantage of, rather than being hindered by, the terrain and weather in which they were operating.

103. RESPONSIBILITIES

a. The responsibility for considering the effect of weather and terrain extends to every unit leader. This responsibility is met by planning and by continuous evaluation and adjustment during the execution of combat operations. The ability to evaluate terrain in light of its tactical importance should be cultivated and practiced by leaders from the highest commander to the fire team leader.

b. Every leader is responsible for the analysis and use of terrain and weather intelligence. Military manuals emphasis the role of the intelligence officers in gathering information and intelligence on terrain and weather. However, every commander is responsible for how he uses the information provided him.

104. USE OF TECHNICAL TERMS

a. This manual uses the technical terms of geology and meteorology because they reflect significant physical distinctions. For example, in paragraph 502, two types of climates are discussed under the heading of tropical climates: the tropical wet climate and the topical wet and dry climate. In the tropical wet climate, it is always hot and damp and the land is covered by dense forests or jungles. In the tropical wet and dry climate, the forests are more open than in the tropical wet climate, and some areas are covered by tall grasses, rather than by forests. In the tropical wet climate there are distinct wet and dry seasons. Such distinctions are important to military men, and it is in our best interests to use the terms which draw these useful differences.

b. Military personnel who understand the lexicons of geology and meteorology are more apt to be able to communicate with geologists and meteorologists. Military personnel who can communicate with the experts in these fields can draw on them for advice and information on conducting operations in a specific area. Appendix F provides a terrain analysis checklist.

c. Appendix A provides a listing of publications which should also be read. Appendix B, the glossary, is provided to help the reader learn the technical terms of military geography. Appendix C shows the use of drainage patterns in determining surface configuration and composition of soil.

105. KEY DEFINITIONS

The following terms are used throughout this manual: terrain, terrain intelligence, weather, climate, and season.

a. **Terrain.** The surface character of the land which includes both natural and manmade features. The components of terrain are: (1) topography, (2) relief, and (3) drainage.

(1) **Topography.** A detailed description or representation of the features, both natural and artificial, of an area, including its relief and such features as roads, railways, and canals.

(2) **Relief.** Inequalities of elevation and the configuration of land features on the surface of the earth that may be represented on maps or charts by contours, hypsometric tints, shading or spot elevations (JCS Pub 1).

(3) **Drainage.** The discharge of water from any area through a system of streams.

b. **Terrain Intelligence.** Processed information on the military significance of natural and man-made features of an area (Joint Pub 1-02).

c. **Weather.** Weather is the state of the atmosphere at a given time and place. It includes atmospheric pressure, winds, humidity, clouds and fog, precipitation, and fronts or zones where air masses of different temperatures meet.

d. Climate. The average weather condition at any given place over an extended period, usually more than ten years. (Climate is generally considered to be a characteristic of geographic areas. General climatic expectations are not a substitute for specific intelligence forecasts on weather conditions, but may be used as a general guide in planning.)

e. Season. A period of the year characterized by particular conditions of weather.

106. TRAINING AND FURTHER READING

a. Regardless of how well manuals are written, different people will interpret them differently. Further, the guidance in such publications can never be complete. Only by training can the different interpretations be identified and reconciled, and only by training can the readers learn those subtleties which are commonly included under the headings of judgement and experience.

b. This manual is only an introduction to weather and terrain. Appendix A lists additional publications which should also be read.

SECTION 2

MILITARY ASPECTS OF WEATHER AND TERRAIN

> Maneuvers that are possible and dispositions that are essential are indelibly written on the ground. Badly off, indeed, is the leader who is unable to read this writing. His lot must inevitably be one of blunder, defeat and disaster. The intelligent leader knows that the terrain is his staunchest ally, and that it virtually determines his formation and scheme of maneuver. Therefore he constantly studies it for indicated lines of action.
>
> Infantry in Battle

201. GENERAL

The analysis of weather and terrain is organized primarily around the following set of military considerations: Key Terrain, Observation and Fields of Fire, Concealment and Cover, Obstacles to Movement, and Avenues of Approach (KOCOA). These considerations are discussed in the following paragraph. While the discussions of these considerations focus on terrain, the reader must bear in mind that terrain and weather are inseparable. Terrain which offers good trafficablity when it is dry may be impassable when it is wet. A hill which provides good observation on a clear day may not provide any visibility on a rainy day or at night.

202. KOCOA

a. **Key Terrain.** A key terrain feature is: "Any locality or area the seizure or retention of which affords a marked advantage to either combatant" (JCS Pub 1). Key terrain features must be considered in formulating courses of action. Their selection is based on the mission of the command. Terrain which permits or denies maneuver may be key terrain. Tactical use of terrain often is directed at increasing the ability to apply combat power and at the same time forcing the enemy into areas which reduce his combat power. Terrain which permits this may also be key terrain. The effect of terrain on fire and maneuver, application of combat power and preservation of force integrity are considerations in selecting key terrain. A terrain feature may afford a marked advantage in one set of circumstances but little or no advantage under other conditions. The selection of key terrain varies with the level of command, the type of unit, and the mission of the unit. Further, combat service support and aviation units may have key terrain. Combat service support units need roads over which to move supplies and secure areas in which to establish facilities. Aviation units need high terrain on which to set up radars and communication facilities and large flat areas for airfields.

b. Observation and Fields of Fire. Observation and fields of fire are so closely related that they are considered together. They are not synonymous, but fields of fire are based on observation because a target must be seen to bring effective fire upon it.

(1) Observation is the area over which surveillance can be exercised either visually or through the use of surveillance devices, both optical and electronic. Observation varies with weather conditions, the time of day, vegetation, friendly and enemy smoke, and surrounding terrain. Observation generally is best from the highest terrain features. However, during times of poor visibility, positions in low areas that the enemy must pass through may provide better observation than high points from which nothing can be seen.

(2) A field of fire is: "The area a weapon or group of weapons may cover effectively with fire from a given position" (JCS Pub 1). The fires of high angle weapons such as mortars and howitzers are affected primarily by terrain conditions within the target area which may influence the terminal effect of the projectile. Fields of fire for direct fire weapons such as machine guns and automatic rifles may be affected by terrain conditions between the weapon and the target. The leader identifies those terrain features within the area of operations and those adjacent to the area of operations which afford the friendly or enemy force favorable observation and fire.

c. Concealment and Cover. Concealment and cover are protection from observation and fires.

(1) Concealment is: "The protection from observation or surveillance" (JCS Pub 1) (both air and ground). It may be provided by woods, underbrush, snowdrifts, tall grasses, cultivated vegetation, or by any other feature which denies observation. It may also be provided by weather conditions such as fog and rain, and by darkness. Concealment from ground observation does not necessarily provide concealment from air observation or from electronic or infrared detection devices. Terrain that provides concealment may or may not provide cover. The commander evaluates the concealment and cover available to both friendly and enemy forces. (See fig. 2-1.)

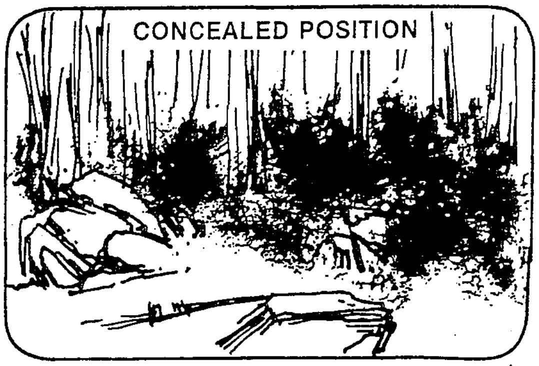


Figure 2-1. Concealment

(2) Cover is protection from the effects of fire. It may be provided by rocks, ditches, quarries, caves, river banks, folds in the ground, shell craters, buildings, walls, railroad embankments and cuts, sunken roads, and highway fills. Areas that provide cover from direct fires may or may not protect against the effects of indirect fire. Most terrain features that offer cover also afford concealment from ground observation. (See fig. 2-2.)

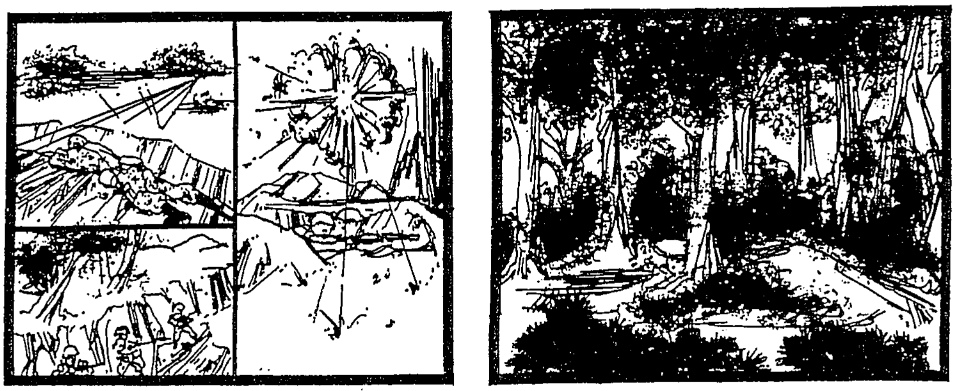


Figure 2-2. Cover

(3) Cover and concealment are used together to provide protection from observation and from the effects of fire. (See fig. 2-3.)

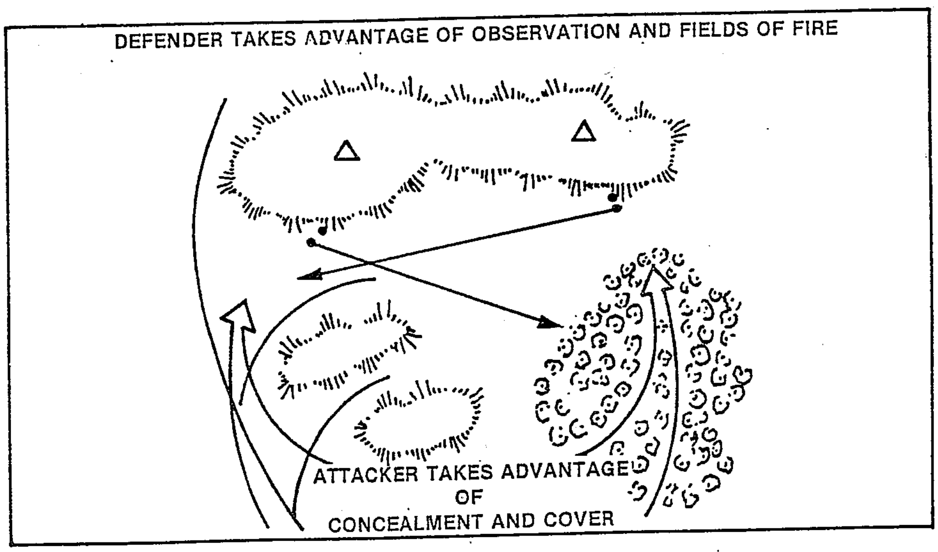


Figure 2-3. Using Cover and Concealment

d. Obstacles An obstacle is anything, including a natural or artificial terrain feature, that stops, impedes, or diverts military movement. Determination of obstacles is influenced by the mission. In defense, the commander identifies as obstacles those features that stop or impede movement within or into his sector. In the attack, he considers the features within his unit's zone of action. An obstacle may constitute an advantage or disadvantage. Obstacles perpendicular to the direction of attack favor the defender by slowing or canalizing the attacker. Obstacles parallel to the direction of attack may assist in protecting a flank of the attacking force. (See fig. 2-4.)

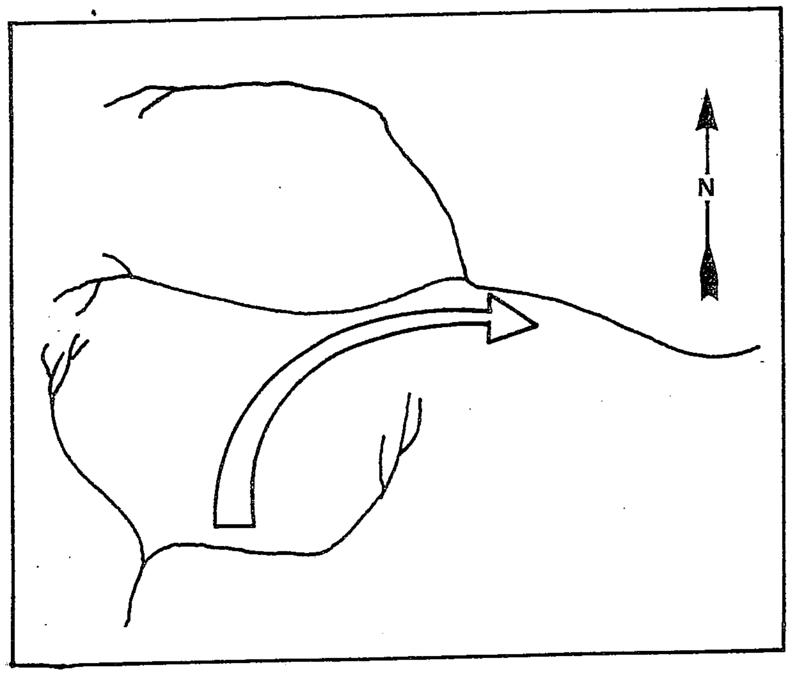


Figure 2-4. Using an Obstacle to Protect an Attacking Force

e. Avenues of Approach An avenue of approach is a route by which a force may reach its objective. Avenues of approach are considered in planning both offensive and defensive operations. All of the other factors of key terrain, observation and fire, concealment and cover, and obstacles are considered from both friendly and enemy points of view. When planning to use or defend an avenue of approach, the mission, and the type and size of the unit are also considered. Generally, commanders must consider avenues of approach that are adequate for the forces operating in the area. The intelligence data relative to each avenue is checked against possible schemes of maneuver both friendly and enemy. Adequate maneuver space is based upon deployment patterns and means of movement. Ease of movement is considered and includes such factors as soil, road, and river trafficability, steepness of slopes, terrain compartments and vegetation.

SECTION 3

COMPONENTS OF TERRAIN

"Those expert at preparing defenses consider it fundamental to rely on the strengths of such obstacles as mountains, rivers and foothills. They make it impossible for the enemy to know where to attack."

Tu Yu, 735-812

301. GENERAL

a. Section II explained the considerations (KOCOA) military leaders use in analyzing weather and terrain. This section discusses terrain features and how the various aspects of terrain (compartments, slopes, etc.) are analyzed to determine and use the considerations of KOCOA.

b. Rifled weapons give the individual soldier a weapon of such accuracy that he can hit almost anything he can see. Radios and modern guns give artillery, naval surface fire ships, and mortars the ability to hit almost anything observers can see. The soldier who exposes himself to the enemy can be hit by the enemy. Consequently, the soldier who uses terrain and weather for cover and concealment is the soldier who will accomplish his mission and survive.

302. TERRAIN FEATURES

The shape of the terrain is categorized as terrain features. There are five major terrain features (hill, ridge, valley, saddle, and depression), three minor terrain features (draw, spur/finger, and cliff), and other terrain features (cut, fill, culvert, clearing, etc.).

a. **Major Terrain Features**

(1) **Hill.** A hill is a small area of high ground. The ground slopes down in all directions from a hilltop. (See fig. 3-1.)

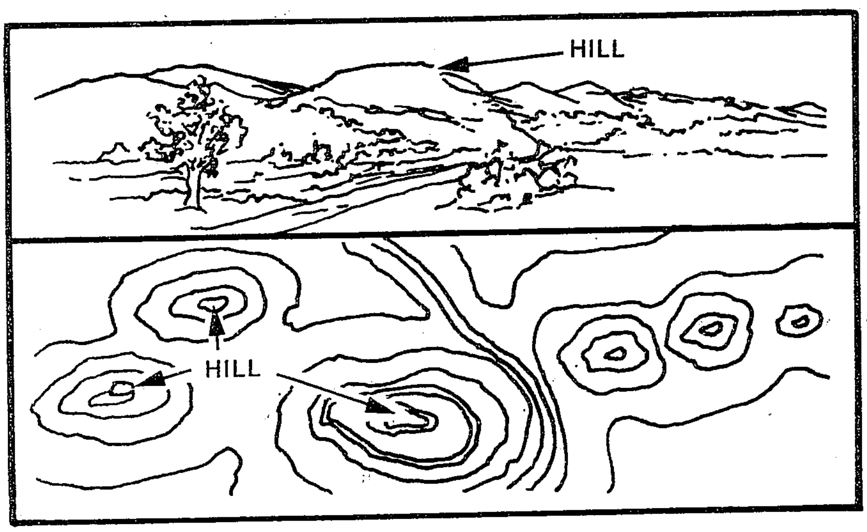


Figure 3-1. Hill

(2) **Ridge.** A ridge is a line of high ground with height variations along its crest. A ridge is not simply a line of hills; all points of the ridge crest are higher than the ground sloping down from either side of the ridge. (See fig. 3-2.)

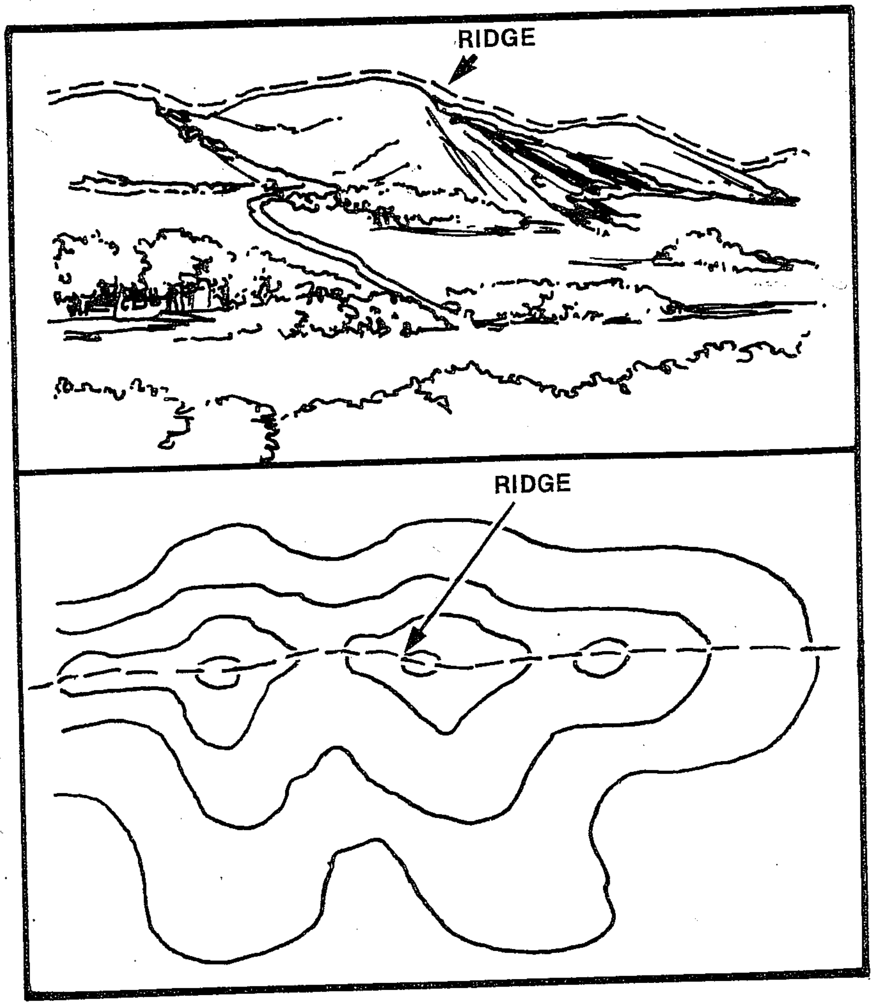


Figure 3-2. Ridge

(3) Valley. A valley is reasonably level ground bordered on the sides by higher ground. A valley may or may not contain a stream course. A valley generally has maneuver room within its confines. Contour lines indicating a valley are U-shaped and tend to parallel a stream before crossing it. The direction of the contour line crossing the stream will always point upstream. (See fig. 3-3.)

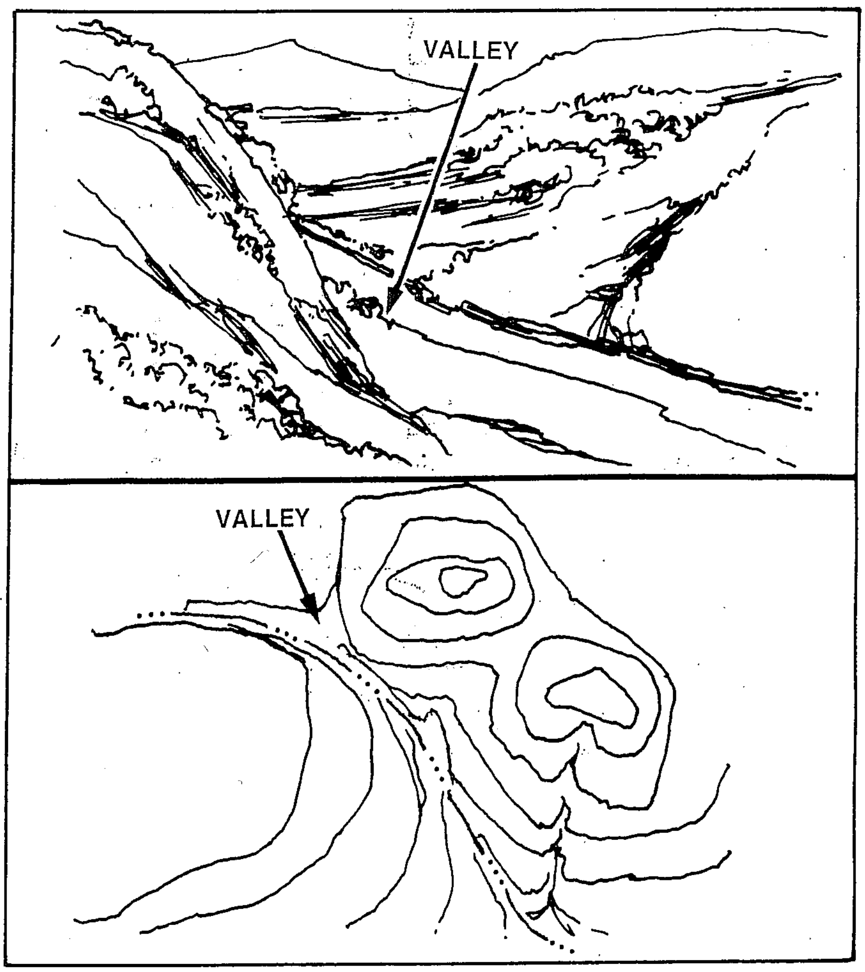


Figure 3-3. Valley

(4) **Saddle.** A saddle is a dip or low point along the crest of a ridge. A saddle is not necessarily the lower ground between two hilltops; it may be a break along an otherwise ridge crest. (See fig. 3-4.)

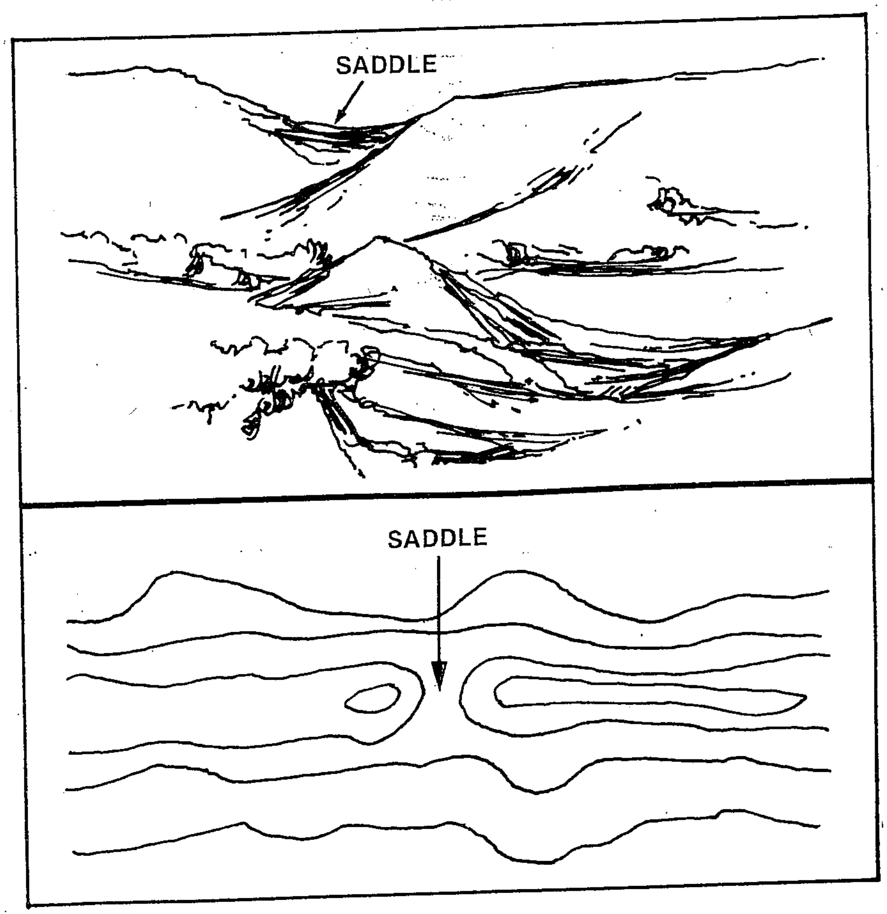


Figure 3-4. Saddle

(5) Depression. A depression is a low point or hole in the ground, surrounded on all sides by higher ground. (See fig. 3-5.)

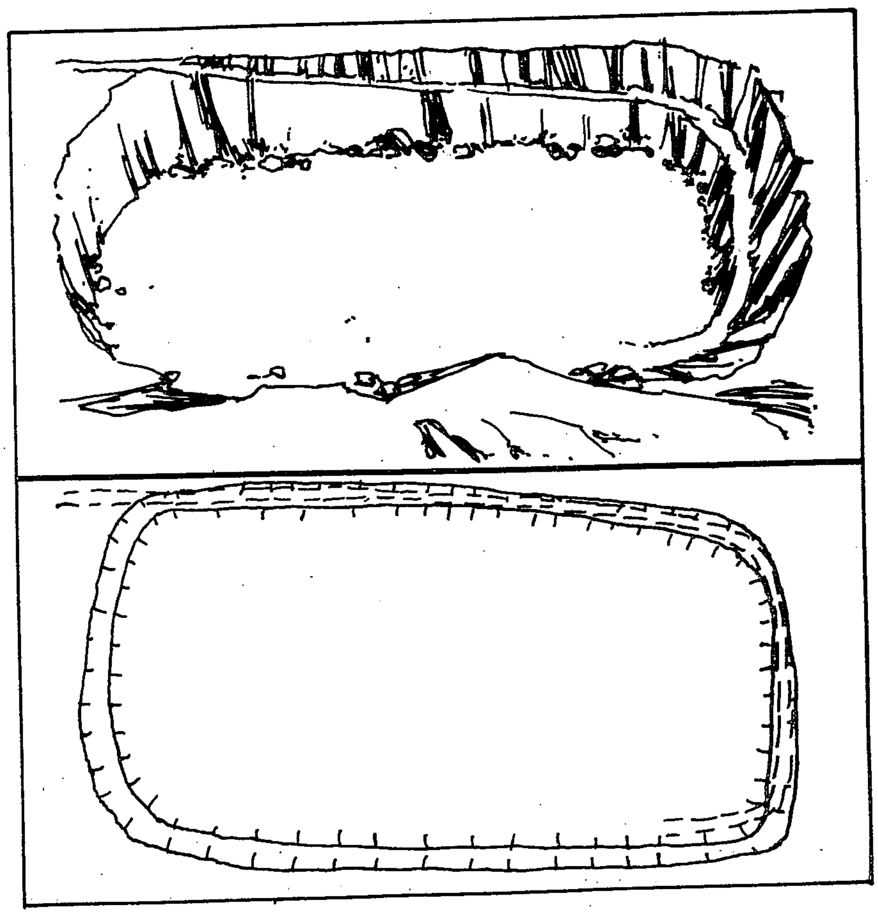


Figure 3-5. Depression

b. **Minor Terrain Features**

(1) **Draw.** A draw is an angular two sided slope in a hillside or ridge in which there is a little developed or former stream course, and in which the sides become smaller and sharper towards the head of the draw. There is generally no level ground and, therefore, little or no maneuver room. Draws caused by flash floods can be found on flat terrain, but normally they are associated with the sides of hills and ridges. Contour lines indicating a draw are V-shaped, with the point of the V towards the head of the draw. (See fig. 3-6.)

