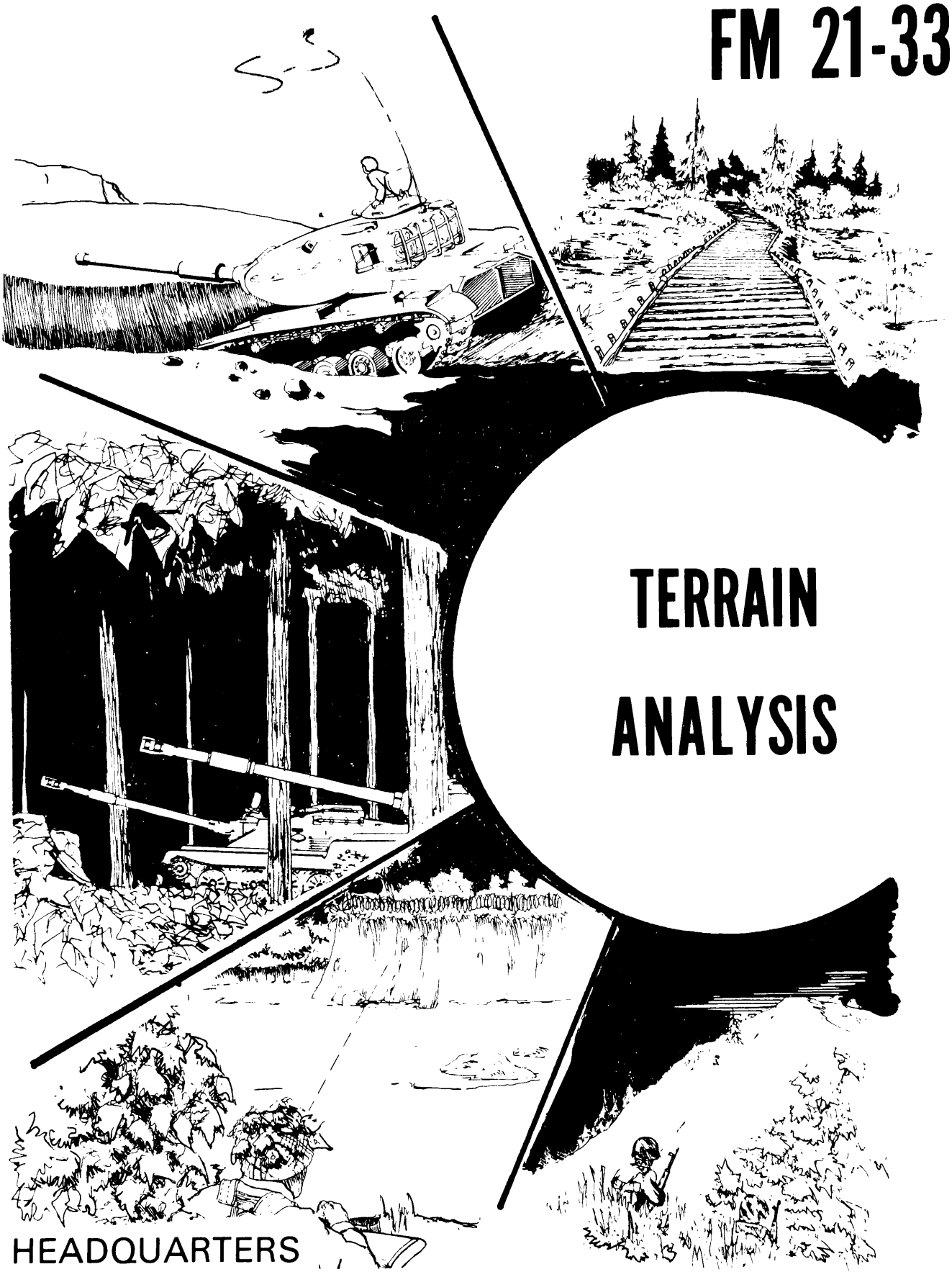
FM 21-33



TERRAIN ANALYSIS

HEADQUARTERS
DEPARTMENT OF THE ARMY

MAY 1978

The word "he" or "his" in this publication is intended to include both the masculine and feminine genders and any exception to this will be so noted.