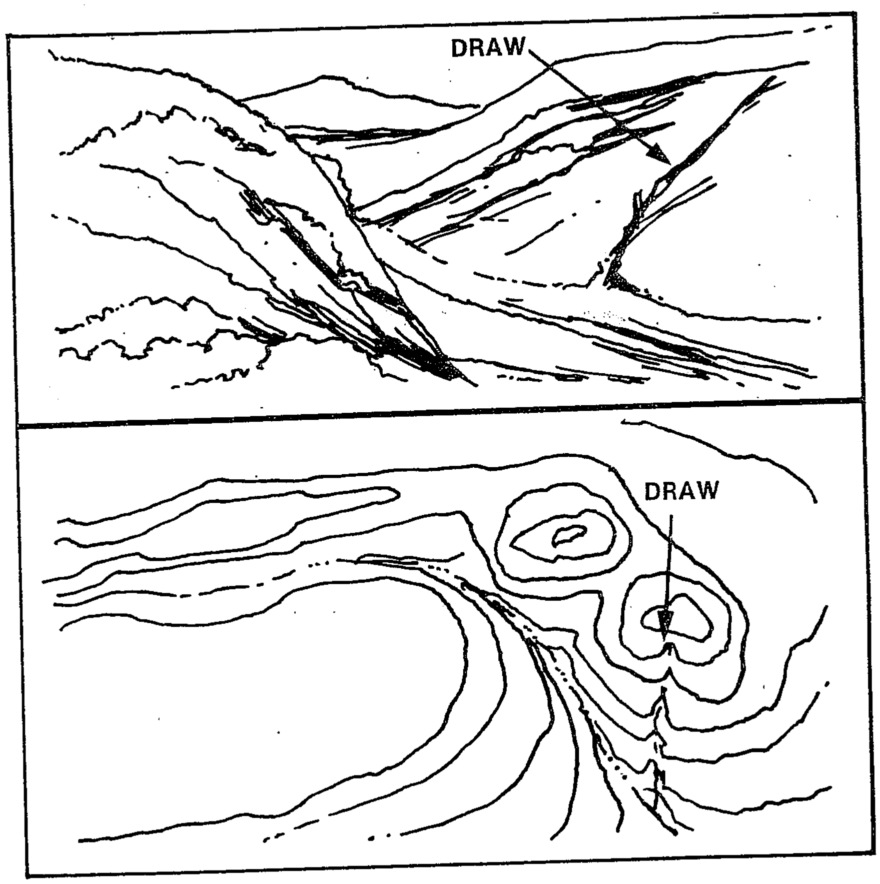


Figure 3-6. Draw

(2) **Spur/Finger.** A spur, or finger, is a short, continuously sloping line of higher ground, normally jutting out from the side of a ridge. A spur is often formed by two roughly parallel streams cutting draws down the side of a ridge. Two or more spurs can combine to create a draw. (See fig. 3-7.)

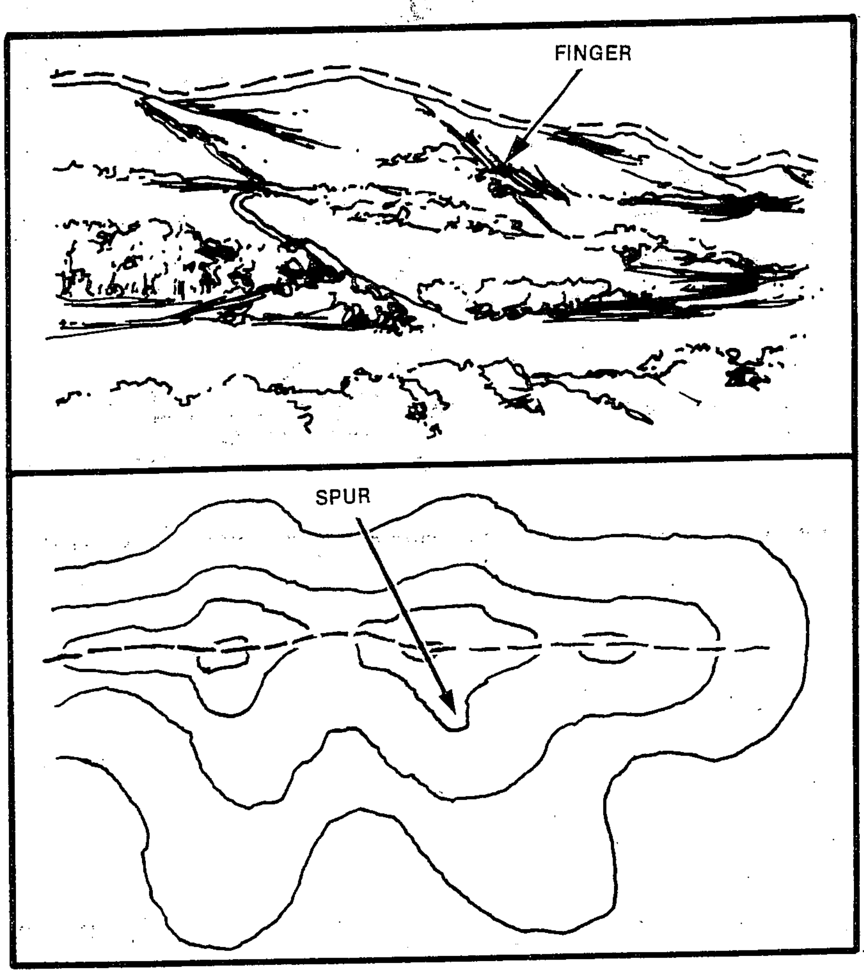


Figure 3-7. Spur/Finger.

(3) **Cliff.** A cliff is a vertical or near vertical slope. A cliff may be shown on a map by contour lines which are very close together, touching, or by a ticked "carrying" contour line. The ticks always point towards the lower ground. (See fig. 3-8.)

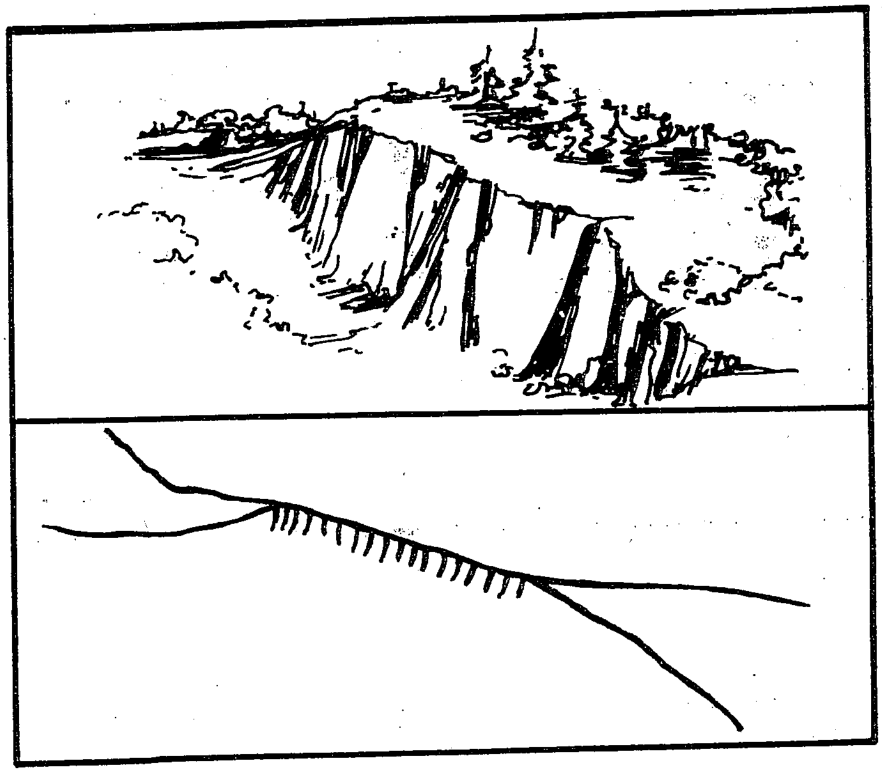


Figure 3-8. Cliff

(4) Other Terrain Features. Additional terrain features other than the major and minor ones listed above are illustrated in figure 3-9. There are many others that are peculiar to specific geologic areas of the world.

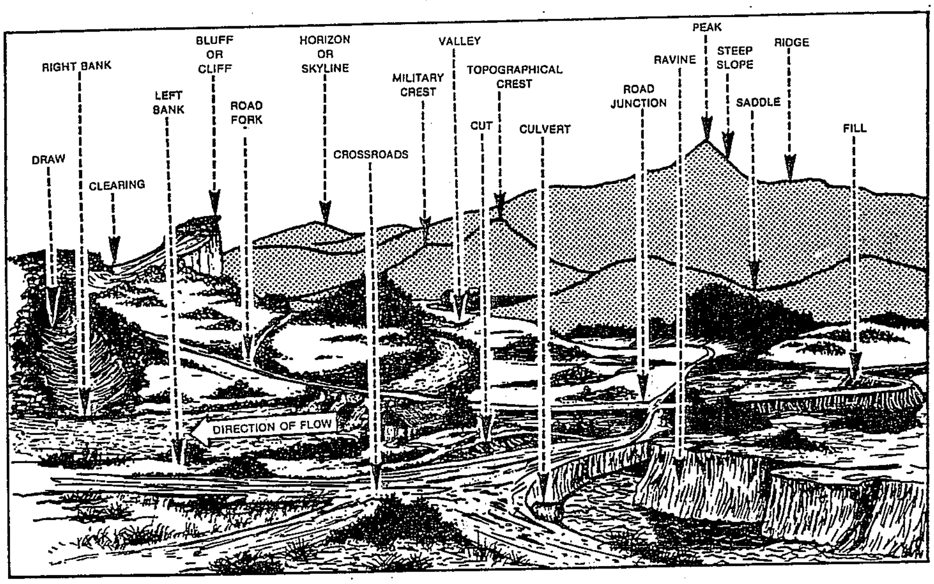


Figure 3-9. Other Terrain Features

303. TERRAIN COMPARTMENTS

a. Terrain compartments are areas enclosed on at least two opposite sides by features that restrict or prevent ground observation or flat trajectory fire into the area. Compartments may, however, have more than two sides and may be of any size or shape.

(1) Limiting Features. These are features that limit or prevent ground observation, such as trees, hills, ridges, etc.

(2) Delimiting Lines. Imaginary lines drawn along limiting features, from which ground observation into the compartment is limited.

b. To facilitate terrain analysis, compartments are divided into three types.

(1) **Compartments Formed by Relief and Drainage.** In compartments formed by relief and drainage, the delimiting lines are generally behind the military crest. (See fig. 3-10.) (The military crest is a fixed line on the forward slope of a hill or ridge from which maximum observation and flat trajectory fire covering the slope down to the base of the hill or ridge can be obtained. It is not always at the highest point of elevation. See paragraph 306b for additional information on the military crest.)

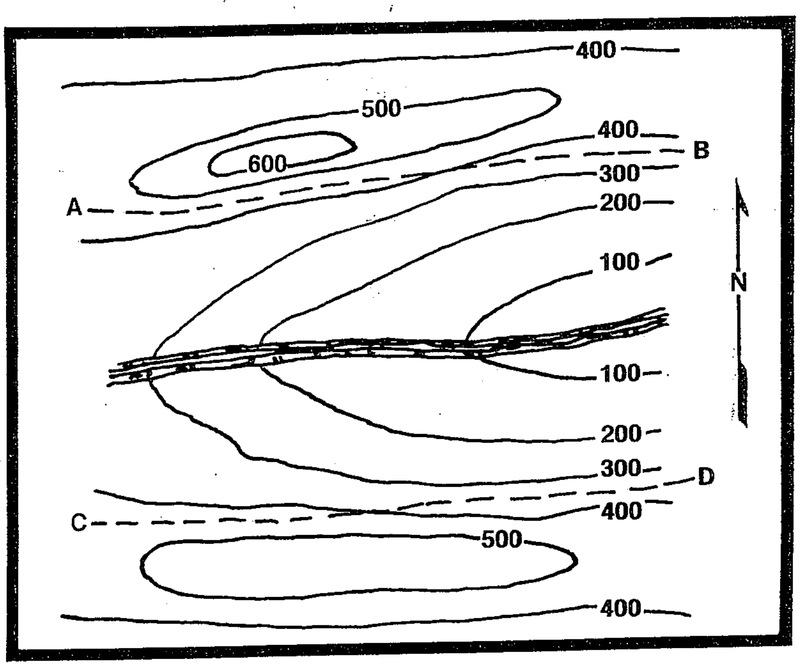


Figure 3-10. Terrain Compartment Formed by Relief and Drainage

(2) **Compartments Formed by Vegetation or Cultural Features.** With this type of compartment, delimiting lines run within the edge of the woods or village. The depth at which the delimiting features run depends on the the density of the vegetation or cultural feature and their proximity to each other. (See fig. 3-11.)

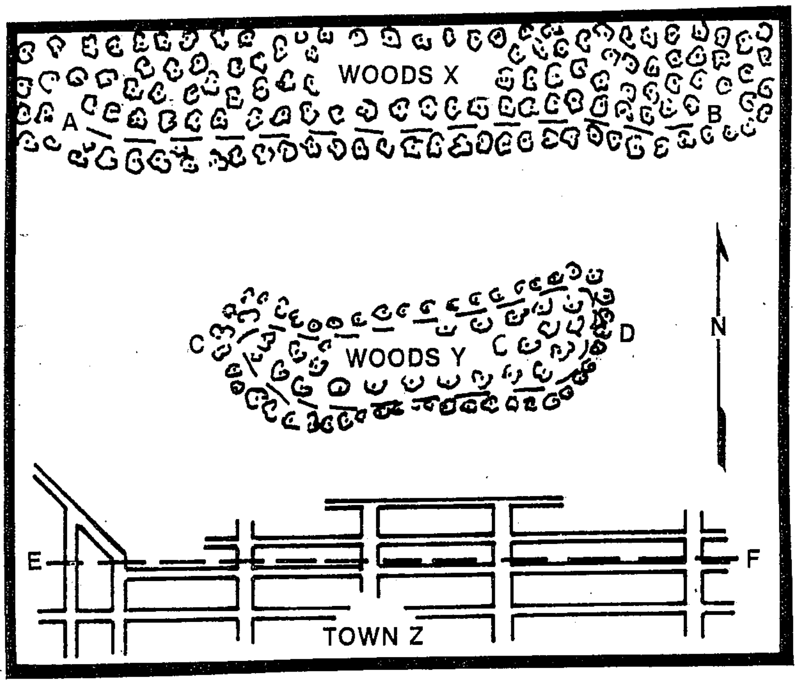


Figure 3-11. Compartment Formed by Woods and Town

(3) **Compartments Formed by Combinations of Relief, Drainage, Vegetation, and Cultural Features.** The third type of compartment is one formed by relief and/or drainage and by vegetation and/or cultural features.

c. Complex Terrain Compartment. A complex compartment is a compartment having a smaller compartment, or compartments, within it. This is the type of compartment most often encountered. Figures 3-12 shows a complex compartment.

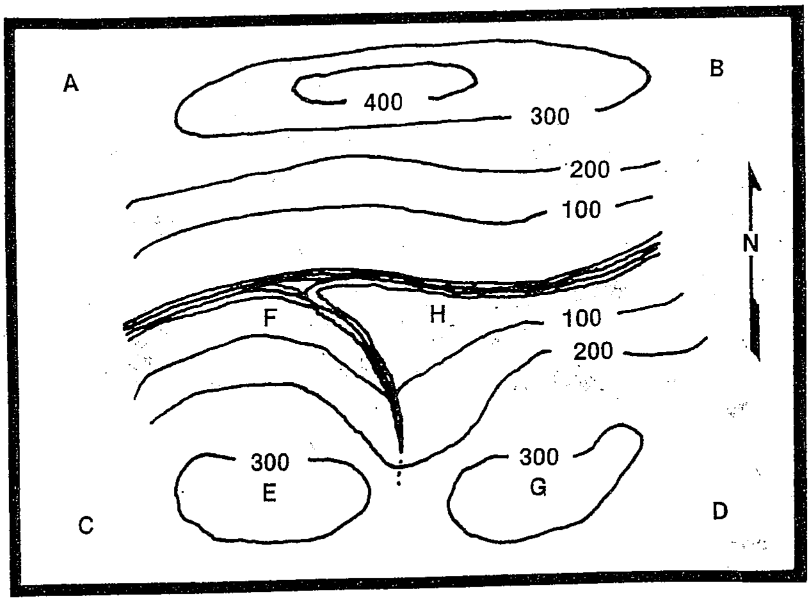


Figure 3-12. Complex Terrain Compartment

d. Corridor and Cross Compartment. A compartment whose long axis is parallel to the direction of advance of a unit is termed a corridor. A compartment whose axis is perpendicular or oblique to the direction of advance is called a cross compartment. In figure 3-10, if a unit were advancing north or south, it would be moving over a cross compartment. If the unit were advancing from the east or west, it would be moving through a corridor. In figure 3-11, a unit advancing north would be moving over cross compartments. In figure 3-12, a unit advancing north between **E** and **G** to Hill 400 would be advancing through a corridor until it reached the river. Then it would be advancing over a cross compartment. Note that there is no physical change in the compartments. Corridor and cross compartment are terms by which we describe the position of the long axis of a compartment in relation to our direction of movement.

304. IMPORTANCE OF HIGH GROUND

a. The high ground is important for many reasons. Some of these are:

(1) **Observation.** One can usually see further from a hilltop than from a valley floor. The placement of observation posts on high ground allows for better observation than would otherwise be possible and, thus, more effective employment of the supporting arms. (See figs. 3-13 and 3-14.)

Figure 3-13. View from High Ground

Figure 3-14. View from Low Ground

(2) **Direct Fire Weapons.** Direct fire weapons on high ground can usually be brought to bear on many more targets than can direct fire weapons on low ground.

(3) **Defense.** Since it is usually more difficult (whether in a vehicle or on foot) to go uphill than to go downhill, a force defending on high ground has more time to fire on the enemy before he closes than does a force defending on low ground.

(4) **Communication.** Very high frequency (VHF) radio emissions go in straight lines; i.e., line of sight. Thus, elements which communicate with VHF radios usually can communicate farther from positions on high ground than from positions on low ground.

305. INFLUENCE OF THE SHAPE OF HIGH GROUND

The shape of a hill can influence the ability of a force attacking or defending the hill to mass fires.

a. **Concave Surface.** If the hill's surface is concave (see fig. 3-15) a force defending the hill can mass the fires of its direct fire weapons on any point it can see.

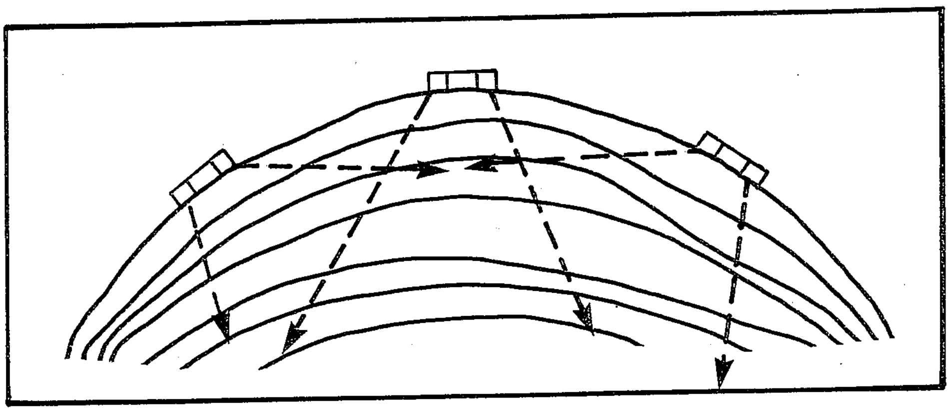


Figure 3-15. Concave High Ground

b. **Convex Surface.** If the hill's surface is convex (see fig. 3-16) the defending force will have difficulty massing the fires of its direct fire weapons. A finger is an extreme example of a convex surface. It is relatively easy to mass the fires of direct fire weapons to support the attack on a finger. However, once the finger has been seized, it is also easy for the defender to mass his fires to stop an advance up the finger.

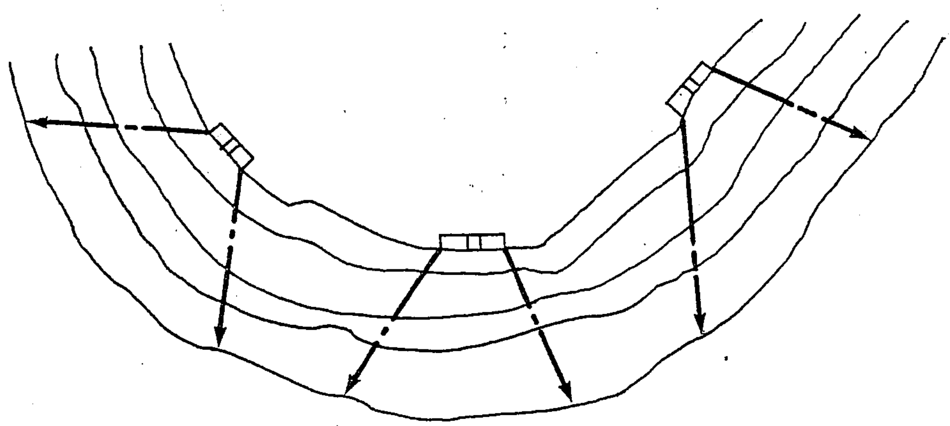


Figure 3-16. Convex High Ground

306. SLOPE AND MILITARY CREST

a. Slope. Slope is the inclined surface of a hill, mountain, ridge, or any other part of the earth's surface. It is the inclination, not only of macro-relief features, such as hills and mountains revealed on topographic maps, but also micro-relief features such as small gullies, mounds, low escarpments, small pinnacles and sink holes. Although some of the micro-relief features might appropriately be considered as a roughness factor rather than slope, they are included in the general factor of slope because their obstacle value is due to the steepness of their slopes. (See fig. 3-17.)

(1) Slope is related to soil strength. Greater soil strength, however, may reduce climbing ability due to reduced traction. On steeper slopes there is but little gain in climbing capability even if soil strength is substantially increased. Most military vehicles are able to climb slopes of at least 60 percent. This limit, however, is too high for vehicles to negotiate in military operations. 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 percentages can be increased slightly. Short vertical or near vertical slopes, such as those associated with rock ledges, streams, and gullies, may be deterrents or obstacles on terrain with a general slope much below 40 to 45 percent. Vertical heights above 1.5 meters (4 feet) are generally considered to be the maximum for tanks and .3 meters (1 foot) the maximum for trucks. Infantry can, of course, move over ground that is too steep and rough for either tanks or trucks. However, slopes of 60 percent are about the steepest that troops can climb by walking straight up the slope. Above this limit they will normally have to zigzag. Above 100 percent, the going is very difficult, although not impossible.

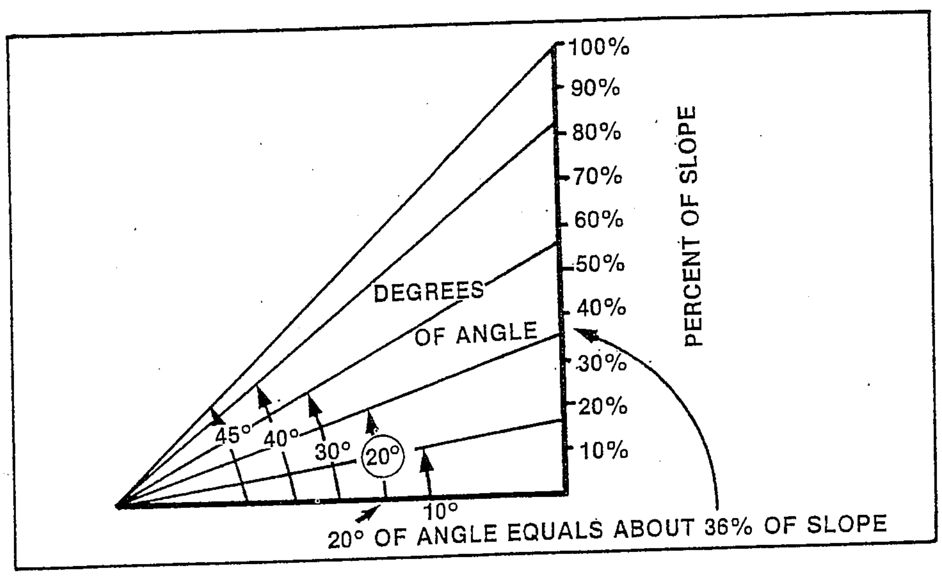


Figure 3-17. Slope Grade

(2) The relative direction at which a slope is negotiated must also be considered. The angle of movement of the vehicle with respect to the strike of the slope dictates the magnitude of the forces applied by the vehicle to the soil surface. For example, the downslope track or wheel has a greater load than the upslope and, as a result, deeper rutting occurs on the downslope side. This increases the effective slope.

(3) The most reliable information about slopes, particularly short steep ones, is obtained by reconnaissance. In conducting reconnaissance, an instrument, such as an M-2 compass, for measuring slope should always be used because slopes tend to appear much steeper than they actually are. At best, slope can be determined only on a small portion of the area by this procedure. Therefore, heavy reliance must be placed on other sources, such as topographic maps and aerial photographs.

(4) Topographic maps are important sources of information on slope and land form. The percent of slope can be determined by dividing the contour intervals by the horizontal distance between the contour lines and multiplying by 100. Devices have been developed for quickly determining slope by measurement of the distance between contour lines. When determining slope based only on contour lines, much micro-relief, or roughness, may be hidden between the contour lines. If the contour interval is 20 meters, for example, a hill or depression 15 meters below or above the general land surface will not be shown. The larger the interval between contour lines and the smaller the scale of the map, the greater the amount of micro-relief that may be hidden. Conversely, the smaller the contour intervals and the larger the scale of the map, the less micro-relief will be hidden; but even on topographic maps at the large scale of 1 :25,000 and a contour interval of 10 feet, there is always the possibility that some micro-relief may not be revealed. Therefore, maps must be interpreted with caution and supplemented, if possible, by other information, such as geologic, geographic, and soil reports, and current aerial photographs. Many of these contain land form descriptions that reveal terrain characteristics and also help in interpreting topographic maps. Soil maps contain information on slope and serve as useful supplements to topographic maps.

(5) Sometimes aerial photographs are the best source of information for interpreting slope. From them, it may be possible to obtain information not only on macro-relief but also on important

micro-relief features. For example, small gullies, which can drastically slow movement, are not shown on topographic maps, but usually appear plainly on aerial photographs. Stereo pairs and a stereoscope are needed for making slope interpretations. For good results the photos themselves should be of high quality and reasonably large scale, 1 :20,000 or larger. Slope interpretations must be done carefully; there is a danger of interpreting slopes to be steeper than they are because of inherent exaggeration in stereovision. Aerial photographs usually do not correctly reveal all relevant micro-relief features.

b. **Military Crest.** The **military crest** is the highest point on a hill or ridge from which good observation down the side of the hill can be obtained. This may be different from the **topographic crest,** which is the highest point on a hill or ridge. Figure 3-18 shows the military crest. It is point B. From this point it is possible to see down the side of the hill. Point A is the topographic crest. It is not possible to see down the hillside from that point. Some hills or ridges do not have military crests. These hills or ridges have curved sides which get steeper as they get further from the topographic crest. This is illustrated in figure 3-19.

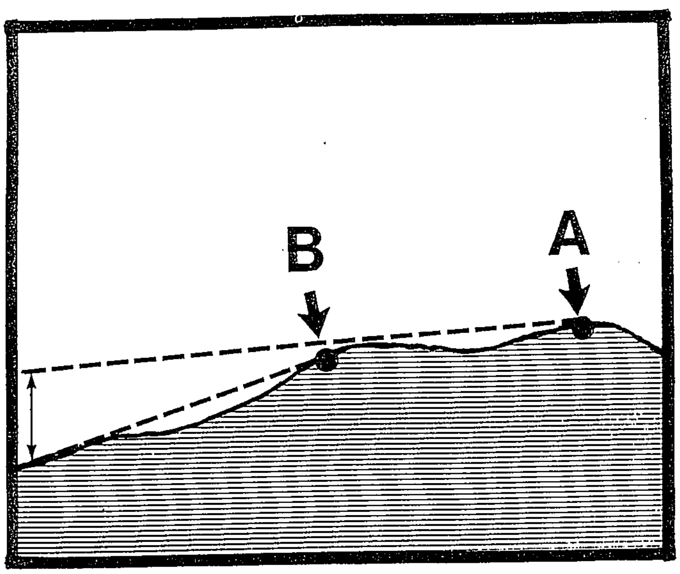


Figure 3-18. Military Crest

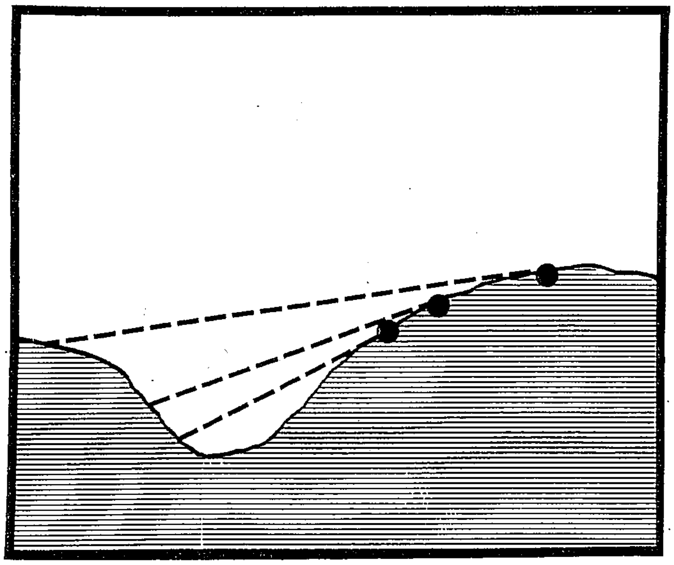


Figure 3-19. Hill Without a Military Crest

307. SURFACE MATERIALS

Surface materials determine the trafficability and the drainage of an area and they influence field fortifications and radio communications.

a. Trafficability. Trafficability is: "capability of terrain to bear traffic. It refers to the extent to which the terrain will permit continued movement of any and/or all types of traffic" (JCS Pub 1). In general, all soils, except very loose sand, afford good trafficability when dry. Unfortunately, soils are seldom dry, and water can quickly change a hard baked clay to very sticky mud. It is therefore important to be able to recognize and avoid poor soils when they are wet and near saturation.

(1) Soils that will support vehicular traffic in nearly all conditions are those that are granular, permeable, well drained, and non-cohesive.

(2) Soils that are completely non-trafficable when wet are those that are very fine grained, impermeable, poorly drained, and co-hesive

(3) Trafficability Factors. The following factors affect trafficability:

(a) **Shear Strength.** Soil trafficability is the ability of the soil to permit the movement of vehicles and personnel. The principal soil characteristic affecting trafficability is its shear strength. Shear strength is a function of the soil's moisture content, grain size, grain shape, mineral composition, organic content, plasticity and density. The principal factor affecting the shear strength of a soil is its moisture content. Most soils in a comparatively dry state are trafficable to all military vehicles. However, at a higher moisture content, a soil's strength, and consequently its trafficability, may be such that only certain vehicles can pass. Shear strength is evaluated through use of the cone penetrometer, as described in FM 5-530.

(b) **Bearing and Traction Capacity.** Bearing and traction capacities of soil are primarily functions of the shear strength. The trafficability is considered adequate for a given vehicle if the soil has sufficient bearing capacity to enable it to develop the forward thrust necessary to overcome its rolling resistance. When the rolling resistance is equal to or greater than the forward thrust, the vehicle becomes immobilized; e.g., spins its wheels and sinks.

(c) **Slipperiness and Cohesiveness** Slipperiness is a condition of deficient traction capacity in a thin layer of a soil that is otherwise trafficable. A vehicle immobilized solely because of slipperiness spins its wheels or tracks but neither moves forward nor sinks excessively. Cohesiveness is a condition that causes soil to cling to and build up on the wheels or tracks of vehicles. When this happens, the rolling resistance of the vehicle is increased and steering becomes difficult. In extreme cases, cohesiveness causes enough rolling resistance to "freeze" the running gear of the vehicle.

b. **Soil Types.** Soil types can be closely determined by the study of drainage, slope, tones on aerial photographs, and vegetation. Granular soils drain the water off very quickly, forming short, stubby, steep-sided gullies, and steep prevailing ground slopes. The soil dries out quickly and is generally light in photographic tone. Cohesive, impermeable soils do not readily allow the water to filter through, but force it to drain away as runoff. Its cohesiveness holds it together forming gentle slopes and smooth gully cross sections. Water that is absorbed by the soil is not easily released, and the soil stays wet and impassable for long periods of time, photographing dark. Intermediate grades of soil vary between these two extremes in both trafficability and characteristics. Figure 3-20 summarizes the terrain characteristics of various types of soil. Also, see Appendixes C and D.

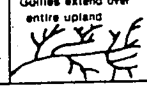
SOILS			RECOGNITION			
TYPE	PROPERTIES	TRAFFICABILITY	AIR PHOTO SOIL TONE	DRAINAGE DEVELOPMENT	SLOPE	VEGETATION
Sand or well-graded mixtures	Noncohesive Permeable Granular Good internal drainage	Usually good	Very light (uniform)	Gullies and drainage practically undeveloped ——— Gullies short and stubby 	Prevailing ground slopes steep	Grass or jack pines in sand Agriculture in mixtures
Sandy clay mixtures Silts	Moderately cohesive Partially impermeable Low plasticity Fair internal drainage	Good when dry Poor during and for a short while after wetting	Generally light to grey (nonuniform)	Moderate development of drainage net and gullies ——— Gullies extend short way into upland 	Slopes highly variable	Rich agriculture Varying dense vegetation and cleared areas
Clays or silty clays	Cohesive Impermeable Plastic No internal drainage Retains water	Good only when dry Poor when slightly wet or damp	Dark (spotty)	Drainage net covers entire area ——— Gullies extend over entire upland 	Soft prevailing ground slopes	Sparse forests Pastures

Figure 3-20. Characteristics of Various Types of Soil

c. Soil. Soil is the loose material which forms the upper layer of the mantle rock. In relative order of size it is classified as of clay, silt, sand, gravel, or cobbles, with clay being the smallest and cobbles the biggest.

d. Components of Soil. There are two components of soil: sediment and organic matter. Sediment is an aggregate of unconsolidated particles of mineral or rock which has been transported and deposited by water, wind, ice, or the action of gravity. It is classified according to diameter. Organic matter is material of dead plants and animals.

308. SNOW

a. Snow is considered along with soil because it substitutes partly or entirely for the soil and because its trafficability behavior is similar to that of soils. Its strength can be measured with the cone penetrometer and its trafficability can be determined. Most snow behaves more like fine-grained soils than coarse grained.

b. Snow is seldom a critical obstacle for tracked vehicles although it frequently may be a hindrance due to its slipperiness, especially on slopes. However, in spring and fall it may cover saturated ground and conceal potentially dangerous mud or water traps. On level or gently sloping terrain, tracked vehicles, such as tanks, can function reasonably well in snow as deep as 0.9 meter (3 feet) and perhaps even a little deeper. Although there are many places where snow accumulates to depths greater than 0.9 meter, such places are commonly forested or mountainous or both and, hence, generally unsuited for movement for reasons other than deep snow.

c. Snow is considerably more of a hindrance and hazard to wheeled vehicles. Light snow just covering the ground may create slipperiness that makes movement of wheeled vehicles difficult, although their capability can be enhanced by tire chains and by reduction of tire pressures. If the depth of snow exceeds 20 to 25 cm (8 to 10 inches), most wheeled vehicles are likely to become immobilized unless the snow is quite dense and hard, and again, depending on the use of high flotation, low pressure tires which enhance the capability of wheeled vehicles on snow just as on sand.

309. WATER BODIES (Rivers and lakes)

a. Water bodies vary in their characteristics from time to time depending on weather and climate. Although streams are relatively low and slow during periods of low precipitation and high and rapid during periods of high precipitation, the relationship is not always this simple. Melting snow, for example, may cause high water downstream even in regions where rainfall is low. Continuous below freezing weather can reduce stream flow even though precipitation may be high. Low temperatures may cause water to freeze over and form ice strong enough to carry vehicles. Then, instead of being obstacles, water bodies may become good avenues for movement. Foot troops in single file at a 2-pace interval may move on ice 7.6 cm (3 inches) thick, and lightly loaded 2 1/2-ton trucks may move on ice .3 meters (10 inches) thick. However, movement on ice is risky because of weak places such as those caused by thaws or water issuing from springs. In deserts, stream channels such as wadis also may become preferred avenues for movement during periods of little or no flow, although there may be quicksand or other soft places where vehicles can bog down, and there is the danger of flash floods.

b. The ease of crossing streams is stated in terms of fordability. This depends on the characteristics of both the vehicles and the stream. 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 and fording, even of the smallest streams, requires selection of sites where favorable conditions coincide. Streams are no hindrance where fords (places shallow enough to be crossed) are available and usable with little or no improvement. Streams are a hindrance if suitable fords are lacking, or if fording requires considerable preparation of approaches, reinforcement of bottoms, or the use of special equipment on vehicles. A tank can bridge stream channels less than 3 meters (9 feet), however wheeled vehicles do not have this capability. Once the selfbridging capability of vehicles is exceeded, streams can be crossed only by bridging, ferrying, or fording. The width of a stream, although important to bridging, is of relatively little significance to ferrying and fording except that usually the wider the stream the greater the hazard involved. For fording, the maximum depth of water permissible for most tanks is about 0.9 meters (3 feet) and for trucks, about 0.6 to 0.9 meter (2 to 3 feet). Vehicles can be equipped with devices so they can cross water bodies considerably deeper than 1.3 meters (4 feet), but usually they are not so equipped.

c. Stream velocities should be less than 1.5 meters (5 feet) per second for reasonably safe fording. The bottom of stream channels must be firm enough to support the vehicles. Bottoms made up of fine-grained material can prevent fording even though the water may be only a few centimeters deep. Suitable bottoms are restricted to those that are sandy, gravelly, or rock, but even sandy bottoms may give way to the weight of vehicles, or boulders may prevent vehicular movement. The banks also are important. Hard, vertical banks will be obstacles to tanks if their height exceeds 1.3 meters (4 feet), and to trucks if their height exceeds about 0.3 meter (1 foot). Greater heights can be tolerated if the bank slopes are less than 45 percent and provided the vehicles can get adequate traction. The strength of the material composing the banks may be significant. Banks made up of fine-grained soils may give way under the weight of vehicles. Sandy and gravelly materials are likely to provide adequate strength, although exceptions can occur.

d. Reasonably adequate information is commonly available on large streams, but not for the small ones. Every stream is a potential obstacle and, as there are many more miles of small streams than of large, the problem of obtaining information pertains mainly to small streams, ditches, and canals. Reconnaissance is the best source of information, and for many areas it is the only reliable source. However, topographic maps and geographic maps and reports, along with aerial photos, are often the best sources of information generally available. In addition, useful data can be found in publications on geology, agriculture, soils, and forestry.

310. VEGETATION

a. Vegetation includes not only the so called natural vegetation but also crops grown by farmers. The primary concern in cross country movement is with forest vegetation; trees are the principal obstacles to movement. Although grass and brush also have some effect, they are of relatively low significance. Nearly all forests have a slowing effect on movement. The problem is not whether forests will slow movement but whether they will slow movement slightly, drastically, or make it altogether impracticable. Furthermore, whatever the size of the forces originally committed, combat in forests eventually becomes a series of small unit actions.

b. 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 aerial photography. Maps and reports that are likely to be of most value are those dealing with vegetation, particularly forests. However, useful information may also be found in other publications. Among these are agricultural reports and reports on soils, geology, and geography. Foresters, botanists and ecologists are best prepared to interpret the probable spacing and the size of trees. Since forests may be, and frequently are, altered by thinning or cutting, or by burning, information must be recent if it is to be highly reliable.

c. Brush or tall grass may impair visibility for drivers of tanks and trucks and may obscure obstacles such as stumps and boulders. Brush that hinders or stops trucks 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. Low growing vegetation less than 1 meter (3 feet) tall has no significant effect on movement except where it obscures obstacles or where there is a grass sod. The surface of sod 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. Most military vehicles are so heavy that they simple cut through it.

d. Vegetation must be exploited. Figure 3-21 shows an infantryman who is failing to use the vegetation for concealment. Figure 3-22 shows an infantry man who is using the vegetation for concealment. While figures 3-21 and 3-22 show infantry, every element of a force must use vegetation to its full advantage.

Figure 3-21. Infantryman in Open

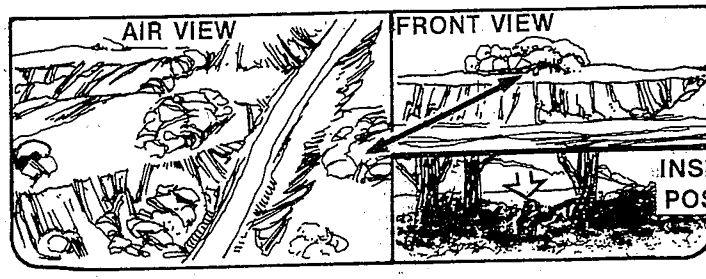


Figure 3-22. Infantry Using Vegetation for Concealment

311. CULTURAL FEATURES

a. Cultural features are the works of man, such as stone walls, hedge rows, roads, dikes, canals, cuts, fills, built up areas, etc. Cultural features are treated as a separate factor to insure that they are not overlooked in evaluating terrain for cross country movement.

b. Many cultural features act as deterents or obstacles to movement. A stone wall may be a serious obstacle unless the sheer weight of a vehicle pushes it over. Therefore, the height and thickness of such walls, as well as the slopes on either side, determine their value as obstacles. Embankments more than 3 meters (10 feet) high with side slopes greater than 45 percent are likely to be serious obstacles; cuts have similar significance. The critical values cited above for streams also apply to ditches and canals, but, in addition, embankments of various heights may occur alongside these features and increase their obstacle value. Large gravel pits or areas where strip mining has taken place may present obstacles or traps for vehicles. These too must be evaluated, particularly on their slope and soil characteristics.

c. Roads. Roads differ in many respects. They are constructed of all types of materials: dirt, logs, concrete, macadam, and others. Some are single lane while others have two, three, and four lanes. Some are not affected by weather but others will turn to mud and become impassable during some seasons of the year. Some can be used by any type of vehicle, yet others will be destroyed if used by heavy or tracked vehicles. Roads are important to military operations because they facilitate communications and the movement of units and supplies. In close terrain such as forests, swamps, hills, and mountains, roads can be even more important than in other, more open types of terrain. Without roads it is very difficult in close terrain to support forces operating away from roads with motor vehicles. Further, since vehicles must stick to these roads, surprise becomes more difficult because advancing forces must normally move along roads. This type of terrain also enables opposing forces to more easily channel movement, create obstacles, and conduct ambushes.

d. Information on cultural features that may be relevant to cross country movement is frequently difficult to obtain unless reconnaissance can be conducted. Some of the features can be interpreted from airphotos and some may be shown on topographic maps, but dimensions, which are very 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 culture features.

312. DRAINAGE PATTERNS

Drainage is the removal of water from the earth's surface either by its flowing off in streams and rivers or by its sinking into the earth. The shape of the land itself can cause or allow the water to drain off. The composition of the soil can also determine the amount of drainage. As a rule, soil formed from sand and unconsolidated particles lets the water sink in rapidly. Soil which is composed largely of clay provides poor drainage. Drainage is important because in poorly drained areas fighting holes and bunkers can fill with water forcing soldiers from their fighting positions, ruining supplies, causing bunkers to collapse, and roads to become impassable. Drainage patterns can be observed and analyzed by using aerial photographs. There are six types of drainage patterns: dendritic, trellis, rectangular, radial, annular, and parallel, each revealing something of the character of the land. See Appendix C. Relief is the term given to alternate areas of elevation and depression on the earth's surface. Drainage consists of the areas of depression of relief which serve as water runoffs or collection points such as streams, rivers, ponds, and lakes. The higher portions of relief form a network, a study of which will indicate the general shape of the ground. Drainage forms a similar system which interlocks with, or complements, the relief network. These two systems are normally studied together. Irregularities in the ground caused by drainage can influence tactics by the degree of observation afforded the forces, ease or difficulty of movement, and the degree of protection afforded from enemy fires.

SECTION 4

COMPONENTS OF WEATHER

"Some soldier once said, 'The weather is always neutral.' Nothing could be more untrue. Bad weather is obviously the enemy of the side that seeks to launch projects requiring good weather, or of the side possessing great assets, such as strong air forces, which depend upon good weather for effective operations."

Eisenhower, Crusade in Europe

401. GENERAL

a. Weather, climate, and season are defined in paragraph 105. The elements of weather which affect military operations are:

- **Air Temperature**
- **Atmospheric Pressure**
- **Winds**
- **Humidity**
- **Clouds and Fog**
- **Precipitation**
- **Fronts**

These elements and their effects on military operations are discussed in the following paragraphs.

b. Light is important because it affects observation. Therefore, although not part of weather, two factors which affect the amount of light from just before night until just after night (twilight and moonlight) are discussed in paragraphs 409 and 410.

402. AIR TEMPERATURE

a. Air temperature is the degree of hotness or coldness of freely circulating air as measured by a thermometer that is shielded from the sun. The freezing and boiling point of pure water is used as a standard reference. The United States utilizes the Fahrenheit scale with the freezing point of water being plus 32° and the boiling point being plus 212°. Countries using the metric system employ the Celsius scale with freezing point of water being 0° celsius and the boiling point 100° celsius. The temperature conversion scale for Fahrenheit to Celsius and vice versa is as follows:

$$C = 5/9\,(F - 32)$$

$$F = 9/5\,C + 32$$

b. Air temperature has a significant influence on military operations. This influence is apt to be overlooked in the planning phases when the area of operations is remote from where the planning is being done. Coupled with the effects of humidity, the temperature dictates type of clothing and survival equipment, vehicle and aircraft operating procedures, caloric and water consumption and rate of march. Operations in either extreme hot or cold requires special preparation, training, and conditioning.

(1) Cold Weather Operations. Cold weather requires special clothing, generally increases caloric intake, and requires special considerations for weapons and equipment. Logistic support is often made more difficult, especially where snow is a factor. Operations in cold weather are described in FM 31-70, Basic Cold Weather Manual; FM 31-71, Northern Operations; FMFM 7-29, Mountain Operations; and FMFMs and FMFRPs in the 7-20 series (see Appendix A).

(2) Hot Weather Operations. Hot temperatures result in an increase in water consumption, overheating in vehicles and electronics equipment, a decrease in rates of march and aircraft lift capability, and the need for special clothing. Operations in hot weather are described in FMFM 7-27, Desert Operations, and FMFM 7-28, Jungle Operations.

403. ATMOSPHERIC PRESSURE

a. **Definition.** Atmospheric pressure is the force exerted per unit area by the weight of the atmosphere from the level of measurement to the top of the atmosphere.

b. **Measurement.** The standard device for measuring atmospheric pressure is a mercurial barometer which balances the weight of the atmosphere with a column of mercury. The standard sea level pressure is equal to the force exerted by a 760 millimeter (29.92 inches or 1013.2 millibars) column of mercury at 32° F and at standard gravity. Barometer readings significantly below 760 millimeters usually indicate low pressure areas and those significantly above 760 millimeters indicate high pressure areas. In general, cold air, being heavier and denser than warm air, causes high barometric pressures while hot air, which is light and less dense , causes low pressures. Mean sea level is used as a reference for surface weather observations, and pressure measurements are shown on weather maps and climatic charts as if the entire surface of the earth were at sea level.

c. **Weather Indication.** Air pressure is a useful indicator of weather conditions. A sudden change in air pressure may signal an approaching storm. Air pressure below 29.92 inches is considered low and denotes poor weather, generally rain and cool temperatures. Should the pressure drop very low (around 28.8 in.), severe weather in the form of thunderstorms, tornadoes, and hurricanes can be expected. Air pressure above 29.92 in. denotes warmer temperatures and generally clear skies. Operations in high altitude aircraft, where air pressure is very low, require special equipment and pressurization. Operations at reduced air pressure and oxygen levels can also be encountered in mountains.

404. WINDS

a. Wind is air in motion and results from differences in atmospheric pressure as well as changes in temperature. A wind is described by its direction and speed. The direction of a wind is the direction from which the wind is blowing, e.g., a wind that is coming from the north is termed a north wind. Wind direction is determined in relation to true north and is reported in meteorological reports to the nearest 10°. Thus, a wind with a direction of 090° would be reported as 09.

b. Wind direction is important when considering the use of smoke, chemical agents carried by the air, airborne radiation, and cloud cover for air operations. High velocity winds can be very destructive. Personnel, vehicles, and especially aircraft are vulnerable and need protection from the effects of high velocity winds. Operations are affected by wind:

(1) Amphibious Operations

(a) May cause postponement of landing.

(b) Affect state of the sea.

(c) Affect landing craft handling.

(2) Armor/Infantry Operations

(a) Trajectory data and first round hit capability degraded by high crosswinds.

(b) Affect the rate at which troops march.

(c) Smoke disperses quickly.

(3) Artillery/Naval Gunfire Operations

(a) Affect sound/flash ranging capabilities.

(b) Affect accuracy of projectiles. (See FMFM 7-4, Field Artillery Support)

(4) Aviation Operations

(a) Affect parked aircraft and those moving about the ground.

(b) Affect landing and take off.

(c) Affect aircraft control near the ground.

(d) Affect ground speed for low level flight.

(e) Affect flight times and fuel consumption. (See FMFM 5-1, Marine Aviation.)

(5) **Communications/Electronics Operations**

(a) May damage antennas and transmission lines.

(b) May cause cable blowdown.

(c) Interfere with antenna installation. (See FMFM 3-30, Communications.)

(6) **NBC Operations**

(a) Affect NBC agent dispersion

(b) May decrease chemical agent persistence.

(c) Affect aerial delivery of NBC agents

(d) May degrade effectiveness of smoke operations. (See FMFM 11-3A, Field Behavior of NBC Agents.)

(7) **Parachute Landings**

(a) Winds are critical in safely dropping personnel and equipment.

(b) Increase personnel and equipment dispersion.

(c) Increase impact velocities.

(d) Increase drift velocities.

(e) Affect aloft selection of release points.

405. HUMIDITY

a. Humidity is the amount of water vapor in the air. Relative humidity is the amount of moisture the air actually contains compared with the amount that it could hold at a given temperature and pressure. When the air mass is holding all the moisture that it can, it is described as having a relative humidity of 100%.

b. A large amount of water vapor in the air (high humidity), increases the probability of rust and causes physical discomfort. High humidity impedes the natural cooling process of the body thereby increasing the chance of heat casualty. A small amount of moisture in the air (low humidity) promotes the creation of static electricity. In wintertime, the humidity is generally quite low and static electricity quite prevalent. Care should be taken when operating in these conditions since an arc caused by static electricity could easily ignite some fuels. Proper grounding can prevent the hazard produced by static electricity.

406. CLOUDS AND FOG

Clouds and fog reduce visibility. Air observation, flight operations, air support, and target spotting are reduced in proportion to cloud and fog conditions.

407. PRECIPITATION (Rain and Snow)

Rainfall or snowfall can reduce visibility and provide concealment for both friendly and enemy troops. Rainfall masks noise and makes stealth easier to achieve. The effects of rain and snow from a military point of view are listed below:

a. Preservation and Maintenance. Shelter for food stuffs, electronic equipment and maintenance activities must be provided. Precautions must be taken with weapons and equipment to prevent rust and corrosion.

b. Trafficability. Precipitation affects soil trafficability and, hence, cross country movement. Heavy precipitation can turn otherwise passable terrain into an impassable quagmire. In areas of seasonal precipitation, the cross country movement characteristics of an area may change drastically each season. Seasonal floods may swell or flood streams, making fording and bridging operations impossible. Snow and sleet hamper movement on roads in winter, often making them impassable in mountainous regions.

c. Visibility. Precipitation usually limits visibility but it may also wash impurities from the air and thereby subsequently enhance visibility. Since rain and snow aid concealment they may help to facilitate surprise attacks.

d. **Chemical Neutralization.** Rain and snow tend to wash away chemical and biological agents, thus reducing their effectiveness. Nuclear radiation, however, is carried along by precipitation and may be spread over a large region or concentrated in small areas or "hot spots."

e. **Communications.** Precipitation may reduce the range of field wire circuits and may produce "clutter" in radars, thereby reducing their effectiveness.

f. **Personnel.** Excessive precipitation promotes trench foot, various fungus infections, and colds. It also causes physical discomfort for the troops. These factors can hurt morale and make personnel reluctant to leave their shelters to perform their duties.

g. **Air Operations.** Precipitation has a great influence on air operations. It can prevent aircraft from taking off as well as preventing airborne aircraft from accomplishing their mission while airborne.

408. FRONTS

Masses of cold and warm air are continuously moving across the earth's surface. Where they meet is called a front, either a cold front or a warm front. These fronts cause abrupt changes in atmospheric conditions and often determine the weather.

a. **Cold Fronts.** Cold fronts occur when warm surface air is replacing a mass of cold air. On the surface, cold fronts are characterized by:

(1) An abrupt decrease in temperature.

(2) A marked wind shift, usually more than 90°.

(3) A decrease in the moisture content of the air.

(4) A marked decrease in barometric pressure as the front passes, followed by a rapid increase.

b. **Warm Fronts.** Warm fronts occur when warm air replaces cooler air. On the surface, warm fronts are characterized by:

(1) An increase in temperature.

(2) A slight wind shift, usually less than 90°.

(3) An increase in the moisture content of the air.

(4) A decrease in barometric pressure as the front approaches followed by a gradual increase after passage.

409. TWILIGHTS, MORNING AND EVENING

In determining times of attack and the length of time daylight will be available, the commander must consider twilight phases. Although not an integral part of weather, twilights are so closely related that in terrain studies they are considered under weather. Disregarding the effects of weather such as fog and haze, twilights are the periods of solar illumination prior to sunrise and after sunset. Both morning and evening twilights are divided into three periods: astronomical, nautical, and civil. These periods are defined with reference to the sun's position below the horizon: astronomical (18 degrees - 12) degrees; nautical (12 degrees - 6 degrees); and civil (6 degrees - 0 degrees).

a. Astronomical twilight affords such meager light, if any, that for military purposes it may be considered as a period of darkness.

b. Civil twilight affords sufficient light to carry on normal day activities. This period is the earliest or latest that provides sufficient natural illumination of targets to allow efficient observed artillery fire or day bombing.

c. Nautical twilight provides enough illumination to carry on most types of ground movement without difficulty, and approaches conditions expected under full light of day. Vision is usually limited to 400 meters or less. For military purposes, during the nautical periods weapons can be employed within the range of vision stated and daylight calculations relative to movement will apply, including restrictions on such movement. Bomb loading and repair work cannot be carried on without the use of artificial light, nor can tanks move buttoned up without using night-vision devices. Nautical twilight is most frequently used for military purposes and is expressed as the "beginning of morning nautical twilight" (BMNT) and as the "ending of evening nautical twilight (EENT)".

410. MOONLIGHT

Moonlight varies with the degree of the moon's fullness and the conditions of the weather. It can have a great effect on visibility at night ranging from pitch black to the near brightness of day. Thus, it can also have a great effect on night operations.

SECTION 5

CLIMATES

"I cannot command winds and weather."