FIELD MANUAL
No. 21-33

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 15 May 1978

TERRAIN ANALYSIS

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CHAPTER 1

INTRODUCTION

PURPOSE

This manual is intended to assist you in identifying the duties of a Terrain Analyst, and to serve as a reference when you are performing such duties.

SCOPE AND RELATION TO OTHER MANUALS

You will find here the procedures that are followed in performing the tasks that a Terrain Analyst is expected to be able to do. This manual does not repeat procedures that are explained in other manuals or in courses that should be completed before you enter the Terrain Analyst course, but it tells you where to find such information when you need it. If you have the right reference materials you can readily find the answers to questions of technique and procedure that may arise in your study and work. A list of manuals that are useful for a Terrain Analyst is found in the Appendix.

CHANGES AND COMMENTS

The Army would like to have your comments and recommendations for improving this publication. Use DA Form 2028 (Recommended Changes to Publications), giving the specific page, paragraph, and line of the text for which the change is recommended and reasons for the proposed change. DA Form 2028 should be sent direct to the Commandant, U.S. Army Engineer School, Fort Belvoir, VA 22060.

WHAT IS TERRAIN ANALYSIS

Terrain Analysis is the process of analyzing a geographical area to determine the effect of the natural and manmade features on military operations. The product of terrain analysis is a terrain study, which is one of a number of sources of information (maps, photographs, interrogation, etc.) on which a commander can base his decisions.

Terrain is defined as a portion of the earth's surface, including manmade and natural features. Terrain data (or terrain information) are raw data in any form about a segment of terrain. When these data have been evaluated, analyzed, interpreted, and integrated, they become terrain intelligence, which may be presented in a number of different formats, one of which is a terrain study.

Terrain intelligence is thus one aspect of operational intelligence. As an enlisted terrain analyst, your duties will most likely be to produce terrain intelligence for use at the tactical level of operations. Operational intelligence, however, is required at all levels, so your product may be used either by the commander of the organization you are in or by higher headquarters.

LEVELS OF PROFICIENCY IN TERRAIN ANALYSIS

A beginning terrain analyst will not usually be called on to prepare detailed terrain studies, but he should know how to go about it in order to develop increased proficiency with experience. Ordinarily, a beginner (grade E5) will be required to extract basic facts from his data sources and present them on factor overlays. At the next level (E6) he should be able to interpret these facts in terms of military activities and to combine the information from several factor overlays in order to answer specific questions. At the senior level (E7) he should be able to supervise the work of several analysts, to prepare more complex terrain studies, and to predict the performance of various types of equipment under the prevailing conditions of weather and season.

THE INTELLIGENCE CYCLE

Since intelligence may be useless or even dangerous unless kept up-to-date, its production and revision must never end. This continuing activity is carried on through a four-step cycle called the intelligence cycle: (1) plan to collect data, (2) collect required data, (3) process collected data into intelligence, (4) disseminate the intelligence. Details of these four steps will be described in the rest of this manual. It is called a cycle because after you complete the four steps, you begin over to keep your intelligence up-to-date.

SKILLS YOU WILL NEED

To be a terrain analyst you must be thoroughly proficient in topographic map analysis, and map interpretation. Almost as important are skills in interpreting photographic and other remotely sensed imagery. These skills include the use of formulas and measuring techniques, both on photographs and maps and on the ground. You also should know how to do cartographic drafting and should be able to write clear, factual reports.

Before starting the Terrain Analyst Course you should have either courses or practical experience in Soils Analysis, Image Interpretation, and/or Map Compilation.

CHAPTER 2

COLLECT DATA

SECTION 1. KINDS OF DATA

As a terrain analyst you are responsible for analyzing data that come to you from a variety of sources. Part of your job is to collect the data yourself. You should know something about the sources of information in order to be able to request it when needed, and you should know the advantages and disadvantages of each kind.