Nelson: To the British Minister, Genoa,
April, 1796

501. GENERAL

Climate is the average weather conditions at a given place over an extended period, usually more than ten years. The world is divided into regions based on climate. Climatic conditions are generalizations and there can be extreme variations from these. Still, a knowledge of an area's climate is useful for planning. The small unit leader should key on such phrases as "hot and damp" because there are special tactical and logistical requirements for such conditions. Appendix G gives the average temperature and precipitation of a city in each of the climates discussed below.

502. TROPICAL CLIMATES

a. **Description.** The climate in tropical areas varies. Close to the equator all seasons are nearly alike with rains throughout the year. Further from the equator, especially in India and Southeast Asia, climates vary from wet to dry.

b. **Tropical Wet Climate.** The tropical wet climate occurs in a belt generally extending from 5° to 8° latitude. In some regions, such as the Amazon Basin and the Congo Basin, the air is always hot and damp, there are frequent torrential rains of short duration, and the winds are feeble or absent for long periods. This climatic type is also found on windward coasts, where, between latitudes of 5° and 25°, easterly trade winds blow almost constantly over hills or mountains. The cooling of these winds as they rise over the hills or mountains produces an extremely heavy rainfall. This occurs, for example, in portions of Hawaii, the Philippines, the eastern coasts of Central America, Brazil, Madagascar (Malagasy), and most of the islands in the southern Pacific Ocean. In this type of climate, the rays of the sun are nearly vertical most of the time, so that days and nights are practically equal in length throughout the year. Night temperatures usually are a few degrees lower than daytime temperatures. There are no clearly marked seasons. Relative humidity is high at all times, and cloudy weather may prevail at times. There are heavy rains on at least four or five days each week during the rainiest months, with the greatest amounts during the periods when the sun is most directly overhead. The rains are torrential, often accompanied by thunder and lightning, and flooding can occur at these times. Ordinarily the rain begins in the afternoon, when the heated air is rising most rapidly, and ends before nightfall, although occasionally a light rain will continue into the night.

c. **Tropical Wet and Dry Climate.** The tropical wet and dry climate occurs generally in the regions from 5° to 15° latitude, between the dry climates and the tropical rain forest regions. Instead of the dense forests typical of the tropical wet climate, the regions with tropical wet and dry climates have more open forests and large areas covered with tall grasses. Regions with tropical wet and dry climates have high temperatures, with annual ranges (difference between mean temperature of the warmest and coldest months of the year) varying between 5° and 15° F. The total amount of rainfall is less than that of the tropical wet climate. There are distinct wet and dry seasons, and usually the rainy season begins and ends with squalls and violent thunderstorms. During the rainy season, periods of intensely hot sunshine also alternate with brief, violent deluges of rain. The amount of rainfall varies considerably, so that there are years of drought and years of flood. In the dry season the weather resembles that of desert regions, with very little rainfall. Trees lose their leaves, many small streams are dry, and the soil becomes hard and cracked. Visibility is greatly reduced by dust and the smoke from grass fires. In certain parts of southern and southeastern Asia, the climate is greatly influenced by monsoon winds. The wet and dry seasons coincide respectively with the onshore and offshore winds.

503. DRY CLIMATES

a. **Description.** Dry climates are those in which the evaporation rate exceeds the precipitation rate. The dry climates are located on the leeward interior portions of continents. Dry climates are characterized by extreme seasonal temperatures with large annual ranges. Daily ranges also are high. Humidity is relatively low, averaging from 12 to 30 percent around the middle of the day. Generally the skies are clear and cloudless. Because vegetation is meager, the barren surface of the dry earth becomes very hot during the day and cools rapidly at night. The vegetation offers little friction to the moving air, and accordingly, strong, persistent winds are typical. There are two subdivisions: the arid or desert type, and the semi-arid or steppe type.

b. **Desert or Arid Climate.** A desert climate is essentially that of continental interiors characterized by extremes of temperature. The average temperature of the warmest month may be 80° F. and average temperature of the coldest month may be 25° to 50° F. Temperature variations of 100° F. and more within a 24 hour period are not uncommon. The foregoing temperatures represent central characteristics; average monthly temperatures of 15° or 90° F commonly occur in desert areas. In desert regions, rainfall is not only small, but erratic and uncertain. Much desert rainfall comes from heavy thunderstorms or "gully washers". Such storms may yield half of the average rainfall in a single storm. Often there is no rainfall for several years. The skies are almost always clear.

c. **Steppes.** In general, the steppe is a transitional region surrounding the desert and separating it from the humid regions. These are semi-arid, having a short period of rain bearing winds and storms each year. Precipitation, however, is meager and erratic. Steppe regions on the poleward sides of deserts have almost all of their annual rainfall in the cool season. Those adjoining savannas on the equatorial sides of deserts generally have a brief period of relatively heavy rains during the time when the sun is highest.

504. SUBTROPICAL CLIMATES

a. **Description.** These climates are characterized by moderate temperatures that occur in a seasonal rhythm. They are divided into two general categories - Mediterranean climate and humid subtropical climate.

b. **Mediterranean Climate.** This type of climate occurs in five regions - the borderlands of the Mediterranean Sea, central and coastal Southern California, central Chile, the southern tip of South Africa, and parts of southern Australia. This climate has hot, dry summers, and mild winters during which most of the annual precipitation occurs. Annual rainfall usually ranges from 38 to 64 centimeters (15 to 25 inches). In the winter months, the average temperature is usually between 40° and 50° F.; in the summer, it ranges generally from 70° to 80° F. Coastal areas often have a modified type of Mediterranean climate, with cool summers accentuated in some areas by the cool ocean currents offshore. There is apt to be a cool daily breeze along the seacoast and for a short distance inland. Relative humidity is high. Fogs are frequent, but usually are dissipated by the heat of the sun in the early morning hours. Winters are mild and frost infrequent, rainfall is relatively abundant, and the annual change in temperature at some locations is small. Summer days in Mediterranean climates are warm to hot, with bright sunshine, low relative humidity, and nearly cloudless skies. In autumn, daily weather becomes erratic and unpredictable. The winds are less regular, there is occasional rain, and the temperatures remain relatively high.

c. **Humid Subtropical Climate.** This climate occurs in regions located on the eastern sides of continents, generally from about latitude 25° poleward (north or south) to 35° or 40°. This type of climate is found, for example, in the American Gulf States. Temperatures are similar to those of the Mediterranean climate, with less contrast between regions on the coast and those located inland. Rainfall ranges from 75 to 165 centimeters (30 to 65 inches) a year at most locations. In the summer, humidity is high, temperatures average from about 75° to 80° F. in the hottest month, and there are frequent thundershowers. Nights are hot and sultry. There is no drought season, but normally there is less rain in winter than in summer. Severe tropical cyclones occur most frequently in the late summer and early fall. Winters are relatively mild in this type climate. Temperatures in the cool months usually average between 40° and 55° F. with the midday temperature around 55° to 60° F. and the night temperature from 35° to 45° F. The high humidity, however, makes the nights chilly and uncomfortable. Snow may fall occasionally, but it does not remain for more than 2 or 3 days. Daytime temperatures may be raised above 60° or 70° F. by the arrival of a tropical air mass, then be reduced by a subsequent polar wind as much as 30° F. in 24 hours, resulting in a severe freeze.

505. TEMPERATE CLIMATES

a. **Description.** The temperate zone is that part of the earth's surface and atmosphere lying between the Tropic of Cancer and the Arctic Circle in the northern hemisphere and between the Tropic of Capricorn and the Antarctic Circle in the southern hemisphere. The temperate zone is characterized by having a climate that is warm in the summer, cold in the winter, and moderate in the spring and fall. The area has two types of climates: the temperate oceanic and temperate continental.

b. Temperate Oceanic Climate. This climate occurs on the western or windward sides of continents, poleward from about 40° latitude, and results from onshore westerly winds that blow over the land from adjoining oceans. It borders the Mediterranean type on its equatorial margins, extends into the higher middle latitudes and ends at the subarctic or tundra climate. Where mountains are closely parallel to the west coast, as in Scandinavia, this type of climate is confined to a relatively narrow region on the seaward side of the highlands. In parts of western Europe, where there are extensive lowlands, the effects of the ocean conditions have an influence on the climate for many miles inland. Summers are cool with occasional hot days but no severe or prolonged heat waves. Rainfall is fairly abundant. Winters are mild, particularly in western Europe, where a great mass of warm water known as the North Atlantic Drift lies offshore. Cloudy skies and a humid atmosphere are prevalent. There are frequent severe frosts. The midday temperatures of most winter days are relatively high. During unusually cold periods, temperatures may remain below freezing for several days. The winter season is marked by severe storms, fogs, and mist. Where the western coasts are bordered by mountain ranges, as in Norway and Chile, precipitation may reach a total of 250 to 380 centimeters (100 to 150 inches) a year. In areas consisting predominantly of lowlands, rainfall usually averages from 50 to 90 centimeters (20 to 35 inches) a year. In mountainous regions, such as the Cascade Range or the Scandinavian Highlands, snowfall is very heavy. The marine west coast climate is cloudy, and has mist or fog for at least 40 days a year at many locations.

c. Temperate Continental Climates. These climates border the marine west coast climatic regions. Where there are mountain barriers, as in North America, the change between the two types of climates is abrupt, but it is very gradual where there are no barriers, as in the lowlands of western Europe. Seasonal differences are extreme, with very cold winters and warm to hot summers. Along the seaboard, the summer heat is oppressive and sultry because of the higher humidity, and the winter cold is more raw and penetrating than in the drier interior regions. Along the interior margins, humid continental climates border upon the dry climates and have subhumid characteristics. The prairies of North America and interior Eurasia are examples of such climatic regions. In these areas, the maximum rainfall usually occurs in late spring and early summer, rather than at the time of greatest heat. In winter, regions with a humid continental type of climate normally have a permanent snow cover that lasts a few weeks to several months. Summer rains usually occur in sharp showers accompanied by thunder and lightning. Winter in the prairie regions is characterized by frequent changes in weather conditions, with occasional blizzards. Although there may be no precipitation falling, the air can be filled to a height of several hundred feet by swirling masses of dry, finely pulverized snow. Afternoon thunderstorms frequently occur during summer in prairie regions.

506. MOUNTAIN CLIMATES

While there is no such thing as a specific mountain climate in the sense of the other climates discussed in this section, the weather found in mountains is different enough that it does not fall within any of the other climates discussed in this section. Within mountain regions there is an almost endless number of local climates. Conditions change markedly with altitude, latitude, and exposure to atmospheric winds and air masses. In addition, the climatic patterns of two ranges located at basically the same latitude may differ radically. Normally, there is a temperature drop of 3 to 5 degrees per 300 meters gain in altitude. At high altitudes, there may be differences of 40 to 50° F. between the temperature in the sun and in the shade. Wind velocity usually increases with altitude and is accentuated by mountainous terrain. Rain in mountains increases with altitude. Maximum cloudiness and rain generally occur near 1800 meters elevation in the middle latitudes and at lower levels approaching the poles. Both rain and snow are common to mountain regions.

507. BOREAL OR SUBARTIC CLIMATES

This climate occurs in latitudes of 50° to 60° in the Northern Hemisphere. The Eurasian region extends from Finland and Sweden to the Pacific coast of Siberia, and in North America, the subarctic stretches from Alaska to Labrador and Newfoundland. Long, extremely cold winters and very brief summers characterize this type of climate. Winter quickly follows summer, with only a short period of autumn intervening. A large part of these regions is frozen to a considerable depth, with only a few feet of the upper part thawing out in the summer. There is little precipitation in subarctic regions. No more than 40 centimeters (15 inches) a year falls over the greater part of the Siberian area. In most of subarctic Canada the precipitation is less than 50 centimeters (20 inches) annually. Precipitation exceeds 50 centimeters (20 inches) chiefly along the oceanic margins of Eurasia and North America.

508. POLAR CLIMATES

a. Description. The poleward limit of forest growth is usually considered the dividing line between polar climates and those of intermediate latitudes that coincide with a line (isotherm) connecting points having a temperature of 50° F. for the warmest month. A mean annual temperature of 32° F. or below is also a distinguishing feature of polar climates. In the southern hemisphere, the only large land areas with a polar climate is Antarctic. In the northern hemisphere, this climatic region includes the Arctic Sea, the borderlands of Eurasia and North America, with island groups that are north of the continents, and ice covered Greenland. Polar climates usually are divided into two types: tundra and ice cap.

b. Tundra

(1) When one or more months in the warm season have an average temperature of above 32° F. but below 50° F., the ground is free from snow for a short period, and low, sparse vegetation is possible. The variations are considered to be 50° F. on the equatorial side and 32° F. on the poleward side. Over land areas, tundra climate is confined largely to the northern hemisphere, the most extensive areas of which are on the Arctic Sea margins of Eurasia and North America. In the southern Hemisphere, ocean prevails in those temperature ranges that would otherwise be suitable for tundra, with the exception of the most northern fringes of Antarctic and on some small coastal islands. Summers warm enough to develop a tundra climate occur only in the most northern fringes of Antarctic and on certain small islands near Antarctic. The most extensive tundra areas are on the Arctic Sea margins of Eurasia and North America. Tundra climates have long, cold winters and brief, cool summers.

(2) Average temperatures usually are above freezing for only two to four months a year, and a killing frost may occur at any time.

Average temperatures in the Arctic coastal areas of Siberia average about -35° to -40° F. in January and February, with even lower temperatures inland. Fog is prevalent along the coast, frequently lasting for days. During the summer, snow cover disappears for one or two months and lakes usually are ice free. Drainage is poor because of the permafrost, resulting in many bogs and swamps. Along the Arctic borders of North America, the temperatures for comparable periods are higher and winters are less severe.

(3) Annual precipitation normally does not exceed 25 to 30 cm (10 to 12 inches) in tundra regions, although larger amounts are received in parts of eastern Canada, particularly in Labrador. Usually the most precipitation occurs in summer and autumn, the warmest season. Most of it falls as rain, with occasional snow.

c. Ice cap. This climate characterizes the permanent continental ice sheets of Greenland and Antarctica and the ocean in the vicinity of the North Pole. The average winter month temperatures range from -35° to -45° F. Storms or violent winds do not occur as frequently in the inner portions of the ice caps as in other climatic regions, but in some marginal areas there are extreme gales caused by the precipitous descent of cold air from the continental ice plateau.

SECTION 6

APPLICATION OF WEATHER AND TERRAIN ANALYSIS

And therefore I say, "Know the enemy, know yourself; your victory will never be endangered. Know the ground, know the weather; your victory will then be total."

Sun Tzu (500 B.C.) The Art of War

601. GENERAL

a. General. Sections 3, 4, and 5 discussed climate and the analysis of terrain and weather. This section discusses how the insights gained by the analysis of terrain and weather are used in planning helicopterborne operations and in the selection of firing positions, avenues of approach, boundaries, and defensive positions.

b. The reader must remember the caution contained in paragraph 106: No publication can give complete guidance; only by training can one learn those subtleties which are commonly included under the headings of judgement and experience. To master the contents of this section, one must train in the field.

602. SELECTING FIRING POSITIONS

a. A unit's effectiveness in combat is largely dependent on selecting firing positions which: (1) allow the unit's weapons to be employed effectively and (2) keep the enemy from employing his weapons to best effect. For example, a unit which is preparing a defensive position in anticipation of attack by enemy tanks will position its TOW's so the TOW's can first be used at their maximum effective range (about 3000 meters). If these firing positions are protected by obstacles beyond the tanks' maximum effective range (about 1500 meters), all the better. Ideally, firing positions for the Dragons will be located where enemy tanks can not see or fire on the Dragon gunners until the tanks are within the maximum effective range of the Dragons (about 1000 meters).

b. There are many points to consider in selecting a firing position. Some of these are:

(1) **The Mission.** If a unit's mission is to hold a hill, the unit's firing positions must facilitate the accomplishment of the mission, regardless of how good other firing positions may be.

(2) **The Enemy.** An enemy's capabilities will often determine how he will attack or defend. Mechanized units usually attack through fields and other open terrain where they can use the speed of their vehicles to advantage. Infantry, however, seeks to use the cover and concealment provided by woods and other close terrain. Firing positions which are ideal for defending against mechanized units may be useless for defending against infantry.

(3) **Observation and Fields of Fire.** Seek to: (1) fire on the enemy when he can not fire on you and (2) do not let the enemy fire on you when you can not fire on him.

(4) **The Plan of Defense/Scheme of Maneuver.** How the commander plans to employ his unit may influence the selection of firing positions. For example, if the commander plans to surprise the enemy, firing positions will be selected where the fires of all or most of the weapons be can brought to bear on the enemy simultaneously. If the commander plans to destroy as much of the enemy force as possible before it reaches his battle position, firing positions will be selected in depth from which fires can be delivered on the enemy before these weapons are moved to new positions to the rear or flanks.

603. SELECTING AVENUES OF APPROACH

a. General. An avenue of approach is a terrain feature, or combination of terrain features, which offers an attacker a favorable route to his objective. Desirable terrain characteristics of an avenue of approach are:

(1) Ease of movement toward the objective.

(2) Concealment and cover from the defenders' observation and fire.

(3) Favorable observation and fields of fire for the attacker.

b. Factors to be considered in selecting the best avenue of approach are enemy dispositions, the size of the attacking unit, the anticipated rate of advance, the type and amount of supporting weapons, and surprise. However, the following paragraphs pertain to terrain aspects only and in this respect avenues of approach are based on an analysis of:

(1) Relief and drainage.

(2) Trafficability.

(3) Vegetation.

(4) Routes of communication.

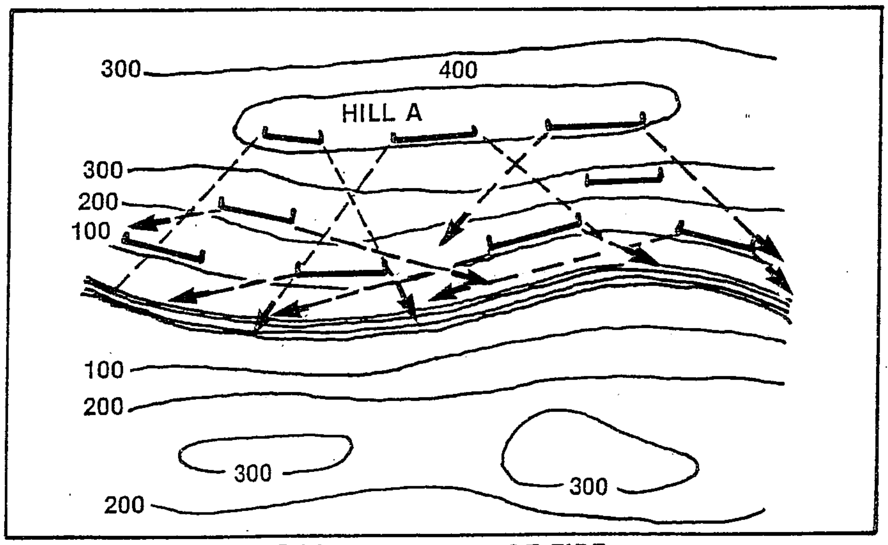
c. Relief and Drainage. The effects of relief and drainage on avenues of approach are considered in terms of compartments and corridors.

(1) Cross compartments.

(a) In general, cross compartments favor the defender and are not considered as favorable avenues of approach. They afford the defending unit maximum observation and fields of fire which in turn increases their ability to gain mutual support between units (laterally and in depth). In addition, the defenders' flat trajectory fires can be easily massed on points threatened by an attacker. Cross compartments enable a unit to defend on the forward slope and still have cover for reserves to assemble in preparation for a counterattack, or the defense can be moved to the reverse slope while the topographic crest is used for long range observation.

(b) A unit attacking through a cross compartment may also have good observation and fields of fire, particularly from the viewpoint of overhead fire from flat trajectory weapons, and initially may have concealment and cover. However, once the attack begins, cover is lost. The attackers' frontal fires are pitted against the enfilading fires of the defender, which can be concentrated at that point where the attack threatens most.

(c) Figure 6-1 shows a schematic defense of a cross compartment. The defender obtains centrally located observation from hill A, which enables him to coordinate the entire defense. Observation and fields of fire extend across the entire width and depth of the position, facilitating mutual support laterally and in depth. Enfilading fires are obtained, and all fires may be massed where most required. The size of the compartment, irregularities in ground, vegetation, steepness of slope, and other factors will influence the desirability of any particular cross compartment for the defense. For example, a long, uniform slope offers increased fields of fire, while a short irregular slope decreases fields of fire.



POSSIBLE FIELDS OF FIRE

Figure 6-1. Cross Compartment Defense

(2) Corridors or Ridges

(a) Corridors or ridges forming the limiting features of a compartment present favorable avenues of approach. This is because the defenders' lateral organization of observation and fields of flat trajectory fire are obstructed by limiting features of compartments which decrease the ability of the defender to obtain mutual support between units.

(b) Figure 6-2 shows a schematic defense of a corridor. The topographic crests divide observation and fields of flat trajectory fire into three sections. The defender no longer has centralized observation nor can he mass all of his fires at any one point. Mutual support between units is limited by topographic crests. Fire becomes more frontal and fields of fire are shortened. Defensive elements located in the low ground lack observation except to their front. The size of the corridor and ridges, the steepness of slopes, vegetation, and other factors will modify the defense. The steeper the slopes and the more pronounced the ridge, the more the defenders' fires and observation will be limited.

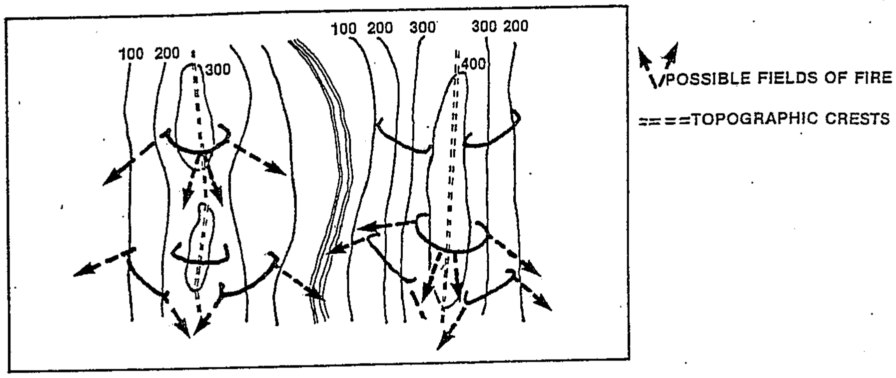


Figure 6-2. Defense along Ridge or Corridor

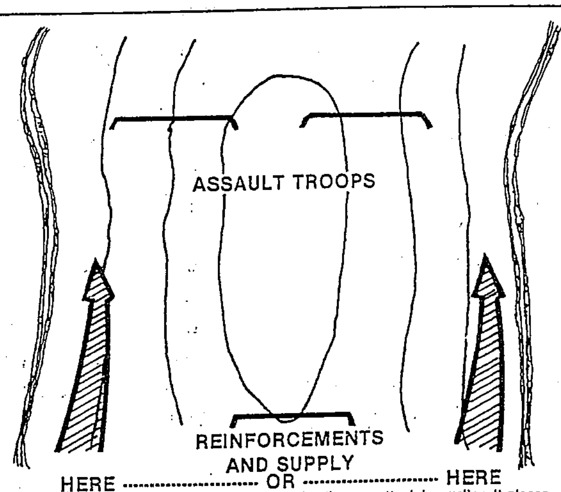
(c) A corridor is dominated by two axes of observation with the ridges forming the limiting features of the compartment. As long as the enemy retains observation into the corridor, troops cannot advance through the center. Enemy observation into the corridor must be blinded, or the vantage point must be seized.

(d) In advancing through a corridor (along a valley) the best axis of advance is frequently along the shoulders of the ridges forming the corridor. By advancing along the shoulders, the attacker can seize short range ground observation from the enemy by clearing the slopes up to the military crests, which in turn serves to reduce the effectiveness of the defenders' fires into the corridor.

(e) In advancing along the axis of a ridge, the attackers do not get the protection from fire that they get within a corridor. To minimize effects of enemy fire, the bulk of the troops move just below the topographic crest.

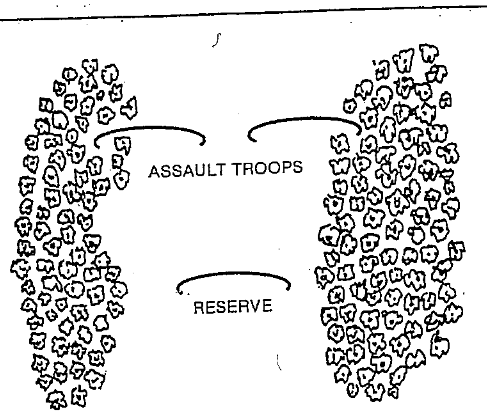
(f) A careful analysis must be made in determining whether to advance along a valley or along a ridge. If enemy ground observation can be denied, a valley approach offers more protection from fire. It will be easier for a commander to coordinate the efforts of the attack echelon if all of his unit is in one compartment where he can observe it and where elements of the assault can observe each other. The attacker can mass his fires wherever he so desires. Once having seized or denied ground observation into the valley, it will be possible to supply and support the attack from a centralized route through the valley. On the other hand, if the enemy can maintain continuous observation into the valley, if obstacles render the valley a less suitable approach, or if a particular weapon is not suited for employment in the valley, it may be more desirable to attack along the ridge.

(g) The primary advantage of attacking along a ridge is that the attack is made on an axis of dominant observation. Once the ridge is seized, enemy units in adjacent valleys become very vulnerable to flanking attacks. Furthermore, units in adjacent valleys are in a poor position to contest an advance made along a ridge. Consequently, defense of the ridge is largely dependent upon the personnel located on it. Frequently, successful attacks along ridges make defensive positions in adjacent valleys untenable, forcing the enemy to withdraw under the threat of being isolated. A disadvantage of attacking along a ridge is that forces disposed there have less cover from enemy flat trajectory fire than when attacking in a valley. Coordination between elements disposed on either side of a topographic crest is more difficult than when both elements are in the same corridor. Covered routes for supply and reinforcements may not be as centrally located as they are in a valley approach. Supplies will often be moved through adjacent valleys as soon as possible and fed laterally up the ridge to the attacking troops. See figures 6-3 and 6-4.



NOTE: This type of attack is frequently more decisive than an attack in a valley. It places defending units in valleys in unfavorable positions without actually engaging them. It is more difficult to obtain mutual support between elements in the assault, and supplies and reinforcements do not have a centalized, covered route of advance.

Figure 6-3. Attacking Along a Ridge



NOTE: Observation into the corridor must be denied. This axis of advance affords protection to troops from fires initiated outside the corridor.

Figure 6-4. Attacking through a Corridor

d. Trafficability

(1) Although corridors and ridges may provide favorable characteristics of an avenue of approach, their effects may be completely nullified by the lack of trafficability. The details of determining trafficability are discussed in Appendix D, Soil Tests.

(2) By combining the trafficability of an area and obstacles such as steep slopes, heavy vegetation, or man-made obstacles, and integrating their effects a cross-country movement map or overlay may be made. A cross-country movement map is one specially marked to show the effects of soils and obstacles on cross-country movement. (See fig. 6-5.)

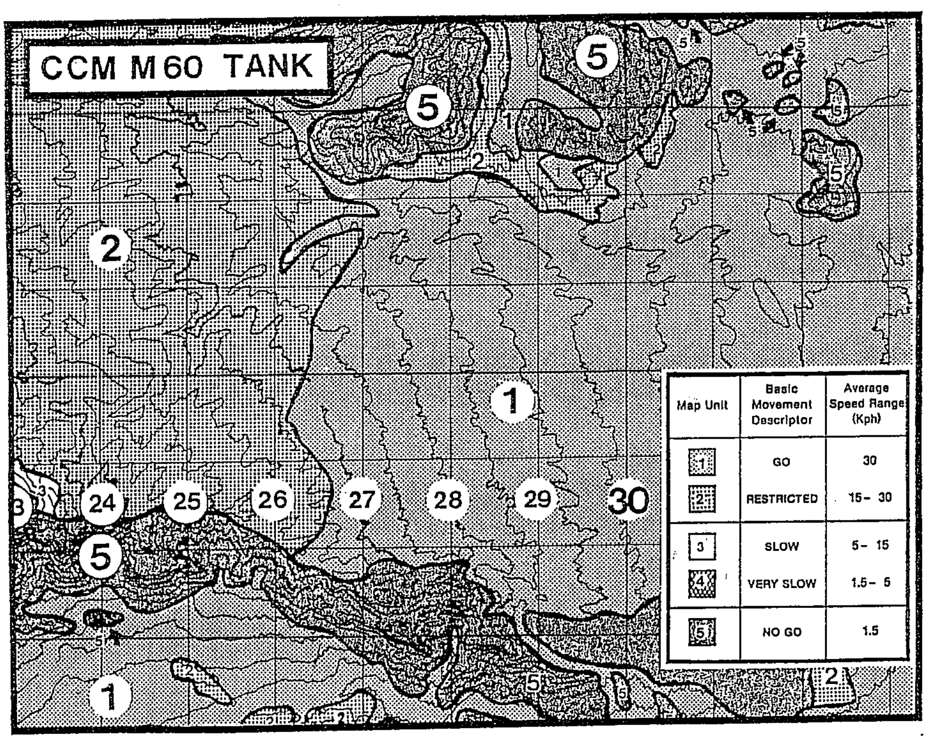
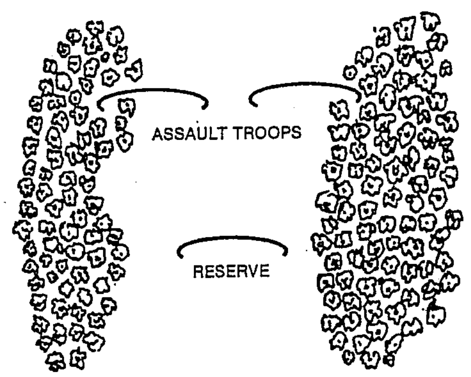


Figure 6-5. Cross-Country Movement Map

(3) Figure 6-6 shows a force attacking through a corridor formed by vegetation.



NOTE: Observation into the corridor must be denied. This axis of advance affords protection to troops from fires initiated outside the corridor.

Figure 6-6. Attack Through a Corridor Formed by Vegetation

(4) Figure 6-7 shows a force attacking through a corridor formed by woods.

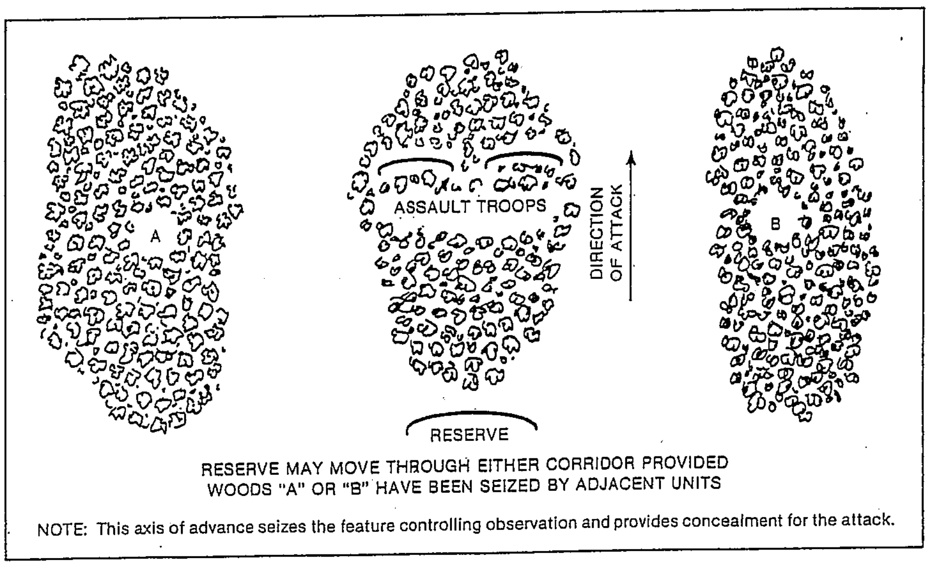


Figure 6-7. Attacking Through a Corridor Formed by Woods

604. PLANNING HELICOPTERBORNE OPERATIONS

a. A helicopterborne operation is one using helicopters for both tactical and administrative/logistics missions. Tactical missions may consist of helicopterborne assaults to seize critical terrain, to isolate pockets of enemy resistance, to attack the enemy's flanks and/or rear, to conduct raids, or to conduct patrols. This paragraph discusses some of the ways terrain influences helicopterborne operations.

b. The terrain in the objective area influences the size and extent of the landing zone (LZ) and assignment of missions to units landing in the LZ. Adequate terrain intelligence is needed to permit units to (1) select landing and assembly areas, (2) to plan operations to seize and defend objectives, and (3) to plan reconnaissance of routes to objectives, assembly areas, or other positions. The terrain affects (1) nature and extent of obstacles to enemy movement, particularly armor, that must be constructed, (2) the air-landing facilities that must be constructed, and (3) the requirement to use helicopters to provide water to the force being supported by the helicopterborne operation.

c. Information of a general nature concerning helicopter LZ's is in in the appropriate FM's and FMFM's on helicopter assault support operations, NATOP's manuals, and the Assault Support Helicopter (ASH) manual. Landing zone data which must be obtained includes:

(1) The geographical location of each helicopter landing site, using either geographic or military coordinates as directed.

(2) Altitude as determined by either map inspection, use of altimeter or other barometric instrument, or reconnaissance personnel.

(3) The directional orientation of the site and its immediate approaches, with respect to dominating terrain. Concealment is a major concern in selecting avenues of approach.

(4) Descriptions of prominent terrain, unusual natural or man-made formations, bodies of water, structures, or other landmarks that would tend to help in orientation of helicopter pilots and disembarking troops.

(5) All physical factors of each site affecting either helicopter or ground operations as outlined below.

(a) Size. The physical dimensions of the helicopter landing.

(b) Maximum Absorption of Aircraft. The number of helicopters that can be accommodate. Unusable portions of the zones must be located and marked. Individual helicopter landing points are selected so that the rotor of one helicopter is no closer than twice the main rotor diameter to an adjacent helicopter.

(c) Surface Material and Soil Trafficability. Information concerning surface materials present and the soil trafficability within the sites or zones. The former should be considered in regard to possible rotor wash effect, the latter for vehicular, troop and logistic mobility. Loose debris can cause clogging of engine intakes, temporary loss of visibility, possible bodily injury to troops, or damage to the helicopter. The following specific surface materials should be considered as suggested below.

1 Grass and vegetation from newly mowed fields. It can clog shielded intakes.

2 Loose dirt and sand. It can cause damage to engine and rotor blades, temporary loss of pilot visibility and temporary blinding of troops.

3 Snow. It is not recommended as a landing site surface without prior reconnaissance because the underlying surface may be unsatisfactory.

4 Ashes. If blown into the eyes of pilots or troops, they will cause temporary incapacitation.

5 Dry grass. Hot exhaust gases may start fires.

(d) Obstacles (natural and manmade). To evaluate obstacles effectively, familiarity with helicopter landing and takeoff characteristics is essential. For example, helicopters must land and take off into the prevailing wind. This is particularly important at high altitudes, high temperatures, or heavy load conditions. Ingress and egress routes must be evaluated accordingly. Some obstacles will affect helicopter landings, while others will affect disembarked infantry. For example, a line of trees or power lines in the area may prevent helicopter landings while not materially affecting troop activities. On the other hand, deep, precipitous ravines or extensive swamps would not only constitute a barrier to helicopters but would also significantly influence the infantry's operations.

(e) Slope. Terrain sloping in excess of 14 percent (8 degrees) is usually considered too steep for mass helicopter landings.

(f) Cultivated Features. Cultivated cover can be a restricting factor in the landing of helicopters, particularly in mass landings. High trees at the edge of a site are restrictive, but may not rule out the use of the area as a whole. Brush, if over 3 feet high is usually considered restrictive to landing helicopters because of likely damage to fuselage and tail rotors. The following specific vegetative types should be evaluated as suggested:

1 Field crops are generally not restrictive except in cases where the crops have supports, such as vineyards. Newly plowed fields are usable but not desirable because of uneven surface and the danger of helicopters sinking into the soil. Cornfields are not restrictive. However, bamboo and like grasses are restrictive.

2 Rice fields are generally restrictive during crop season when paddies are flooded and ground surface is soft. However, off-season use is safe if the paddies are drained and hardened.

3 Grasslands are generally desirable unless associated with meadow marsh, scattered rocks, or broken surface.

(g) Adjacent Terrain and Exits. Adjacent terrain and exits must be studied in light of the relief, drainage, vegetation, cultural features, communications, routes of approach, observation, visibility, cover, and concealment. The nature and size of exits from the helicopter landing site, both natural and man-made, existing routes of communication, and general area trafficability can then be evaluated.

605. PLANNING FOR THE ATTACK

a. Objectives. Consistent with the mission of the command, key terrain features may be selected, the seizure of which will assist in the accomplishment of the mission. If the mission is to seize or to secure an area, the key terrain feature or features may be selected with reference to that area. If the mission is to destroy certain enemy forces, key terrain features are selected from which the accomplishment of that mission may be more easily or decisively effected. The key terrain feature, or features, selected may be designated as objectives of the attacking force. Subordinate commands may in turn select key terrain features and assign them as objectives of their attacking units. In this manner commanders can tie their missions to the ground and begin to develop a scheme of maneuver.

b. Scheme of Maneuver. Objectives having been selected, it becomes necessary to select avenues of approach to them. Along that approach which most promises success, the commander will plan his main effort. Thus, by selecting his objectives, his routes to the objective, and the route of his main attack, the commander has begun his scheme of maneuver. There is probably no other single factor that influences a commander's scheme of maneuver more than terrain considerations.

c. Boundaries

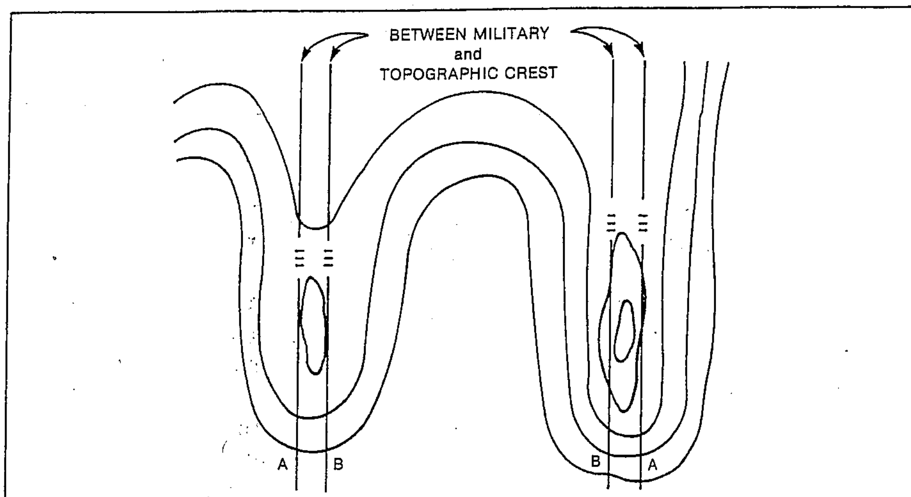
(1) If the avenue of approach selected is in a corridor or along the limiting features of a corridor, the commander places his boundaries so as to secure the advantages inherent in those approaches. Primary terrain considerations such as roads and rivers, for example, for locating boundaries in corridors and along ridges are:

(a) Key terrain should not be split between two units.

(b) Sufficient slope must be assigned to enable the attacker to seize, at the minimum, short range observation into corridors.

(c) Topographic crests must be assigned to one unit to insure their control.

(2) Figure 6-8 shows some possible boundary locations for a regiment attacking through a corridor. By locating the boundaries between the military crests and the topographic crests, enough of the ridges are assigned to this regiment to insure control of short range observation into the corridor, thus limiting the defenders' flat trajectory fire into the corridor. The boundary line B would assign the topographic crests of the limiting features to adjacent units. The boundary line A would include the topographic crests in the zone of responsibility of this regiment, thus enabling it to control both long and short range observation. Combinations of the boundary lines may be made assigning one or the other of the topographic crests to the regiment.



NOTE: Boundaries are located between military crests and topographic crests. Boundaries indicated by either A or B, or a combination thereof, would be normally correct.

Figure 6-8. Possible Boundaries for an Attack Through a Corridor.

(3) Figure 6-9 shows possible boundaries for two regiments attacking on parallel ridges. In order to insure full control of the ridges, each regiment is assigned both the topographic and military crests of their respective ridges. The boundaries in the valley are located to insure its control by one of the regiments. If boundary A were assigned, the right regiment would be primarily responsible for the valley. If boundary B were assigned, the left regiment would be responsible for the valley.

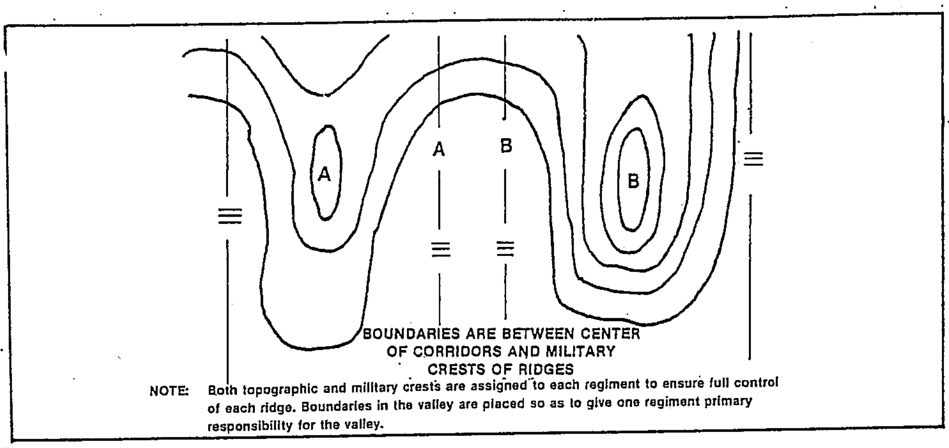


Figure 6-9. Possible Boundaries for Attacking Along the Axis of Ridges

(4) Boundaries through corridors formed by vegetation or cultural features would, in principle, be the same as the boundaries illustrated in Figures 6-8 and 6-9. That is, in the case of units advancing in corridors, boundaries should extend sufficiently beyond the delimiting lines to insure control of short range observation and to provide maneuver for major subordinate elements. When units are advancing on the axis of limiting features, their boundaries should include enough of the features to insure its control.

(5) Figure 6-10 shows combination of boundaries through corridors and along limiting features of corridors formed by vegetation and by cultural features. The First Battalion is attacking on the axis of woods A. The Second Battalion has the choice of advancing through the corridor itself or through town B. The Third Battalion is advancing through the corridor formed by town B and woods C.

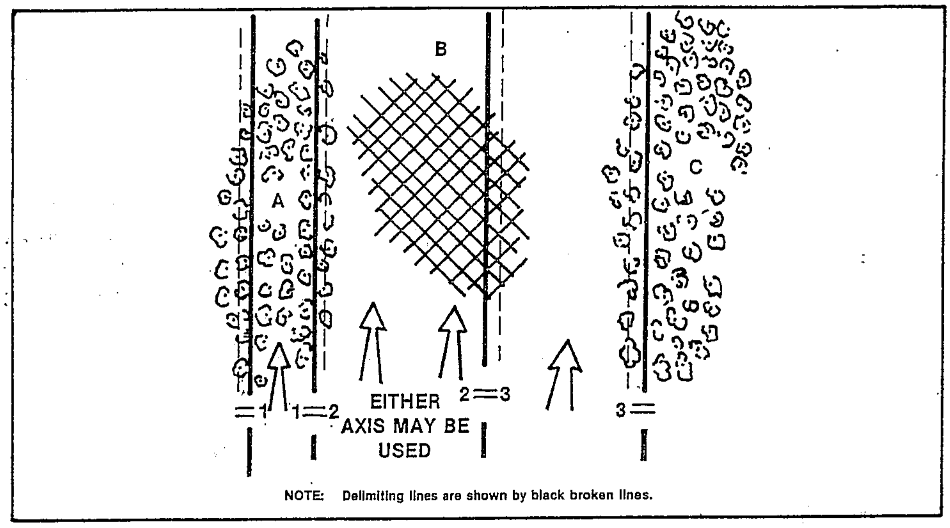


Figure 6-10. Attack Boundaries Through Compartments Formed by Vegetation and by Cultural Features.

606. PLANNING FOR THE DEFENSE

a. **Selection of Position.** In the defense, key terrain features are features which, if not in our possession, render our position untenable. Consequently, they constitute the objectives of an enemy force whose mission is to destroy defending troops or seize their defensive position. The defense is organized, protecting these features, with centers of resistance on dominating terrain. The possession of dominating terrain insures observation and fields of fire as well as covered assembly areas and routes of approach for counterattacking units.

b. Cross compartments present several aspects favorable to the defender. Their nature often enables the defender to obtain observation and fields of fire throughout his position, facilitates organization laterally and in depth, and provides the defender with organization laterally and in depth, and provides the defender with successive defensive or delaying positions. The cover or concealment provided by each limiting feature permits the defender to shift reserves and meet or counter the threat of the attacker.

c. Avenues of approach into a position from the direction of the enemy constitute the weak points of defense. The defensive organization must insure the blocking of these avenues of approach by means of artificial obstacles and by the use of fire. Corridors entering a defensive position break up the position so that observation and direct fire used to defend one corridor cannot be used to assist in defending any other part of the position. The defender must try to seek a position without corridors.

d. Boundaries. In assigning boundaries between units in the defense, the responsibility for key terrain should be assigned to one unit. In addition, the responsibility for an avenue of approach should be assigned to one unit, the unit that is most threatened by that avenue of approach.

(1) The application of these principles to units defending a simple cross compartment is dependent not so much on terrain as it is on such factors as the size and strength of the defending unit and the amount and type of supporting weapons.

(2) Simple compartments are rarely found. Consequently, units find themselves defending complex cross compartments where smaller draws and corridors may extend into their defenses. The attacker can be expected to use these smaller draws as avenues of approach, thereby minimizing the advantage of the defenders' position. In defending corridors, emphasis is placed on organizing the limiting features as centers of resistance while fire is primarily relied upon to defend the valleys. The defender endeavors to force the enemy to expend his strength negotiating avenues of approach and then, at the proper moment, to counterattack from the high ground.

(3) Figure 6-11 shows the application of the principles of assigning defensive boundaries in corridors. The First Battalion is assigned responsibility for hill A, where it will organize its center of resistance in order to obtain the observation and fields of fire that will control draw B. Draw B provides a possible avenue of approach to hill A. Hence, the First Battalion is given responsibility for its defense. The right boundary is located far enough up the slope of the adjacent ridge to give the First Battalion sufficient high ground to insure control of the draw. It is located at some point between the military crest and the lowest portion of the draw. Similarly, since draw C leads back into the Second Battalion area, the Second Battalion is assigned responsibility for its defense.

(4) The same principles apply to boundaries located in corridors formed by vegetation and cultural features. The woods or villages provide the terrain features which control the corridors, and they will be the areas organized and occupied by the defender. (See fig. 6-12.)

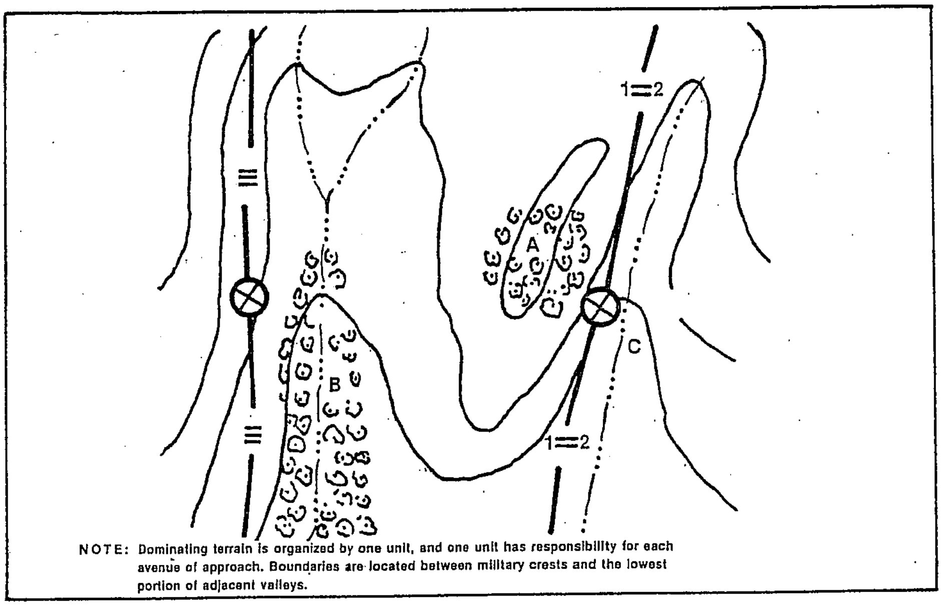
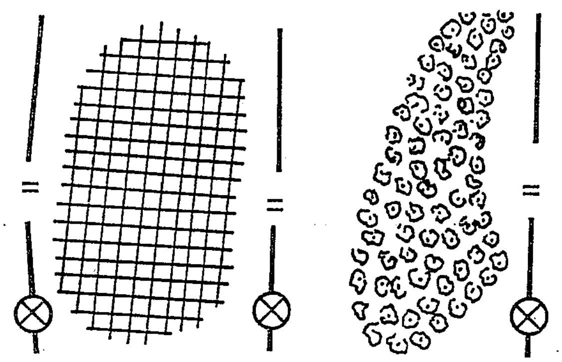


Figure 6-11. Boundaries in Defense of Corridors



NOTE: The woods and village are physically occupied and organized for defense. Fire from the woods and village will be the primary defense of the intervening corridor.

Figure 6-12. Boundaries in Defense of Corridors Formed by Woods and Village.

e. Reverse Slope Defense

(1) Definition. The reverse slope is the part of the slope masked from enemy fire or observation (or both) by the topographical crest, and extends back from the crest only to the maximum effective range of rifle fire. (See fig. 6-13.)

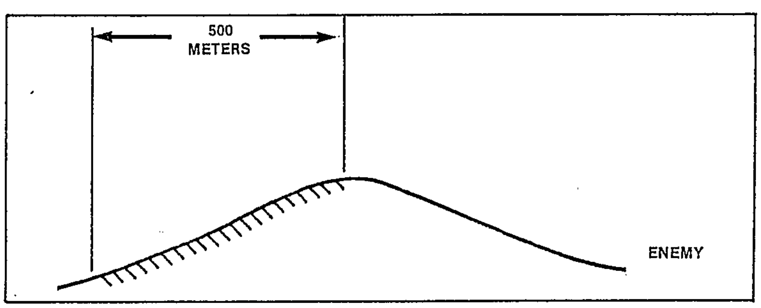


Figure 6-13. Reverse Slope

(2) If the position chosen for front line units is farther back than about 500 meters, the enemy will have been given possession of the crest. The defender no longer will have cover from his observation and fire, and the defender will not be, by definition, defending a reverse slope.

(3) **Who Selects.** If a reverse slope position must be within some 500 meters of the last cover (toward the enemy), the battalion commander is the highest commander who has the decision as to whether or not to organize a reverse slope. The battalion is the largest unit which will ordinarily occupy a defense area so limited that the positions which subordinate units must organize must be specified within 500 meters. Usually, however, company commanders will decide whether front-line platoons will defend from the rear or forward slopes.

(4) **Considerations.** The factors to be considered in coming to that decision are simple. Mainly, the forward slope offers fields of fire; the reverse slope, protection from observed enemy fire. However, there are many other considerations. The most important are:

(a) **Enemy Activity**

1 **Forward Slope.** If the enemy is **distant or inactive,** a forward slope position can be organized in detail and cover can be constructed at leisure which will later minimize the effect of enemy observed fire.

2 **Reverse Slope.** If the enemy is **within range and aggressive,** he can be held off by security groups on the crest while the rest of the unit is organizing the reverse slope.

(b) **Terrain**

1 **Forward Slope.** If the terrain in the direction of the enemy is such that at no place can he get particularly good observation over the forward slope, then the great disadvantage of defending on the forward slope no longer exists (see fig. 6-14). It is generally easier to furnish mutually supporting fires in front of adjacent localities from a forward slope.

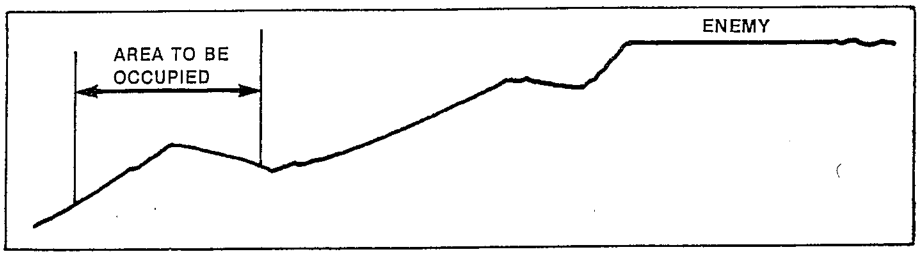


Figure 6-14. Good Enemy Observation

2 **Reverse Slope.** If, although the enemy is out of range while on the move, ground exists where he can overlook the position, then the forward slope can be made untenable whenever he, the enemy, elects (see fig. 6-15). In order to successfully defend a reverse slope, it is essential that automatic weapons of adjacent localities can support each other by fire across forward slopes from covered positions on the reverse slope or the shoulders of it. If such positions cannot be found or constructed, the reverse slope should be occupied only when its other advantages are decisive. (See fig. 6-16.)

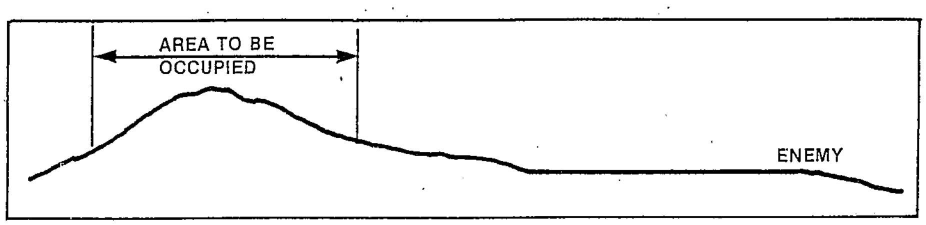


Figure 6-15. Poor Enemy Observation

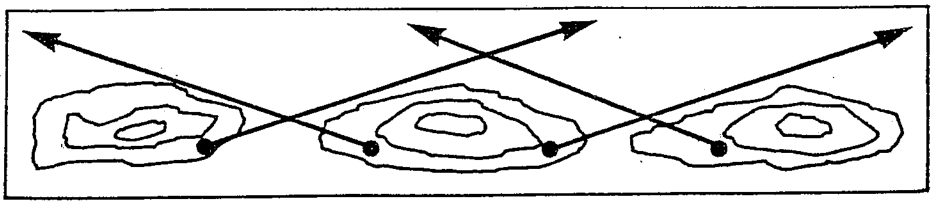


Figure 6-16. Mutual Support by Automatic Weapons

(c) Time and Light. If the position is to be occupied **after dark**, and the later advantages of being on the forward slope are desired, the fact that the position can be occupied and constructed under cover of darkness becomes the decisive factor. Many times the forward slope would seem to offer the greatest advantages but the fact that the position must be occupied, and constructed in **daylight**, under fire, will make it too expensive.

(5) Basic Principles. When the various considerations having been weighed and the decision to defend on the reverse slope made, the basic principles upon which that defense is built are:

(a) Automatic Weapons. The backbone of the defense of a reverse slope, as in any defense, is the coordinated fire of machine guns across the front. In defending a reverse slope, the emplacement of these weapons will have two unique characteristics. The weapon and crew will have complete cover and protection to the front, and their sectors of fire will be severely limited. (See fig. 6-17.)

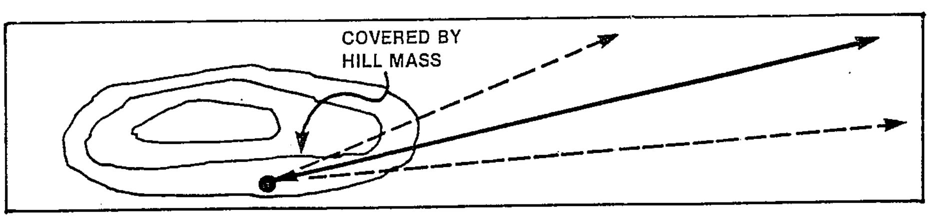


Figure 6-17. Automatic Weapons

(b) Where such positions cannot be found, i.e., where fire cannot be delivered across the front of adjacent **forward** slopes, the decision to defend from the rear slope should be very carefully reviewed.

(c) Some automatic weapons must be included in the organization of observation and security groups. Where these are sited will depend on the ground. If it is rough and broken, and covered routes of withdrawal around the shoulders of the hill are available, these guns should be sited well forward. (See fig. 6-18.)

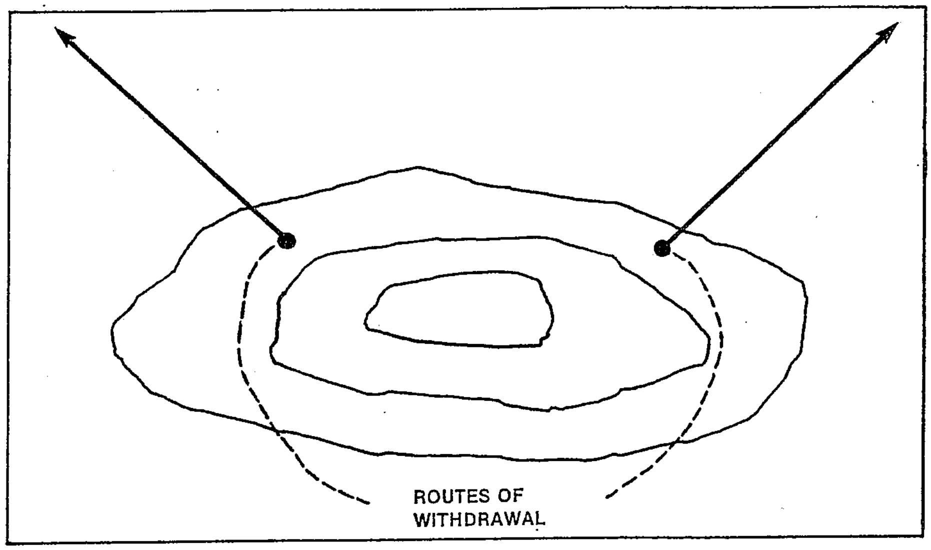


Figure 6-18. Broken Ground with Routes of Withdrawal Available

(d) If the forward slope is smooth and unbroken, the forward automatic weapons should be immediately in front of the topographical crest, routes of withdrawal being planned or dug back over the crest. (See fig. 6-19.)

(e) Riflemen must be placed on the reverse slope so that they can deliver effective fire upon the crest and are out of range of hand grenades thrown or grenade launchers shot from behind the crest. They will therefore occupy an area between 100 and 500 meters back of the crest; from 200 to 400 meters is probably ideal.

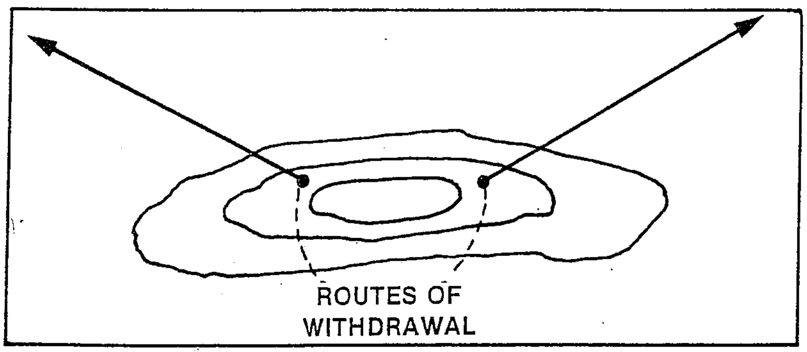


Figure 6-19. Smooth Ground

(f) The organization of squads, dug in and dispersed in depth, is similar to that of a forward slope. Great attention must be paid to flanks, particularly upon terrain where the hill mass is broken by transverse approaches such as valleys, gullies, ravines, etc. (See fig. 6-20).

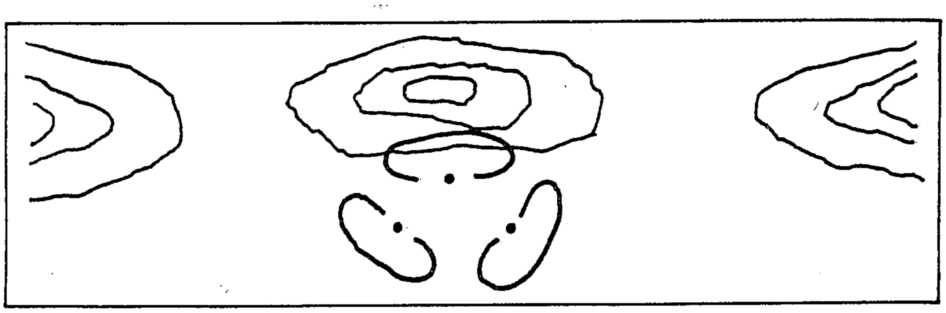


Figure 6-20. Organization of Squads

(6) Observation and Security Groups

(a) If the enemy gains possession of the crest, at least if he does so prior to his final assault, then the advantage of concealment from observed fire is lost. Therefore he must be prevented from securing that observation. This must be done by establishing observation and security groups, strong in SAW's, or LMG's on the forward slope. These will be on the shoulders or near the crest, wherever the terrain is most suitable.

(b) Then the completely organized company position will be, schematically as shown in figure 6-21.

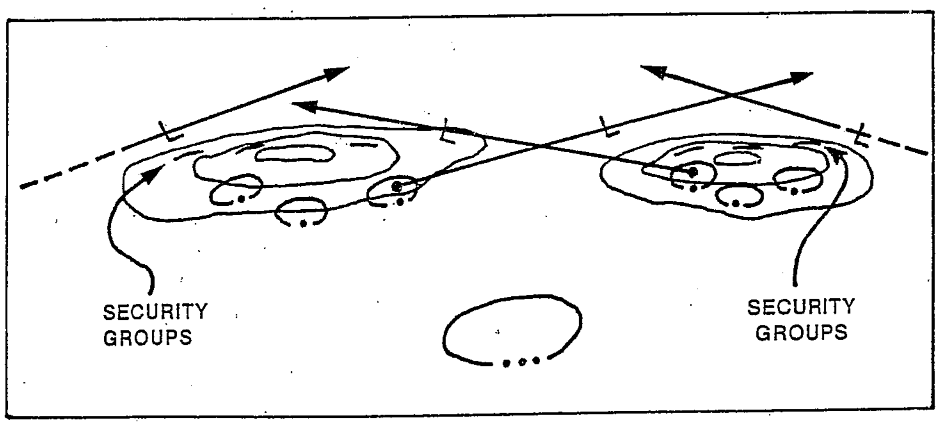


Figure 6-21.

(7) Supporting Arms. Use of artillery and mortar fires is normal. A normal barrage should be planned for forward slopes, over the crest from the reverse slope position, to assist in breaking up attacks before they reach the crest.

(8) Counterattacks. Counterattacks to restore a reverse slope position will ordinarily be made by reserve units initially located farther back than the actual reverse slope itself. However, one of the virtues of the reverse slope is that defenders can move forward and dislodge an enemy who has gained a momentary foothold on the crest without exposing themselves to observed artillery fire or the direct fire of any weapons except those which the enemy has been able to hurriedly emplace upon the crest.

SECTION 7

SOURCES OF INFORMATION AND INTELLIGENCE ON WEATHER AND TERRAIN

> When it is desired to apply oneself to this essential part of war, the most detailed and exact maps of the country that can be found are taken and examined and reexamined frequently. If it is not in time of war, the places are visited, camps are chosen, roads are examined, the mayors of the villages, the butchers, and the farmers are talked to. One becomes familiar with the footpaths, the depth of the woods, their nature, the depth of the rivers, the marshes that can be crossed and those which cannot . . . The road is chosen for such and such a march, the number of columns in which the marsh can be made estimated and all strong camping places on the route are examined.
>
> Frederick the Great:
> Instructions for his Generals

701. GENERAL

This section discusses sources of information on weather and terrain. Some of these sources are directly available to the field commander, while support from the others must be requested through higher headquarters.

702. MAPS

A map is a representation on a flat surface of the earth's surface. It provides detailed information on those aspects of the terrain which are important to the intended users of the map. Aspects which are considered unimportant to the users are distorted or not portrayed.

a. Military Maps. On military maps, detailed information is provided on those aspects of land features which are important to military operations; e.g., elevation, vegetation, and water bodies. Military maps are not available for all areas.

b. Civilian Maps. Civilian maps are available for almost all areas. Since these maps are usually intended for users other than military personnel, they do not provide all the information needed for military operations; e.g., grid lines. Civilian maps, however, are better than no maps at all. Civilian maps may be available through military channels, or it may be necessary to procure them from local sources in the theater of operations.

703. AERIAL PHOTOGRAPHS

The degree to which information can be interpreted from aerial photographs varies with many factors, such as quality and scale of the photographs, the nature of plant cover (vegetation), the nature of the soils, and, most important, the skill of the photo interpreter or terrain analyst. While technicians can employ photography to their fullest extent, many general facts may be interpreted by personnel with a minimum of training. For instance, orchards usually are planted in well drained sandy soils; vertical cuts are evidence of deep loessial (silty, fine grained) soil; and tile drains in agricultural areas indicate poorly drained soils, probably silts and clays.

a. Interpretation of Tone. It is often possible to determine the trafficability group of a soil by its tone in an aerial photograph. A skilled interpreter generally can determine where soils have good drainage and where they do not, but it must be remembered that aerial photographs reveal conditions at the time they were made. Aerial photographs made months or years ago can serve only to indicate the general drainage conditions. Light tones on a black and white photo generally indicate higher elevations, sandier soils, and lower moisture content than do dark tones. However, it should be noted that the same tone will not signify exactly the same conditions throughout the same photograph and may have an entirely different significance on two separate photographs. Also, natural tones are apt to be obscured and modified by tones created by vegetation, plowed fields, and cloud shadows.

b. Drainage Pattern. A drainage pattern is the pattern formed by the streams and rivers in a given area. A drainage pattern is easily identified on aerial photographs. See Appendix C for descriptions of the six basic drainage patterns and discussions of what these patterns indicate.

704. REPORTS FROM FRONT-LINE UNITS

Front-line units can provide some of the best information on the terrain. Such units can provide information either because they are tasked by higher headquarters or because they believe their have information is important to higher headquarters. Information on the terrain can be submitted in the form of a spot report or a terrain sketch. Terrain sketches are discussed in the next paragraph and in FM 21-26, Map Reading.

705. TERRAIN SKETCHES

Terrain sketches serve two purposes. First, they are often a better and more reliable means of portraying the information about terrain than are verbal messages. Second, the Marine who draws the sketch studies the terrain more carefully, than he would otherwise. Even if the sketch is not submitted, comments from a Marine who has made a terrain sketch will usually be better than a report from an observer who has not made a terrain sketch. The Marine who makes the sketch probably learns more from making the sketch than those to whom he passes the sketch learn from studying the sketch. Personnel at all levels must develop the skill of making and using terrain sketches. Sketches should be made by, among others, reconnaissance and front-line troops, intelligence personnel, and small-unit leaders.

a. **Elements of a Terrain Sketch.** A terrain sketch shows only the significant features of an area from one perspective. A sketch should include only the necessary details but at least the following information:

- Date and time of the sketch.
- Coordinates from the point where the sketch was made.
- Location of the enemy, if known.
- Identification of key terrain.
- Reference points.

b. **Perspective.** Terrain sketches can be made from one of two perspectives: the aerial point of view or the observer's point of view.

c. **Types of Terrain Sketches.** Terrain sketches are usually one of the following five types: road sketches, position sketches, outpost sketches, place sketches, and panoramic sketches. See FM 21-26, Map Reading, for more information on terrain sketches.

706. WEATHER FORECASTS

Weather forecasts are vital. Rain can make firm soil into impassable mud; cold weather can make mud and swamps passable and can cause cold injuries and equipment problems; hot weather can cause heat casualties; and fog can provide concealment. Weather forecasts are acquired through intelligence channels. Normally, the weather forecast includes -

- The synoptic situation.
- Sky condition.
- Cloud bases and tops.
- Visibility.
- Precipitation.
- Obstructions to vision.
- Severe weather.
- Temperature extremes.
- Surface winds.
- Light data.

(See Appendix E for definitions of some of the terms used in weather forecasting.)

a. Types of Weather Forecasts. There are two types of weather forecasts: **short range forecasts** for the next 12 - 48 hours, and **long range forecasts** for the period after the first 48 hours.

b. Sources

(1) While part of a Navy force, Marine Corps units will receive all forecasts from Navy assets. Once the air combat element (ACE) of a Marine Air-Ground Task Force (MAGTF) is established ashore and has the capability to produce weather forecasts, forecasts will be furnished by the weather unit supporting the ACE. MAGTF commanders must insure that planning includes providing for the production and distribution of forecasts and designating the channels through which weather information is passed.

(2) The Air Weather Service, part of the Air Force, provides weather forecasts for the Army. In a tactical environment, a tactical forecast unit (TFU) is established to prepare forecasts for the area of operations. Even though the Marine Corps is not within the TFU's reporting chain of command, Marine Corps commanders should be aware that it exists and, with proper liaison, can provide weather information. For detailed information on support for tactical operations provided by the Air Weather Service, see FM 34-81, Weather Support for Army Tactical Operations.

(3) U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA., has developed the Battlefield Environmental Effects System, (BEES) with climatic data bases, almanac programs, and personnel stress programs. This program covers historical data of a specific city or area by city name or latitude and longitude. It covers items such as absolute maximum temperature, daily maximum temperature, average monthly temperature, maximum and average monthly precipitation, and average wind speed by hour. This information can be very useful to the planner of an operation.

707. SOIL TESTS

Many of the characteristics of soil which are important in military operations can be obtained only by performing certain tests. Some of these tests are difficult and time-consuming. Most engineer units can perform these tests. Detailed information on these tests is provided in FM 5-530, Materials Testing, and FM 5-541, Military Soils Engineering. Appendix D explains the types of soil tests and the information gained from these tests.

a. Soil Trafficability. The ability of the soil to permit the movement of vehicles and personnel is soil trafficability. The principal soil characteristic affecting trafficability is its shear strength. Shear strength and the other soil factors affecting trafficability are described in paragraph 307.

b. Reconnaissance. There is no substitute for field examination of soils to determine their characteristics. Although reconnaissance permits on-the-spot determination of a soil's characteristics, it requires considerable time, and such time may not be available. Moreover, areas to be studied frequently may be difficult to reach due to the nature of the terrain itself, time constraints, severe weather, or enemy action.

If the question is to determine trafficability immediately after the reconnaissance, it is necessary only to determine if the soil is strong enough to support the vehicles to be used. If such hasty inspections are to be valid, they should be made by people with extensive experience in soil analysis. In many places, a hasty determination can be made by simple inspection. In others, mainly in wet places, some soil trafficability testing will be necessary.

If the reconnaissance is made to determine trafficability conditions at some time in the future, it is necessary to determine the kind of soil and its natural drainage condition. Does the soil lie on sloping terrain where excess water runs off, or is it in depressions where water will remain and may also flow in from an adjacent slope? Is there evidence of seepage from upslope, or drainage obstruction downslope? Is the soil permeable? Is there an impermeable layer below the surface? Is there evidence of a high water table? Answers to such questions, along with climatic data, are necessary to predict if and when the soil is likely to be wet.

c. Maps and Reports. If soils cannot be examined in the field, the next best means is reports and map studies. Analysts should seek soil maps and studies, and accompanying reports. However, material of this type may be scarce. The search must not be limited to items labeled "soils." Frequently there is information about soils, or at least clues to their characteristics, on maps and in reports concerning geology, geography, ecology, forestry, agriculture, climate, vegetation, and similar subjects.

d. Aerial Photographs. See paragraph 703.

708. ENGINEER UNITS

Engineer units can perform soil tests and analyze surface material to determine its suitability for field fortifications, drainage, and trafficability.

709. ENGINEER SECTION, DIVISION HEADQUARTERS

a. The engineer officer has staff responsibility for preparation of an engineering study.

b. The engineer section of a Marine division headquarters is capable of --

(1) Preparing engineering studies, particularly from the engineer's viewpoint.

(2) Providing advice and technical supervision on camouflage matters.

(3) Planning and technically supervising construction of defensive works.

710. G-2 SECTION, DIVISION HEADQUARTERS

The G-2 section of a Marine division headquarters is capable of --

a. Requesting aerial photographs and related products.

b. Determining requirements for maps, charts, graphic aids, and imagery with assistance from other division headquarters sections.

711. FORCE IMAGERY INTERPRETATION UNIT

Force imagery interpretation units are capable of --

a. Planning, collecting, and disseminating aerial imagery required by the MAGTF.

b. Planning, collecting, and disseminating information obtained from the aerial reconnaissance effort.

c. Interpreting imagery and preparing imagery interpretation reports.

712. TOPOGRAPHIC PLATOONS

a. The mission of the topographic platoons is to provide tailored mapping, charting, and geodetic products and services to the Marine expeditionary forces (MEF) and other MAGTFs .

b. The topographic platoons are organic to the intelligence company, surveillance, reconnaissance, intelligence (SRI) groups, and are organized into a headquarters, cartographic/terrain analysis, and geodetic/hydrographic sections. The topographic platoons are intended to support MAGTFs of all sizes. Terrain analysis and geodetic/hydro-graphic survey teams may be employed simultaneously to fulfill a mapping, charting, and geodetic (MC&G) requirement of the MAGTF.

c. Terrain analysis teams can provide tailored, mission-oriented, topographic map products as a supplement to standard Defense Mapping Agency (DMA) maps and charts. Geodetic survey teams provide the positional data necessary for the effective employment of command, control, communications, navigation, and weapons delivery systems. Hydrographic survey teams collect riverine, port, harbor, and near-shore coastal hydrographic data to support the

MAGTF's operational plans and objectives. The topographic platoons collect, analyze, synthesize, and disseminate terrain information to support combat intelligence efforts.

d. All special MC&G products should be requested from the topographic platoon within a MEF prior to requesting DMA support.

713. DEFENSE MAPPING AGENCY

a. The Defense Mapping Agency (DMA) is responsible for providing mapping, charting, and geodetic support by producing and distributing maps, charts, and geodetic and digital data for tactical operations. To help commanders understand as much as possible about the battlefield, the Defense Mapping Agency prepares and provides basic data. This data is reviewed by the topographic platoons' terrain teams. There are two standard formats for this data: a planning terrain analysis data base (PTADB) at a scale of 1:250,000 and a tactical terrain analysis data base (TTADB) at a scale of 1:50,000. These scales coincide with the planning and tactical maps used by Marine Corps units and the planning maps used at joint and combined commands. Terrain data bases include terrain factor overlays with the following information:

- Vegetation (summer/winter)
- Surface materials (soils)
- Surface drainage
- Surface configuration (slope)
- Obstacles
- Transportation (lines of communications (LOC))
- Ground water (planning data base only)

The following products are printed on a subdued base map:

- Cross-country movement (CCM) map.
- Transportation maps (road and bridge information)

See FM 34-130, Intelligence Preparation of Battlefield, for additional information on digital products. See appendix F for a terrain studies checklist.

b. DMA's products are listed in catalogs under the following categories: aerospace, hydrographic, topographic, air target, submarine navigation, and general purpose. These standard products are listed in the DOD Defense Mapping Agency Catalog of Maps, Charts, and Related Products. This multivolume catalog is held by division, wing, FSSG, and SRI Group headquarters. DMA's products and services are requested through G/S2 sections.

c. DMA can also produce special products such as one-time area coverage by a map, chart, or data base (data overprints on existing products, formatting of digital and analog data, computer/plotter support), photographic support, geodetic and geophysical surveys, technical data, and special studies. However, DMA's primary efforts are devoted to the standard products listed above. Users should request special products from the topographic unit supporting them before requesting DMA to produce a special product.

714. SATELLITE PHOTOGRAPHS/IMAGERY

a. General knowledge of the terrain is essential to military operations. This knowledge has traditionally been stored or displayed on maps. Today geographic information systems (GIS) or Marine expeditionary force (MEF) multispectral imagery workstations (MMIW) are using multispectral imagery

(MSI) from Landsat and Spot satellite systems for a storehouse of terrain information. GIS provides users with the capability to collect data in a digital form from maps, MSI, survey data, tables, and tests. Once data has been analyzed, users can select a variety of ways to display the results. Among the various choices of output are maps, perspective views, diagrams, or tables. The capability to answer specific questions in different ways extends applications of GIS beyond the traditional paper map, which must be read by the user in order to extract information.

b. Three Marine expeditionary forces MMIWs are operational and are deployed in the topographic platoons or the SRI groups.

APPENDIX A

REFERENCES

1. This manual is only an introduction to weather and terrain. This appendix lists publications with additional information. Some of these manuals provide technical information such as how to determine soil types. Other manuals and books are military histories which record the interaction of weather, terrain, equipment, and personnel. These histories help Marines to understand how the technical information can be applied effectively.

2. Publications with prefix control numbers (PCNs) are stocked at the Marine Corps Logistics Command, Albany, GA 31704-5001, and can be ordered through the supply system. See section 3 of chapter 3, MCO P5600.31F, Marine Corps Publications and Printing Regulations, or chapter 11 of MCO 4400.84C, Special Programs Manual, for instructions on ordering these and other publications.

3. Publications of other Services which are not stocked at Albany, Georgia, may be ordered by following the instructions in paragraph 3300.8 of MCO P5600.31F.

4. Operational Handbooks are stocked at the Marine Corps Combat Development Command. They can be ordered from the Commanding General (WF12), MCCDC, Quantico, Va. 22134-5001. To order by telephone, call AUTOVON 278-3610/8, commercial (703) 640-3610/8.

Marine Corps Publications

FMFRP 0-51	Small Unit Leader's Guide to Weather and Terrain PCN: 140 000510 00

FMFRP 0-52	Remote Sensing Field Guide, Desert: A Guide to Analysing Desert Landforms PCN: 140 000520 00
FMFRP 0-53	Afoot in the Desert PCN: 140 000530 00
FMFRP 0-54	The Persian Gulf Region, A Climatological Study PCN: 140 000540 00
FMFRP 0-55	Desert Water Supply PCN: 140 000550 00
FMFRP 0-56	Southwest Asia: Environment and Its Relationship to Military Activities PCN: 140 000560 00
FMFRP 0-57	A Study of Windborne Sand and Dust in Desert Areas PCN: 140 000570 00
FMFRP 0-58	Problems in Desert Warfare PCN: 140 000580 00
FMFRP 0-59	The Environment and its Effects on Materiel, Personnel and Operations with Special Emphasis on the Middle East PCN: 140 000590 00
FMFRP 0-60	General Design and Construction Criteria for Kuwait PCN: 140 000600 00
FMFM 5-3	Assault Support Helicopter (ASH) Tactical Manual PCN: 139 000356 00

FMFM 7-20	Marine Air-Ground Task Force Planning and Training for Cold Weather Operations PCN: Not yet assigned.
FMFM 7-21	Tactical Fundamentals for Cold Weather Warfare PCN: Not yet assigned.
FMFM 7-22	Tactical Fundamental for Aviation in Cold Weather Operations PCN: Not yet assigned.
FMFM 7-23	Small Unit Leader's Guide to Cold Weather Operations PCN: 140 072300 00
FMFRP 7-25	Marine Ski Instruction Manual PCN: Not yet assigned.
FMFM 11-3A	Field Behavior of NBC Agents PCN: 139 711800 00
FMFRP 12-2	Infantry in Battle PCN: 140 120200 00
FMFRP 12-3	Artillery in the Desert PCN: 140 120300 00
FMFRP 12-4	Battlefields of the World War PCN: 140 120400 00
FMFRP 12-5	Combat Support in Korea PCN: 140 120500 00
FMFRP 12-6	Commentary on Infantry Operations and Weapons Usage in Korea PCN: 140 120600 00
FMFRP 12-8	Topography and Strategy in the War PCN: 140 120600 00
FMFRP 12-9	Jungle Warfare PCN: 140 120900 00

FMFRP 12-15	Small Wars Manual PCN: 140 121500 00
FMFRP 12-16	Front-Line Intelligence PCN: 140 121600 00
FMFRP 12-20	Naval Reconnaissance PCN: 140 122000 00
FMFRP 12-28	The Door Marked Malaya PCN: 140 122800 00
FMFRP 12-34	History of U.S. Marine Corps Operations in World War II (in five volumes) PCNs: 140 123401 00, 140 123402 00, 140 123403 00, 140 123404 00, and 140 123405 00
FMFRP 12-36	Down in the North PCN: 140 123600 00
FMFRP 12-41	Professional Knowledge Gained from Operational Experience in Vietnam--1967 PCN: 140 124100 00
FMFRP 12-42	Professional Knowledge Gained from Operational Experience in Vietnam--1968 PCN: 140 124200 00
FMFRP 12-78	The White Death: The Epic of the Soviet-Finnish War PCN: 140 127800 00
OH 0-3A	Operational Effects of Terrain and Weather

<u>Other Publications</u>

ATP 17	Naval Arctic Manual (Distributed through COMTAC/Navy publications supply system.)
FM 5-30	Engineer Intelligence PCN: 320 005160 00

FM 5-36	Route Reconnaissance and Classification PCN: 320 005240 00
FM 5-100	Engineer Combat Operations PCN: 320 005250 00
FM 5-101	Mobility PCN: 320 005251 00
FM 5-102	Countermobility PCN: 320 005252 00
FM 5-103	Survivability PCN: 320 005253 00
FM 5-104	General Engineering PCN: 320 005254 00
FM 5-335	Drainage PCN: 320 006033 00
FM 5-530	Materials Testing PCN: 320 006040 00
FM 5-541	Military Soils Engineering PCN: 320 060500 00
FM 21-26	Map Reading PCN: 320 021240 00
FM 21-31	Topographic Symbols PCN: 320 021280 00
FM 21-75	Combat Skills of the Soldier PCN: 320 021400 00
FM 31-70	Basic Cold Weather Manual PCN: 320 031360 00
FM 31-71	Northern Operations PCN: 320 031380 00
FM 34-3	Intelligence Analysis PCN: 320 033090 00
FM 34-81	Weather Support for Army Tactical Operations

FM 34-130	Intelligence Preparation of the Battlefield PCN: Not yet assigned.
FM 90-3	Desert Operations PCN: 320 083000 00
FM 90-5	Jungle Operations PCN: 320 083200 00
FM 90-6	Mountain Operations PCN: 320 083400 00
FM 90-13	River Crossing Operations PCN: 320 083750 00
FM 101-5-1	Operational Terms and Symbols PCN: 320 101122 00
TM 5-349	Arctic Construction PCN: 346 001220 00
TM 5-545	Geology PCN: 346 001550 00
DA PAM 20-231	Combat in Russian Forests and Swamps PCN: 305 006912 00
DA PAM 20-236	Night Combat PCN: 305 006917 00
DA PAM 20-269	Small Unit Actions During the German Campaign in Russia PCN: 305 006952 00
DA PAM 20-290	Terrain Factors in the Russian Campaign PCN: 305 006973 00
DA PAM 20-291	Effects of Climate on Combat In European Russia PCN: 305 006974 00
DA PAM 20-292	Warfare in the Far North PCN: 305 006975 00

Geography of Warfare, Patrick O. Sullivan and
se W. Miller, St. Martins Press, 1983

APPENDIX B

GLOSSARY OF COMMON TERRAIN INTELLIGENCE TERMS

Air Pressure. The weight of the atmosphere from the level of measurement to the top of the atmosphere. Normally measured with a mercurial barometer, the standard measurement at sea level is 29.92 inches or 1013.0 millibars.

Alluvial fan. A gently sloping fan shaped mass of unconsolidated sand, gravel, silt or similar material deposited by a stream at the place where it emerges from an upland into a broad valley or a plain. It may be several feet to a number of miles across. Distinguished from Alluvial Cone, which is small, and has steeply sloping surfaces.

Alluvial terrace (river terrace). Commonly an elongated and relatively narrow shelf or nearly horizontal surface which interrupts the sloping side of a stream valley; it is a remnant of a former flood plain at a higher level.

Alluvium. An aggregate of loose, more or less rounded particles of rock or mineral matter (clay, silt, sand, pebbles, cobbles, and boulders) deposited by running water.

Arroyo. The channel of an intermittent stream, usually with vertical banks of unconsolidated material 2 feet to 30 feet high, generally in arid regions. See wadi.

Badlands. An area of hills consisting of an intricate maze of narrow ravines, sharp crested ridges, and pinnacles; virtually devoid of vegetation and characteristic of areas of soft, fine textured rocks in arid regions.

Barometer. An instrument used for measuring the atmospheric pressure and usually containing the element mercury. "Normal" measurements are 30 inches or 760 millimeters or 1013 millibars.

Bayou. A relatively minor, sluggish waterway or estuarial creek, generally tidal or characterized by a slow or imperceptible current, and with its course generally through lowlands or swamps, tributary to or connecting other streams or bodies of water.

Bearing capacity. The ability of the soil to enable a vehicle to develop the forward thrust necessary to overcome its' rolling resistance.

Bluff. A high, steep bank or cliff, commonly bordering a stream valley. Generally applied to formations of soft materials, as contrasted to rock cliffs.

Bottom land. Lowland bordering a stream or lake or occupying a former lake basin, floored with sediment; a flood plain or a lake plain. (See sediment, flood plain).

Boulder. A more or less rounded piece of rock 256mm (approximately 10 inches) or more in diameter.

Boundary. In land warfare, a line by which areas of responsibility between adjacent units/formations are defined (JCS Pub 1).

Broad gauge. (Wide gauge) railroad: See railroad.

Brush. A growth of shrubs, bushes, small trees and vines; commonly difficult to penetrate on foot.

Bulwark. A protective barrier.

Bund. An embankment, dike or mound; as a paddy-bund. In China and the Far East, a causeway or an embankment; esplanade; quay. Specifically, the thoroughfare on the waterfront; as "bund at Yokohama".

Butte. A flat topped hill of small summit area, capped by a layer of hard rock and bounded for most of its circumference by steep slopes (escarpment); characteristic of dry regions. (See mesa, cuesta.)

Caldera. A large basin-like crater, especially one that is broad as compared to its depth, faced by steep slopes or cliffs. It is formed by the subsidence of the summit of the volcano or the decapitation of the summit or most of the volcanic cone by an explosive eruption.

Canal. An artificial watercourse, usually having relatively uniform width and depth.

Canalize. To restrict movement to a narrow front by natural or man-made obstacles.

Canyon. A deep, steep sided stream valley.

Causeway. A raised road, as over marshy ground or through shallow water on a solid structure of masonry and/or earth.

Cinder cone. A steep sided volcanic cone composed of course cinder-like and/or cellular fragments of lava (scoria and pumice).

Clay. An aggregate of unconsolidated, commonly flat, extremely fine particles of mineral matter less than .004 mm in diameter. Distinguished from silt by the fact that it is plastic and commonly slippery and adhesive when wet. See silt, sediment.

Cliff. A relatively high, steep face of rock. See bluff.

Climate. Climate is the average weather condition at a place over an extended period, usually more than ten years.

Cloud. A mass of small water drops or ice crystals formed by the condensation of the water vapor in the atmosphere.

Cobble. A more or less rounded piece of rock having a diameter not less than 64 mm (approximately 2.5 inches) nor more than 256 mm (approximately 10 inches); commonly about fist size. Cobbles are larger than gravel but smaller than boulders.

Cohesiveness. A characteristic of particles of soil to stick together.

Compartment of terrain. A terrain area bounded on at least two sides by terrain features such as woods, ridges, or valleys which limit terrestrial observation and observed fire into the area from points outside.

Complex compartment. This is a compartment having a smaller compartment, or compartments, within it. This is the type of compartment most often encountered in the field.

Concealment. Protection from observation or surveillance.

Contour line (contour). (1) An imaginary line on the land surface or sea floor connecting points of equal elevation, (2) A line drawn on a map to connect points of equal elevation; represented as a solid line in contrast to Form line, which is dashed. See form line.

Coral. A stoney mass composed of the calcareous external skeletons of various soft bodied marine polyps; characteristic of clear, warm tropical seas.

Corridor. A relatively narrow terrain compartment limited laterally by natural terrain obstacles and having its long dimension oriented in the direction of movement or toward the objective.

Counterslope. A forward slope of a hill to the rear of a reverse slope.

Cover. Shelter or protection, either natural or artificial (JCS Pub 1).

Crest. A terrain feature of such altitude that it restricts fire or observation in an area beyond, resulting in dead space or limiting the minimum elevation or both (JCS Pub 1).

Cross compartment. A compartment whose axis is perpendicular or oblique to the direction of advance

Cross-country movement map. A map that indicates the trafficability of the areas shown on the map.

Cuesta. A ridge or hill having one gentle slope (dip slope) and one steep slope or cliff (escarpment).

Cultural feature. A feature of the terrain that has been constructed by man. Included are such items as roads, buildings, and canals.

Culture. A feature of the terrain that has been constructed by man. Included are such items as roads, buildings, and canals; boundary lines; and, in a broad sense, all names and legends on a map (JCS Pub 1).

Datum (geodetic) A reference surface consisting of five quantities: the latitude and longitude of an initial point, the azimuth of a line from that point, and the parameters of the reference ellipsoid (JCS Pub 1). See geographic reference datum.

Datum level. A surface of which elevations, heights, or depths on a map or chart are related (JCS Pub 1).

Datum point. Any reference point of known or assumed coordinated from which calculations or measurements may be taken (JCS Pub 1).

Deciduous. Trees and shrubs which shed their leaves seasonally or during periods of drought and low temperature (contrasted to evergreen).

Defilade. Protected from hostile observation and fire provided by an obstacle such as a hill, ridge, or bank (JCS Pub 1).

Defile. A narrow, low level corridor between non-trafficable terrain features such as hills, mountains, cliffs, lava flows, water bodies, or marshes; suitable for the passage of military forces on a narrow front. May include man-made bottlenecks such as bridges. (See pass.)

Delimiting lines. Imaginary lines drawn along limiting features from which ground observation into the compartment is limited.

Delta. A low, commonly marshy alluvial plain of either triangular or branching form, which develops at the mouth of a river in a sea, lake, or large, sluggish river by the deposition of silt, as a result of a sudden decrease in the velocity of the river waters.

Depression. An area of ground that is sunk below its surroundings.

Detritus. Loose rock fragments resulting from disintegration.

Dike. (Dyke) (1) An embankment or wall designed to prevent inundation or to delimit an area of reclamation or fill. (2) (geology) A tabular mass of igneous rock, vertical or steeply inclined in attitude; commonly left standing as a wall like surface feature by the erosion of enclosing softer rocks.

Distributary. A small stream which leads water away from a main stream; characteristic of deltas.

Drainage. Discharge of water from an area through a system of streams.

Draw. A natural drainage area, as in a gully, usually surrounded on two sides by steep slopes.

Drowned valley. A valley which has been flooded in its lower part by the water of a sea or lake as a result of the sinking of the land or, more commonly, of the rising of the water level.

Dune. A hill or ridge of wind deposited sand. Types: (1) Barchane dune - a crescent shaped dune characteristic of tropical deserts with prevailing winds, e.g., trade winds; (2) Linear dune - an elongated ridge generally parallel to a shore that is affected by land and sea breezes; (3) Irregular dune - a mound of indefinite shape which is characteristic of interior areas with shifting winds.

Embankment. An artificial bank, mound, or dike built to hold back water, carry a roadway, or for similar purposes.

Escarpment. A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion or faulting.

Evergreens. A term applied to trees and shrubs that experience no general period of leaf fall but remain green all year.

Fault. A fracture of bedrock attended by displacement of one side of the fracture with respect to the other.

Finger. A short continuously sloping line of higher ground normally jutting out from the side of a ridge. It is often formed by two roughly parallel streams cutting draws down the side of the ridge. See Spur.

Flank. The right or left side, when facing in the direction of the objective or viewed from seaward; normally identified by compass bearings.

Flood plain. The alluvial plain, bordering a stream, built up of successive deposits laid down during floods. (See alluvial terrace.)

Fog. Condensed water vapor in cloudlike masses close to the ground and limiting visibility.

Foothill. One of the minor elevations of a mountain range, which mark the transition to adjacent lower land. Commonly used in the plural.

Forecast. To estimate through the analysis of meteorological data and to predict in advance the conditions of weather for a given time and place.

Form line. A line drawn on a map or a sketch to show the shape of the terrain, resembling a contour line but not based on accurately determined elevations; unlike a contour line it is commonly dashed.

Forward slope. That portion of the slope of a terrain feature forward of the topographic crest and facing the enemy.

Front. A line at the earth's surface where warm and cold air masses meet producing changes in weather patterns and temperatures.

Geographic reference datum (horizontal datum or geodetic datum). The intersection of a designated parallel and meridian (commonly the equator and the meridian of Greenwich) to which horizontal positions are referred. See datum.

Glacier. A mass or stream of ice formed on land by the partial melting and refreezing of snow in an area where the total annual snowfall exceeds the total melting, and moving slowly outward from its place of origin under the influence of gravity.

Going map. See cross-country movement map.

Gorge. A deep, narrow valley or canyon.

Gradient. The slope or inclination of a line or surface as compared to the horizontal, usually expressed as a ratio.

Gravel. An aggregate of loose, more or less rounded fragments of rock or mineral, larger than sand, smaller than cobbles. Diameters range from 2 mm to 64 mm (approx. 0.08 in to 2.5 in). Individual pieces of gravel are pebbles.

Gulf. A relatively large sea area, partly enclosed by land; larger than a bay. (See bay.)

Gully. A small, steep sided, V-shaped ditch formed in clay or similar soft material by the erosive action of running water during and immediately after heavy rains; distinguished from arroyo which has perpendicular sides and a flat floor.

Headland (head). A comparatively high promontory with a steep or cliffy face.

High mountain. See mountain.

Hill. A natural elevation of the land, usually somewhat rounded (except in badlands) and having a summit elevation not more than 1,000 feet above the lowest land or water surface that immediately adjoins the individual eminence.

High hill. A hill having a summit elevation of more than 500 feet but not more than 1,000 feet above the lowest land or water surface that immediately adjoins the individual eminence.

Low hill. A hill having a summit elevation less than 500 feet above the lowest land or water surface that immediately adjoins the individual eminence. Hills having differences of elevation of 300 feet or less may occur on a plain.

Hogback. A ridge with a sharp crest and steeply sloping sides, usually formed by the outcropping edge of an inclined rock layer. Contrast to cuesta.

Hook. A spit or narrow cape, turned at the outer end, resembling a hook in form.

Humidity. The state of the atmosphere with respect to the amount of water vapor it contains.

Hummock. (1) A small low elevation, hillock. (2) A mound or ridge of ice on an ice field.

Hydrography. The science of measuring and studying oceans, seas, rivers, and other waters with their marginal land areas, inclusive of all the fundamental elements which have to be known for safe navigation of such areas, and the publication of such information in suitable form for the use of navigators.

Incised valley. A relatively deep, steep sided valley formed in a plateau or other upland by stream erosion. Narrow, deeply incised valleys are canyons.

Intermittent stream. A stream that flows only during, and for short periods after, rains or periods of snow melt; characteristic of dry areas.

Jungle. (1) (popularly) An impenetrable growth of vegetation or an area having such a growth. (2) (specifically) The transition zone between the rain forest and the savanna, characterized by an impenetrable growth of brush, low trees and tall, coarse grass. The jungle is characteristic of tropical areas with heavy rainfall and brief dry seasons.

Karst. A type of topography developed on plateaus or relatively high plains having limestone or other soluble bedrock; characterized by enclosed depressions, underground drainage, and caves. Small funnel-sshaped depressions called sink holes or dolines are numerous in early states of development. Later, these merge to form elongated depressions (valley sinks); still later, steep sided hills with rounded crests, enclosed basins, and limestone pinnacles are characteristic.

Knoll. A small round hill or mound.

Knot. The unit of speed used in navigation; equals 1 nautical mile (6,076.1033 feet) per hour.

Landing place. Any natural or man-made feature located at the shoreline where troops and equipment may be debarked (other than a landing beach or established port facility). It does not permit satisfactory deployment and/or maneuverability for major elements of assault troops particularly during an opposed landing. The term may be applied to a small beach or to a pier that is not part of an established port.

Lava and lava flow. (1) A general term for the molten outpouring of a volcano or fissure. (2) Igneous rock commonly dark colored which has been poured out upon the surface in a molten state and there solidified, usually in sheets. It may be glassy (obsidian) or fine grained (basalt, rhyolite or similar rocks).

Ledge. (1) A ridge or reef, especially one under water near the shore. (2) A narrow flat shelf, especially one that projects from a wall of rock.

Lee. (1) Shelter, or the part or side sheltered or turned away from the wind or waves. (2) (Chiefly nautical) The quarter or area toward which the wind blows.

Leeward. The direction toward which the wind is blowing; the direction toward which waves are traveling (contrast to wind direction).

Levee. A dike or embankment intended to protect land from inundation. (See natural levee, dike.)

Limiting features. Features, either natural or manmade, that limit or prevent ground observation.

Littoral. (1) That part of the shore which is exposed at low tide and covered at high tide. (2) Of or pertaining to a shore, a coastal region.

Loess. A deposit of wind blown dust or silt, usually buff in color, which stands in vertical bluffs.

Low hill. See hill.

Low mountain. See mountain.

Lunar day (tidal day). A day measured by the interval between two successive transits of the moon over the meridian of the observer. The mean lunar day has a length of approximately 24.84 solar hours or 1.035 times the length of the main solar day.

Macro-relief features. Large features of the earth's surface such as mountains, peaks, ranges, cliffs, and canyons.

Mangrove swamp. An inundated tropical coastal area supporting a dense growth of mangrove trees; most extensive in brackish water near river mouths. The trees stand above high tide on prop roots which, at low water, constitute an impenetrable tangle, covered with algae and standing in mud.

Marine railway. An inclined track together with a wheeled cradle and winding mechanism used to draw ships out of the water and onto the shore.

Marsh. A tract of soft, wet, or periodically inundated, essentially treeless land that is characterized by the presence of grasses, cattails, and other similar plants. See swamp.

Meander. One of a series of rather regular bends of a river or smaller stream, developed by the lateral shifting of the course; shifting results in widening of the valley and the development of a flood plain.

Mesa. A relatively extensive, flat topped hill, capped by a layer of hard rock and bounded for most of its circumference by steep slopes or cliffs (escarpments). Characteristic of dry regions. Compare butte (less extensive than mesa) and cuesta (sloping upper surface, escarpment on high side).

Micro-relief features. Small features of the earth's surface such as gullies, mounds, low escarpments, sink holes, and small pinnacles.

Mile, nautical. A unit of measure equal to 6,076.1033 feet or approximately the length of one minute of latitude on the surface of the earth at the equator. (See knot).

Mile, statute. A unit of measure equal to 1,760 yards or 5,280 feet; used in measuring distances on land.

Military crest. The highest point on a hill or ridge from which good observation down the sides of the hill can be obtained. (This may not be the same as the topographic crest which is the highest point on a hill.)

Mole. A massive, solid wharf structure of large size and broad surface located in a harbor or anchorage. It may serve as a breakwater. Its sides may be constructed for berthing vessels.

Monsoon. A seasonal wind that blows from sea to land in summer and from land to sea in winter in response to the differential heating and cooling of land and sea; associated with large continents and the seas and islands adjoining them. (The onshore (summer) monsoon causes heavy rains on coasts and especially on the seaward sides of hills and mountains. The offshore (winter) monsoon causes clear, dry weather.)

Moon, phase. One of the recurring aspects or appearances of the moon. Phases are 7 lunar days apart, as follows: (1) New moon (moon is not visible), (2) First quarter (moon is one-half illuminated), (3) Full moon, (4) Last quarters (moon is one-half illuminated). (See lunar day.)

Moor. An extensive area of waste ground, essentially treeless, covered with peat, and usually more or less wet.

Moraine. A glacial deposit consisting of a heterogeneous mixture of clay, sand, gravel, cobbles and boulders, laid down directly by the ice instead of by streams or lakes associated with a melting glacier. Principal types:

> **Ground moraine.** A layer of material deposited by a glacier covering an area up to thousands of square miles and consisting principally of mixed clay, sand, and gravel, together with minor amounts of cobbles and boulders; characterized by swell and swale topography.

> **Marginal moraine.** A winding ridge formed along the front of a glacier by the deposition of boulders and cobbles mixed with smaller amounts of gravel, sand, and clay.

Mountain. An eminence, peak or ridge, either isolated or part of a group or range, having a summit more than 1,000 feet above the lowest immediately contiguous land or water surface; generally characterized by steeply sloping sides and small summit area (in contrast to plateau which has an extensive summit area).

> **High mountain.** A mountain having a summit elevation more than 3,000 feet above the lowest immediately contiguous land or water surface.

> **Low mountain.** A mountain having a summit elevation more than 1,000 feet but not more than 3,000 feet above the lowest immediate contiguous land or water surface.

Mud. A fluid to plastic mixture of clay and/or silt and water.

Mud flat. A deposit of mud in a bay or river, having a level upper surface which is covered by water at high tide (tidal flat) or at high water in the river.

Narrow gauge railroad. See railroad..

Nautical mile. See mile, nautical.

Obstacle (obstruction). Any terrain feature or object, either natural or manmade, which impedes free movement to the objective.

Obstructed approach. An approach which includes such serious dangers to navigation as to make safe passage improbable.

Overfalls. Breaking waves caused by a conflict of currents or by wind moving against the current.

Oxbow lake. A curved, elongated lake formed in an abandoned river meander (bend) that has become isolated from the main stream.

Paddy. An irrigated field devoted to wet rice cultivation. It is bounded by low ridges or dikes and is completely covered by shallow water for considerable periods of time.

Pass. A narrow gap or terrain corridor which affords a relatively easy route across a mountain range; situated usually on the divide and at a relatively high elevation but commonly lower than adjacent parts of the divide. Distinguished from defile by its higher elevation and its essential association with mountains. See river pass.

Path. A trodden way; a footway. (See trail.)

Pebble. A more or less rounded piece of rock having a diameter of 2 mm to 64 mm (0.08 to 2 1/2 inches); larger than sand; smaller than cobble; collectively called pebbles or gravel.

Perennial stream. A river or small stream which flows throughout the year. (See intermittent stream).

Permafrost. Permanently frozen subsoil characteristic of polar areas.

Pinnacle. An isolated spire shaped pillar of rock either on land or in the sea.

Plain. An area lacking prominent hills and lying at low elevation or at least not markedly above adjacent areas. Characterized by local differences of elevation of 300 feet or less and surface slopes typically low and rarely exceeding 14 percent (14 feet rise per 100 feet). Distinguished from hill (differences of elevation exceeding 300 feet and slopes commonly steeper than 14 percent), and plateau (sharp drop on at least one side, differences of elevation more than 300 feet and streams flowing in canyons or gorges). Note that plains may have upon them low hills having differences of elevation of 300 feet or less.

Plateau. An elevated area characterized by a relatively level upper surface many miles across and a sharp drop in at least one place to an adjoining area at least 300 feet lower. Plateau streams typically flow in canyons.

Playa. (1) The bed of a temporary lake in a dry climate; commonly relatively level and floored with deposits of clay and silt having a high content of salt and/or alkali and typically very slippery and sticky when wet. Sometimes called dry lakes, or, if extremely alkaline or salty "alkali flats," "salt flats," or "salinas." (2) A Spanish word meaning "beach."

Port. A harbor or other water area together with terminal facilities for the transfer of passengers and/or cargo.

Precipitation. Condensation in the form of rain, sleet, hail, or snow that reaches the surface of the earth from the atmosphere.

Promontory. A high point of land extending into a body of water; a headland.

Quay (pronounced key). A stretch of paved bank or solid artificial landing place built against and parallel to the bank of a navigable waterway; used for loading and unloading vessels.

Quicksand. Fine sand suspended in water so that heavy objects sink in it. Draining will remove the "quick" property.

Railroad:

Broad gauge railroad. A railroad on which the rails are spaced more than 4 feet 8 1/2 inches apart.

Narrow gauge railroad. A railroad on which the rails are spaced less than 4 feet 8 1/2 inches apart.

Standard gauge railroad. A railroad on which the rails are spaced 4 feet 8 1/2 inches apart.

Rain Forest (tropical rain forest). A type of forest characteristic of the rainy tropics; having a dense stand of trees of two general heights, a dense mat of vines in the tree tops, and a virtual absence of underbrush. Rain forest is most extensive on plains but also is common on hills and the lower slopes of mountains. It is distinguished from jungle which has dense, impenetrable ground growth.

Ravine. A steep sided, gorge like feature of the land surface, larger than a gully and smaller than a valley, which is developed by the action of running water. Unlike a gully, it may contain a small perennial stream.

Reef. A chain or range of rock or coral rising from the bottom of the sea, usually submerged and dangerous to surface navigation.

Relative Humidity. The ratio between the actual amount of water vapor in a given volume of air and the amount which would be present if the air were saturated at the same temperature; usually expressed as a percentage, thus affording a measure of the relative dampness of the air.

Relief. (1) Inequalities of elevation and the configuration of land features on the surface of the earth that may be represented on maps or charts by contours, hypsometric tints, shading, or spot elevations (JCS Pub 1). (2) the features (as hills and valleys) of a land surface or sea floor considered collectively; individually called "relief features."

Reverse Slope. That portion of the slope of a terrain feature on the opposite side of the topographic crest facing away from the enemy.

Rift Valley. A relatively long, narrow, trough like valley formed by the sinking of a strip of the earths' crust between two approximately parallel and opposed faults or zones of faulting.

River Pass. A navigable channel, especially at a river mouth.

Rubble. (1) Loose, large, angular, water worn stones along a beach; (2) Rough, irregular fragments of broken rock; (3) Debris from wrecked masonry structures.

Runnel. (1) Loose, large, angular, water worn stones along a beach; (2) Rough, irregular fragments of broken rock; (3) Debris from wrecked masonry structures.

Saddle. A low part of a ridge that connects two higher parts of the ridge. (See pass.)
Sand. An aggregate of loose, more or less rounded particles of mineral or rock larger than silt and smaller than gravel. Grain diameters range from 0.062 mm to 2 mm (approximately .08 inch). Particles are sufficiently large so that they will not cohere when wet (unlike clay and silt which have smaller particles). Areas of sand generally are more easily trafficable when wet than when dry, in contrast to areas of clay of silt.

Sandstone beach. A beach of coral sand that has become cemented by deposited lime.

Savanna. A tropical grassland typical of regions having distinct wet and dry seasons, and characterized by coarse grass, 3 feet to 12 feet high and scattered low trees. The grass becomes dry in the dry (less wet) seasons and commonly is burned off by the natives. Most savanna is associated with plateaus and plains.

Sea. (1) An ocean, or alternatively a large body of (usually) salt water less than the size of an ocean; (2) waves caused by wind of the place and time of observation; (3) State of the ocean, sea, or lake surface in regard to waves.

Sediment. An aggregate of unconsolidated particles of mineral or rock which has been transported and deposited by water, wind, ice, or the action of gravity. Sediment is classified according to diameter of particles as:

Clay--0.004 mm or less.
Silt--0.004 mm to 0.062 mm.
Sand--0.062 mm to 2.0 mm (approximately 0.08 inch).
Gravel--2.0 mm to 64 mm (approximately 0.08 inch to 2.5 inches).
Cobbles--64 mm to 256 mm (approximately 2.5 inches to 10 inches).
Boulders--larger than 256 mm (approximately 10 inches).

Shear Strength. The ability of a soil to support a load. (The principal factor affecting shear strength is its moisture content. Other factors determining its strength are grain size and shape, mineral composition, organic content, and density.)

Silt. (1) An aggregate of unconsolidated particles of mineral or rock, finer than sand and coarser than clay. Particles range in diameter from .004 mm to .062 mm. Unlike sand it coheres when wet; unlike clay, it has a silky feel when wet and is not plastic. (2) Fine material carried and deposited by a stream.

Slipperiness. A condition of deficient traction capacity in a thin layer of soil caused by a lack of cohesiveness due to the soil's high water content.

Slope. See gradient.

Slough. A minor muddy marshland or tidal waterway which usually connects other tidal areas; a tideland or bottom land creek.

Spur. A sharp branch or projection from the side of a hill or mountain.

Squall. A violent wind which rises suddenly, has a brief duration and dies suddenly. It is usually of only local importance and is generally associated with a temporary shift in wind direction.

Standard gauge railroad. See railroad.

Statute mile. See mile, statute.

Steppe. (1) A grassland of semi-arid regions that is characterized by short grass or bunch grass. Some steppe also has scattered dry land shrubs or low trees (bush steppe or three steppe). Steppe is characteristic of level to rolling areas; (2) in popular usage, one of the vast grass covered, essentially treeless plains of southeastern Europe and parts of Soviet Asia.

Stream. (1) A course of water flowing through an elongated depression in the earth's surface. (2) a current in the sea such as the Gulf Stream. (See intermittent stream, perennial stream.)

Swamp. A tract of wet land, frequently inundated by fresh or salt water, and characteristically dominated by trees and shrubs. (See marsh.)

Syoptic. A plotting on a map of detailed weather information representing a large number of observations and covering a wide range of areas and conditions.

Tableland. A general term applied to uplands of greater or less exten' having relatively level upper surfaces and bounded, at least in part, by cliffs, or steep slopes. (See mesa, plateau.)

Talus. A sloping heap of loose angular rock fragments lying at the foot of a cliff or steep slope (in British usage, called scree.)

Temperature. The degree of hotness or coldness of the environment influenced by such factors as latitude, elevation, prevailing winds proximity to water, and relative humidity.

Terrace. A shelf or nearly horizontal surface that interrupts a steeper slope; commonly elongated and relatively narrow, of erosional, depositional or cultural origin and usually found along river banks and valleys or the shores of seas and lakes. (See flood plain.)

Terrain. The geographic character of the earth's surface in any given area.

Topographic crest. The highest point on a hill or ridge.

Topography. A detailed description or representation of the features, both natural and artificial, of an area, including its relief and such features as roads, railways, and canals.

Track. An upgraded, unsurfaced road, usually passable only in dry weather; commonly a single pair of ruts on the natural land surface.

Traction capacity. See Bearing Capacity.

Trafficability. The ability of the land surface to sustain the flow of military traffic. It refers to the extent to which the terrain will permit continued movement of any and/or all types of movement.

Trail. A route through a wilderness or wild region. (A path becomes a trail if it is blazed or otherwise marked.)

Training wall. A structure of masonry or masonry and earth, similar to a jetty; used to direct the flow of current in a river in order to stabilize and deepen the channel and also to prevent the erosion of the river banks. (A training wall differs from a groin in that it is usually aligned parallel to the channel and the direction of water flow.)

Tramway. A street railroad, a light railroad for temporary use; any roadway having rails upon which wheeled vehicles may operate; an overhead railway as used in lumber camps.

Tropical rain forest. See rain forest.

Tundra. An area of level to undulating land in polar areas or the high altitude zones of mountains in the middle latitudes or the tropics, in which the vegetation consists of a low dense mat of grasses, mosses, lichens and various low, hardy flowering plants. These are associated with black, mucky soil and permanently frozen subsoil (permafrost.)

Valley. A reasonably level ground bordered on the sides by higher ground. (It may or may not contain a stream course, and it generally has maneuver room within its confines. Contour lines indicating a valley are U-shaped and tend to parallel a stream before crossing it. The direction of the contour line crossing the stream will always point upstream.)

Vegetation. Plant growth. (Vegetation may be classified as cultivated (crops and orchards tended by man), and non-cultivated (grasses, bushes, and trees growing without man's assistance.) A study of vegetation should include density, height, and type of growth, and the diameters of trees. It may restrict our view of the enemy or enable us to conceal ourselves from him. Movement can be made very difficult.)

Volcanic ash. The fragments of volcanic rock, both coarse and fine, formed when included gases escape violently from molten lava during an eruption. Consolidated volcanic ash is classified as (a) volcanic breccia (coarse fragments cemented together) or (b) tuff (fine particles cemented together.)

Wadi. An Arab term equivalent to arroyo; the channel of an intermittent stream, usually having a flat floor and vertical banks of unconsolidated or slightly consolidated clay, silt, or shale. Wadis occur in North Africa, Arabia, and other neighboring desert areas. They may be larger than the arroyos of southwestern United States.

Water gap. A narrow, low gap or defile through a mountain ridge, which was developed by stream erosion and is still occupied by a large stream. (See wind gap.)

Weather. The condition of the atmosphere at any given time and place as described by various meteorological phenomena such as atmospheric pressure, temperature, humidity, rainfall, cloudiness, snow, hail, sleet, and wind speed and direction.

Wind. Air in natural, more or less horizontal motion.

Wind direction. The direction from which the wind is blowing.

Wind gap. A narrow low level gap or defile through a mountain ridge, which was developed by stream erosion, originally a water gap but not now occupied by the large stream which formed the gap.

Wind, offshore. A wind blowing seaward over the coastal area.

Wind, onshore. A wind blowing landward over the coastal area.

Wind rose. A diagram which indicates for a given station, the average percentage of wind coming from each of the principal compass points, together with the percentage occurrence of calm air. It usually consists of a central circle, in which the figure indicating the number of calm days for the reporting period is written and from which emanate eight bars, whose lengths are proportional to the percentage occurrence of the winds they represent.

Windward. The direction from which the wind is blowing.

APPENDIX C

USE OF DRAINAGE PATTERNS TO DETERMINE SURFACE CONFIGURATION AND COMPOSITION OF THE SOIL

1. **General.** The drainage pattern of an area can give one an insight into the area's surface configuration and soil. A drainage pattern is the pattern formed by all the streams and rivers of a given area. Knowing the different types of drainage patterns and the types of soils and surface configurations they denote, one can fairly accurately predict the amount of trafficability, cover, water supply and weapons employment to be encountered.

2. There are six basic drainage patterns that reflect different soil types and structures. The six basic patterns are the dendritic, trellis, rectangular, radial, annular, and parallel. Each one of these patterns is quite distinctive (see figure C-1) and are easily identified on topographical maps and aerial photographs

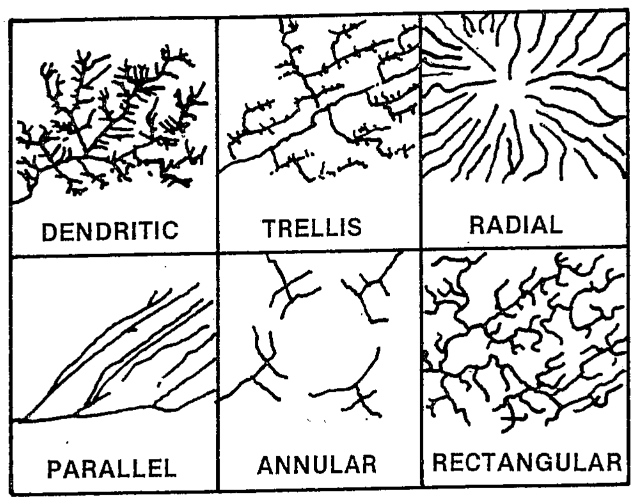


Figure C-1. Drainage Patterns

a. **Dendritic.** The dendritic pattern best resembles the branches of a tree spreading out in all directions and is the most common. This type of pattern denotes an area that was originally flat and composed of fairly uniform materials. The texture of this pattern is the biggest clue as to the surface material to be encountered and in turn a clue to the trafficability of the region. A finely textured pattern that has rounded, shallow cuts is indicative of a hard rock such as granite. The ground in this area can be expected to support most any military vehicle although cross-country movement may be impeded by large boulders. Digging in may be difficult if topsoil is scarce and water will be hard to come by in the dry season. Artillery rounds that have ground impact fuzes are very effective against personnel since surface penetration is minimal in this type of formation. Should the pattern be broad and deep cut, a softer material can be expected. The ability to support heavy equipment may be minimal, while digging in may be easier. In addition, ground impact artillery rounds will be less effective because of the great degree of surface penetration.

b. **Trellis.** The trellis drainage pattern resembles a vine trellis often seen in gardens. The pattern is fairly intricate with each section generally forming right angles to one another. The trellis pattern is characteristic of tilted and folded ground. The more trellis like the pattern, the greater the tilt and hence the greater the slope. This type of pattern forms an endless series of compartments which may prove to be a hindrance to troop movement. The same rules apply to the trellis pattern that apply to the dendritic. The more pronounced the pattern, the softer the material in which it is formed and therefore there is a reduction in the effectiveness of ground impact munitions on personnel. The opposite is true of a poorly defined pattern that is not deeply cut.

c. **Rectangular.** The rectangular drainage pattern is characteristic of sandstone that has been shifted by faults in the earth's surface and is characterized by abrupt, angular changes in stream direction. The prevalence of sandstone would indicate an area that is well drained since sandstone is a porous rock. Surface water is generally scarce in these areas and wells may have to be dug quite deep. The ability of the sandstone to support heavy vehicles (tanks, etc.) may be limited since sandstone is also a very soft rock of limited strength. While sandstone is considered a soft rock by no means does this imply that it is easy to dig into. Equipped with just an E-tool, one would be hard pressed to make any progress.

d. **Radial.** The radial pattern is characteristic of a volcanic cone. It best resembles the spokes of a bicycle tire radiating out in all directions. The material found in this area is generally solidified lava. It is very hard and rough, sometimes attaining a razor-like quality. The ability to dig in is minimal at best. The burst radius of ground impact munitions is maximized by the hard rock and fragmentation is increased by flying rock debris. Trafficability is good if there are no large boulders in the way although the sharpness of the rocks may be sufficient to cut vehicle tires. Since this pattern forms on elevated terrain, whatever water that falls on the surface runs off quite rapidly.

e. **Annular.** The annular drainage pattern is another volcanic formation. Generally forming on domed structures, this pattern has a circular shape whose pattern is characteristic of hard, very weathered rock. Such an area would make for good observation, but these formations almost always have concave slopes which means there would be dead space for someone defending from them. Trafficability is generally good although exposed rock may become quite slippery when wet. Once again the effectiveness of ground impact munitions would be increased by the hardness of the rock.

f. **Parallel.** The parallel pattern is formed by areas of uniform slope. A well defined, deep cut pattern is characteristic of soft material while a shallow cut pattern is characteristic of hard material. The same considerations apply to the parallel pattern as they do to the dendritic. The parallel pattern best indicates the degree of slope. The more parallel and numerous the streams and rivers, the steeper the slope.

APPENDIX D

SOIL TESTS

1. **General.** Many of the characteristics of soil which are important in military operations can be determined by performing certain tests. These tests are described in general terms in this appendix. FM 5-530, Materials Testing, describes these tests.

2. **Soil Terms.** The following terms are used to describe soils.

a. **Bearing Capacity.** The ability of a soil to support a vehicle without undue settlement of the vehicle.

b. **Traction Capacity.** The ability of a soil to resist the vehicle tread thrust required for steering and propulsion.

c. **Critical Layer.** The soil layer in which the rating cone index is considered a most significant measure of trafficability. Its depth varies with the weight and type of vehicle and the soil profile, but it is generally the layer located 15 to 30 cm (6 to 12 inches) below the surface.

d. **Cohesiveness.** The ability of the particles of a soil to adhere to each other.

e. **Slipperiness.** Low traction capacity of a soil's surface due to its lubrication by water or mud.

f. **Fine Grained Soil.** A soil of which more than 50 percent of the grains, by weight, will pass a No. 200 sieve (smaller than 0.074 mm in diameter).

g. **Coarse Grained Soil.** A soil of which more than 50 percent of the grains, by weight, will be retained on a No. 200 sieve (0.074 mm and larger in diameter).

h. **Sand With Fines, (clay and silt) Poorly Drained.** A sand in which water content greatly influences the trafficability characteristics. These soils react to traffic in a manner similar to fine grained soils. They usually contain 7 percent or more of material passing the No. 200 sieve.

3. Trafficability Terms. The following terms are used in describing a soil's ability to support traffic.

a. Cone Index. (CI) An index of the shearing resistance of soil obtained with the cone penetrometer; a number representing resistance to penetration into the soil of a 30-degree cone with 1.27 square cm (1/2 square inch) base area (load in pounds on cone base area in square inches).

b. Remolding. The changing or working of a soil by traffic, or by a remolding test. Remolding may have a beneficial, neutral, or detrimental effect, resulting in a change of soil strength.

c. Remolding Index. (RI) The ratio of remolded soil strength.

d. Rating Cone Index. (RCI) The measured cone index multiplied by the remolding index. It expresses the soil strength rating of a point subjected to sustained traffic.

e. Vehicle Cone Index. (VCI) The index assigned to a given vehicle that indicates the minimum soil strength in terms of rating cone index required for 50 passes of the vehicle.

f. Mobility Index. (MI) A number that results from a consideration of certain vehicle characteristics.

g. Maximum Tractive Effort. The maximum continuous towing force or pull a vehicle can exert expressed as a ratio or percentage of its own weight.

4. Instruments and Test Terms. The following equipment is used in testing soil for trafficability.

a. Cone Petrometer. A field instrument consisting of a 1 meter (39 inch) shaft with a 30 degree cone of 1.27 square centimeters base area mounted on one end and a proving ring with dial gage and handle mounted on the other end. The force required to move the cone at a rate of approximately 1.8 meters per minute through the soil being tested in indicated on the dial inside the proving ring. The force is considered to be an index of shearing resistance of the penetrated soil and is called the cone index of the material.

b. Trafficability Sampler. A piston type soil sampler for taking soil samples.

c. Remolding Equipment. A piece of test equipment with (1) a cylinder of the same diameter as the trafficability sampler mounted vertically on a base and (2) a 2.5 pound drop hammer that travels 30 cm (12 inches) on a 46 cm (18 inch) section of shaft.

5. Tests

a. 100-Blow Remolding Test. This test is used to determine the remolding index of fine grained soils. A sample is taken with the trafficability sampler, loaded into the remolding cylinder, and pushed to the bottom with the drop hammer. Cone indexes are measured at the surface of the soil and at 2.54 cm (1-in) vertical increments to a depth of 10.2 cm (4-in). Next, 100 blows of the hammer are applied and cone indexes are remeasured in the remolded soil. The remolding index is the sum of the five cone index readings made after remolding (a value of 300 is assigned to each depth that cannot be penetrated) divided by the sum of the five readings made before remolding.

b. Vibrated Remolding Test. This test is used to determine the remolding index of sand with fines, (clay or silt) poorly drained, and is conducted in the same manner as the 100-blow test, with two exceptions. The cone index measurements are made with the 0.5-sq-cm (0.2 sq.in.) cone instead of the 1.27-sq-cm (1/2 sq.cn.) cone, and the sample is remolded by placing the soil sample in the remolding cylinder and dropping the cylinder loaded with the soil sample by hand 25 times from a height of 15 cm (6 in.).

c. Field Test. Tests conducted in the field assist in the identification of soil types. See FM 5-530.

(1) Dry Strength Test.

(a) Form moist pat 2" in diameter by ½" thick.

(b) Allow to dry with low heat.

(c) Place dry pat between thumb and index finger only and attempt to break.

<u>1</u> Breakage easy - silt (M).

2 Breakage difficult - low compressible clay (CL).

3 Breakage impossible - high compressible clay (CH).

(2) **Powder test.** Rub portion of broken pat with thumb and attempt to flake particles off.

(a) Pat powders - silt (M).

(b) Pat does not powder - Clay (C).

(3) **Feel Test.** Rub a portion of dry soil over a sensitive portion of skin, such as inside of wrist.

(a) If feel is harsh and irritating, sample is silt (M).

(b) If feel is smooth and floury, sample is clay (C).

(4) **Shine Test.** Draw smooth surface, such as a knife blade or thumb nail, over pat of slightly moist soil.

(a) If surface becomes shiny and lighter in texture, sample is a high compressible clay (CH).

(b) If surface remains dull, sample is a low compressible clay.

(c) If surface is very dull or granular, sample is silt or sand.

(5) **Thread Test.** Form a ball of moist soil (marble size) and attempt to roll ball into 1/8" diameter thread (wooden match size).

(a) If thread is easily obtained - clay (C).

(b) If thread cannot be obtained - silt (M).

6. Indexes of Soil Strength

a. Cone Index. This is an index of the shearing resistance of a soil. It is obtained as described in paragraph 5a above.

b. Remolding Index. This index describes whether a soil loses, gains, or keeps the same strength under repeated blows (such as repeated passes by a truck or tank). It is used primarily to state the ability of soil to support traffic. A soil's strength may change under traffic or other forces. For example, a soil may support three passes by a vehicle, but give way on the fourth. This change in strength is called remolding. 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 high. To measure the degree of remolding that a soil will undergo. After the cone index measurements have been made before and after remolding (before and after simulated traffic) the results are interpreted by calculating a ratio called the **remolding index.** This is simply the ratio obtained by dividing the cone index after remolding into the cone index obtained in the field before remolding.

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

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.

c. Rating Cone Index. This is simply the product of the measured cone index in the field and the remolding index for the same layer of soil.

Rating Cone Index (RCI) = Measured cone index (in natural soil) X 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.

d. Vehicle Cone Index. This is the minimum soil strength that will permit a given vehicle to complete about 50 passes. the vehicle cone index for the M-50 tank, for example, is 49. This means that if the rating cone index is less than 49, the tank will become mired to the point of immobilization before it has completed 50 passes; 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 number are: for foot soldiers, about 20; for the D-7 Engineer tractor, 48; fc the 2 1/2-ton 6 X 6 cargo truck, 61; and for the APC M59, 44. Vehicl cone indices for most Army vehicles are listed in TM 5-330.

APPENDIX E

WEATHER ELEMENTS

This appendix supplements the information provided in Section 4 on the elements of weather.

1. **Recording Air Temperature.** Temperature data may be recorded in the following forms:

a. **Mean Daily Maximum Temperature.** The average of the daily maximum temperatures for a month.

b. **Mean Daily Minimum Temperature.** The average of the daily minimum temperatures for a month.

c. **Mean Daily Temperature.** The average of daily maximum and minimum temperatures for any specific day.

d. **Mean Monthly Temperature.** The average of mean daily temperatures for a given month.

e. **Mean Annual Temperature.** The average of daily mean temperatures for a given year.

f. **Diurnal Variation.** The difference between the maximum and minimum temperatures occurring in a day.

g. **Length of Freezing Period.** The number of days with minimum temperature below the freezing point.

2. **Clouds and Fog. (Vertical and Horizontal Visibility)**

a. Clouds are visible masses of condensed moisture in the forms of fine water droplets or ice particles. Depending upon their size and moisture content, clouds may produce a variety of precipitation such as rain, snow, sleet, or hail.

b. Fog is a mass of minute water droplets suspended near the earth's surface that degrades horizontal visibility. It is formed by condensation of water vapor in the air. The most favorable conditions for the formation of fog are an abundance of water vapor, high relative humidity, and a light surface wind. Fog is usually most prevalent on

coastal areas due to the abundance of water and can be expected mos
frequently in the colder months of the year.

3. Precipitation. Precipitation is visible moisture that falls froı the atmosphere, such as rain, sleet, snow, hail, drizzle or combinatior of these. As an air mass rises, its ability to hold moisture decrease and clouds form. Rain occurs when cloud droplets become too large t be held in suspension, or, if the temperature is below freezing, snow i formed. Sleet is frozen rain formed by droplets passing through a laye of below freezing air. Hail consists of rounded pellets of ice create when raindrops are carried to high altitudes by updrafts, frozen an then dropped to earth.

APPENDIX F

TERRAIN ANALYSIS CHECKLIST

1. General. This appendix provides a list of some of the points which should be considered when analyzing terrain and weather. This checklist is but a beginning. Each unit must consider the effects of terrain and weather on its operations because terrain and weather influence the operations of different units in different ways. Each commander and leader will have to adopt this list to his unit's mission and to the situation.

2. General Description of Terrain. Analyze the following characteristics of the terrain:

a. Relief and drainage system.

(1) Slope and its influence on movement of vehicles and people.

(2) Drainage of defensive positions.

(3) Drainage of areas through which avenues of approach and lines of communications run. Precipitation may cause low areas to flood.

(4) Crossing sites of streams.

(5) Availability of water (which includes access to water points).

(6) Potential for landing zones and airfields.

b. Vegetation.

(1) Distribution of crop land, pasture, wooded areas, brush, and grasses.

(2) Concealment.

(3) Any vegetation which is significant. Example: hedge rows provide concealment for defending infantry and are obstacles for vehicles.

(4) Construction materials.

(5) Surface materials

(6) Cultural features.

c. Surface Material

(1) Soil trafficability for wheeled and tracked vehicles.

(2) Suitability of surface material for field fortifications.

(3) Effects of barrages on surface material.

d. Cultural Features. Determine the number and type of roads railroads, bridges, tunnels, mines, towns, industrial areas fortifications, reservoirs, utilities and power facilities, and othe features of military significance.

3. **Military Aspects of Terrain.** Determine and analyze the following:

a. Observation and fields of fire

(1) Determine the effects of weather, relief, vegetation and cultural features on fields of fire.

(2) Determine which terrain offers the best observation.

(3) Determine which terrain is best for surveillance devices.

(4) Determine what terrain will allow each separate weapons system to be used to best effect.

b. Cover and Concealment

(1) Indicate the effect of weather, relief, vegetation, and cultural features on cover and concealment.

(2) List areas in which cover and/or concealment must be found for both defensive and offensive purposes.

c. Obstacles

(1) List all possible obstacles which could interfere with the completion of the mission including rivers, canals, lakes, swamps, steep slopes, dense woods, sand which vehicles can not be driven through, mountains, cities, and known enemy-made obstacles.

(2) Determine those obstacles which would aid in the defense.

d. Key terrain. Determine key terrain based on the mission, scheme of maneuver, observation, fields of fire, cover and concealment, and obstacles.

e. Avenues of approach

(1) Select avenues of approach which provide adequate room for maneuver and dispersion and ease of movement.

(2) Avenues of approach are based on mission, observation and fields of fire, cover and concealment, obstacles, and key terrain.

(3) Determine the most likely enemy avenues of approach.

(4) List possible air avenues of approach. This will include routes which helicopters can take without being exposed to ground based antiaircraft weapons, and zones in which helicopters or paratroopers can land.

4. Components of Weather

a. Air Temperature.

b. Atmospheric Pressure.

c. Winds.

d. Humidity.

e. Clouds and Fog.

f. Precipitation.

g. Fronts.

5. **Military Aspects of Weather**

a. Effects on personnel.

(1) Physical well being.

(a) Heat casualties.

(b) Frost bite and hypothermia.

(c) Snow blindness.

(d) Seasonal pattern of diseases; e.g., flu.

(e) Trench foot.

(2) Morale. Prolonged exposure can increase physical and mental strain.

b. Effect on equipment and supplies

(1) Precipitation and humidity can cause rust, mildew, and deterioration.

(2) Special handling of some critical items (e.g., plasma, medicine, photographic chemicals) is often necessary.

(3) Damage done by violent weather - winds, sandstorms, hurricanes, monsoons, blizzards. etc.

c. Effect on terrain

(1) Trafficability changes.

(2) Concealment modified.

d. Effects on cultural features

(1) Lines of communication such as railways and roads are affected.

(2) Wire and radio communication can be affected.

(3) Airfield operations influenced.

(4) Buildings altered or damaged.

e. Effects on tactics

(1) Intelligence gathering activities hindered.

(2) Close air support modified.

(3) Communications ability changed.

(4) Engineering tasks such as road building and mine laying influenced.

(5) Weapon delivered capability altered.

(6) Defensive positions must be useable in all types of weather.

APPENDIX G

SAMPLE CLIMATE DATA

CLIMATE TYPE:	ELEMENT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TROPICAL WET PUERTO CORTES, HONDURAS LATITUDE: 15°48'N LONGITUDE: 87°56' ELEV (FT): 3	TEMP (F) PREC (IN)	76 11.5	77 5.0	78 4.9	79 4.4	83 5.2	83 6.1	83 7.6	82 7.8	83 8.9	83 19.2	79 17.8	76 14.7	80 113.1
TROPICAL WET & DRY KEY WEST, FL LATITUDE: 24°33'N LONGITUDE: 81°48'W ELEV (FT): 22	TEMP (F) PREC (IN)	70 2.0	71 1.3	73 1.4	76 1.3	79 3.5	82 4.2	83.5 3.3	83.5 4.5	83.5 6.7	79 6.0	74 2.2	70.5 1.7	77 38.1
TROPICAL DESERT (WARM) YUMA, AZ LATITUDE: 32°45'N LONGITUDE: 114°36'W ELEV (FT): 141	TEMP (F) PREC (IN)	54.5 0.4	59 0.4	64.5 0.3	70 0.1	76.5 <0.1	85 <0.1	91.5 0.2	95.5 0.6	85 0.4	73 0.3	62.5 0.2	55.5 0.5	72.5 3.4
MID-LATITUDE DESERT (COOL) LAS VEGAS, NV LATITUDE: 36°12'N LONGITUDE: 115°10'W ELEV (FT): 2,075	TEMP (F) PREC (IN)	32 1.5	36.5 1.1	41.5 0.8	48 0.5	55 0.5	62.5 0.3	70.5 0.2	69.5 0.2	61 0.2	51.5 0.3	41.5 0.6	33.5 0.9	50.5 7.1
TROPICAL STEPPE MONTERREY, MEXICO LATITUDE: 25°40'N LONGITUDE: 110°18'W ELEV (FT): 1,732	TEMP (F) PREC (IN)	58 0.6	62 0.7	66.5 0.8	73 1.3	77.5 1.3	81 3.0	80.5 2.3	82 2.4	78 5.2	72 3.0	63 1.5	57.5 0.8	71 22.8
MID-LATITUDE STEPPE (COOL) RENO, NV LATITUDE: 39°30'N LONGITUDE: 119°47'W ELEV (FT): 4,397	TEMP (F) PREC (IN)	32 1.5	36.5 1.1	41.5 0.8	48 0.5	55 0.5	62.5 0.3	70.5 0.2	69.5 0.2	61 0.2	51.5 0.3	41.5 0.6	33.5 0.9	50.5 7.1

CLIMATE TYPE:	ELEMENT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
HUMID SUBTROPICAL NEW ORLEANS, LA LATITUDE: 29°57'N LONGITUDE: 90°04'W ELEV (FT): 8	TEMP (F) PREC (IN)	54.5 4.6	57.5 4.2	68 4.7	69 4.8	75.5 4.5	81 5.5	83 6.6	83 5.8	79.5 4.8	71.5 3.5	62.5 3.8	56 4.6	69.5 57.4
MEDITERRANEAN (WARM SUMMER) SACRAMENTO, CA LATITUDE: 38°35'N LONGITUDE: 121°30'W ELEV (FT): 69	TEMP (F) PREC (IN)	45.5 3.8	50.5 2.8	55 2.8	58.5 1.5	64 0.8	70 0.1	74 <0.1	73 <0.1	70 0.3	62.5 0.8	54 1.9	46.5 3.8	60.5 18.6
MEDITERRANEAN (COOL SUMMER) SAN FRANCISCO, CA LATITUDE: 37°47'N LONGITUDE: 122°25'W ELEV (FT): 52	TEMP (F) PREC (IN)	50 4.7	53 3.8	54.5 3.1	55.5 1.5	57 0.7	59 0.1	59 <0.1	59 <0.1	62 0.3	61 1.0	57 2.5	52 4.4	56.5 22.1
MARINE WEST COAST RHEIN MAIN, WEST GERMANY LATITUDE: 50°2'N LONGITUDE: 8°34' ELEV (FT): 368	TEMP (F) PREC (IN)	33 1.9	34 1.4	42 1.3	50 1.6	57 2.1	63 3.4	66 2.8	65 3.4	60 2.1	50 2.2	41 1.8	35 2.2	49.5 26.2
MARINE WEST COAST (COOL SUMMER) KODIAK, AK LATITUDE: 57°48'N LONGITUDE: 152°22'W ELEV (FT): 152	TEMP (F) PREC (IN)	31.5 4.7	31.5 4.7	33 3.8	38 3.8	43 5.9	49.5 4.7	54.5 3.4	55.5 5.1	50.5 5.3	43 7.2	36 5.8	32.5 6.0	41.5 60.4
HUMID CONTINENTAL (WARM SUMMER) CHICAGO, IL LATITUDE: 41°53'N LONGITUDE: 87°38'W ELEV (FT): 823	TEMP (F) PREC (IN)	25 2.0	27 2.0	36 2.6	47.5 2.8	57.5 3.4	67.5 3.5	73.5 3.3	72 3.2	65.5 3.1	54 2.6	40.5 2.4	29.5 2.0	49.5 32.9
HUMID CONTINENTAL (COOL SUMMER) TORONTO ON, CANADA LATITUDE: 43°40'N LONGITUDE: 79°24'W ELEV (FT): 379	TEMP (F) PREC (IN)	23 2.7	22.5 2.4	25 2.6	42 2.5	53.5 2.9	63.5 2.7	69 2.9	67.5 2.7	60 2.9	48 2.4	37 2.8	27 2.6	45 32.1
HIGHLAND MOUNTAINS FLAGSTAFF, AZ LATITUDE: 35°12'N LONGITUDE: 111°40'W ELEV (FT): 6,903	TEMP (F) PREC (IN)	27.5 2.5	31 2.1	36 2.4	43.5 1.3	50 1.0	56 0.4	65 3.1	63.5 2.7	56.5 1.6	46.5 1.4	37 1.4	29 2.0	45.5 21.9
HIGHLAND MOUNTAINS BOGOTÁ, COLOMBIA LATITUDE: 4°36'N LONGITUDE: 74°5'W ELEV (FT): 8,678	TEMP (F) PREC (IN)	57.5 2.3	58.5 2.6	58.5 4.0	59 5.8	58.5 4.5	58 2.4	57 2.0	57.5 2.2	57.5 2.4	58 6.3	58 4.7	57.5 2.6	58 41.5
CONTINENTAL SUBARCTIC DAWSON UT, CANADA LATITUDE: 64°4'N LONGITUDE: 139°29'W ELEV (FT): 1,062	TEMP (F) PREC (IN)	−21 0.9	−12 0.7	4 0.5	28.5 0.5	46.5 1.0	56.5 1.2	59.5 1.5	54.5 1.5	42 1.4	26 1.2	1.5 1.1	−14 1.0	23 12.6

CLIMATE TYPE:	ELEMENT128	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MARINE SUBARCTIC ST. PAUL ISLAND, AK LATITUDE: 57°9'N LONGITUDE: 170°13'W ELEV (FT): 22	TEMP (F) PREC (IN)	25 1.7	23.5 1.2	24.5 1.2	29 1.0	35 1.2	41.5 1.2	45.5 2.4	47.5 3.2	45.5 3.4	39.5 2.9	33.5 2.5	28.5 2.0	35 23.9
TUNDRA BARROW POINT, AK LATITUDE: 71°18'N LONGITUDE: 156°47'W ELEV (FT): 22	TEMP (F) PREC (IN)	−15.5 0.2	−18.5 0.1	−15 0.1	−0.5 0.1	18.5 0.1	34 0.3	39.5 0.9	38.5 0.8	30.5 0.5	17 0.5	1 0.3	−10.5 0.2	10 4.1
ICECAP EISMITTE, GREENLAND LATITUDE: 70°53'N LONGITUDE: 40°42'W ELEV (FT): 9,843	TEMP (F) PREC (IN)	−43 0.6	−53 0.2	−40 0.3	−25.5 0.2	−6 0.1	2 0.1	10 0.1	−1 0.4	−8 0.3	−32.5 0.5	−45 0.5	−37 1.0	−23 4.3