Your three main sources will be photographs, maps, and written reports. In this chapter we will consider what kind of information you can get from each of these sources, and where you can get them. There may be times when you will have to depend on your own resourcefulness to get the data that you need, but normally your detachment commander will order it for you provided you can tell him accurately what you need.

REMOTE SENSING

Much of the data that you will be called on to analyze will be obtained by aerial reconnaissance. These data usually are in the form of photographs, but in recent years other methods have been devised for "remote sensing." Therefore we use the more general term imagery when talking about the results of aerial reconnaissance. There are many different kinds of imagery in use today and others under experimentation. Those discussed below are the principal ones that you should know something about.

PHOTOGRAPHIC IMAGERY

(1) Panchromatic

Panchromatic photography is in black and white, but the film is sensitive to all visible wavelengths. This means that all colors will register on the film, and differences in tone on the photograph will vary with the intensity of the object's color rather than its wavelength. All black and white film used in aerial photography is panchromatic. Despite the many new films and techniques that have been developed, black and white panchromatic is still the most frequently used film.

(2) Infrared Panchromatic

Infrared black and white film is sensitive to blue-violet and infrared light. It is sometimes exposed through red filters; then the exposures are made by red and infrared wavelengths only and called "near-infrared." This type of film is used mostly for detection of different types of vegetation or plant disease. The Army uses it for detecting camouflage because it enables an interpreter to tell cut from live vegetation, and vegetation from artificial material such as nets and paint.

(3) Infrared Color

This film, originally designed by Kodak as Ektachrome infrared aero film, is a false-color, reversal film used for camouflage detec-

tion. It shows colors that are false for natural features. Natural deciduous foliage appears red and painted artificial foliage appears purple. This film is also used for detection of plant disease, insect infestation, and water pollution.

(4) Conventional Color

This film, although expensive and more critical to expose and process, is valuable for identifying soil types, rock outcrops, industrial stockpiles, subsurface water, and shorelines. It is rarely used under field conditions.

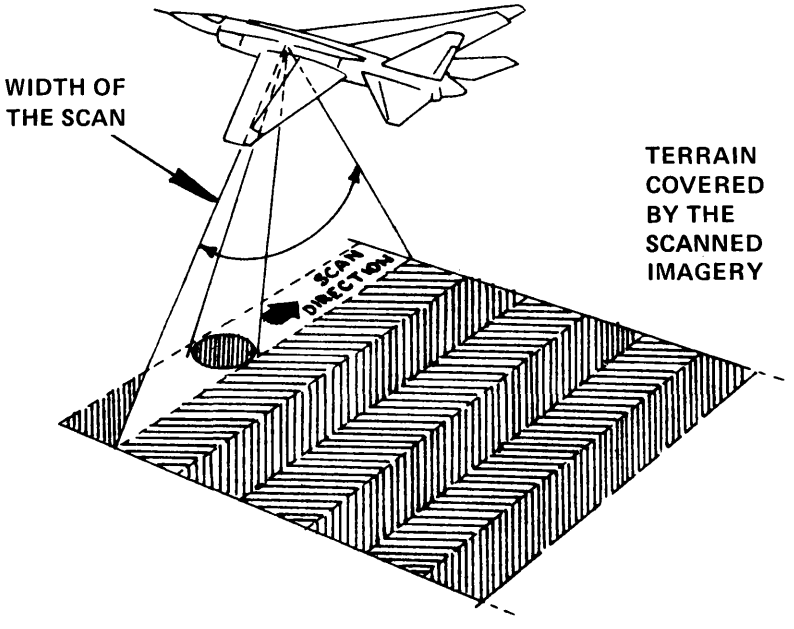
(5) Multiband

Multiband photography is still in the experimental stage. Special cameras have been built using many lenses (up to 9) at the same time, each with a film of different spectral sensitivity. The camera photographs an area with all these films and lenses simultaneously. Each film records different data about different objects because each object reflects different spectral energy. These objects (terrain features) can now be detected as different tones of gray on the different films, whereas they may appear the same on one type of film. Further research is needed before multiband will be operational under field conditions.

NONPHOTOGRAPHIC IMAGERY

(1) Thermal Infrared

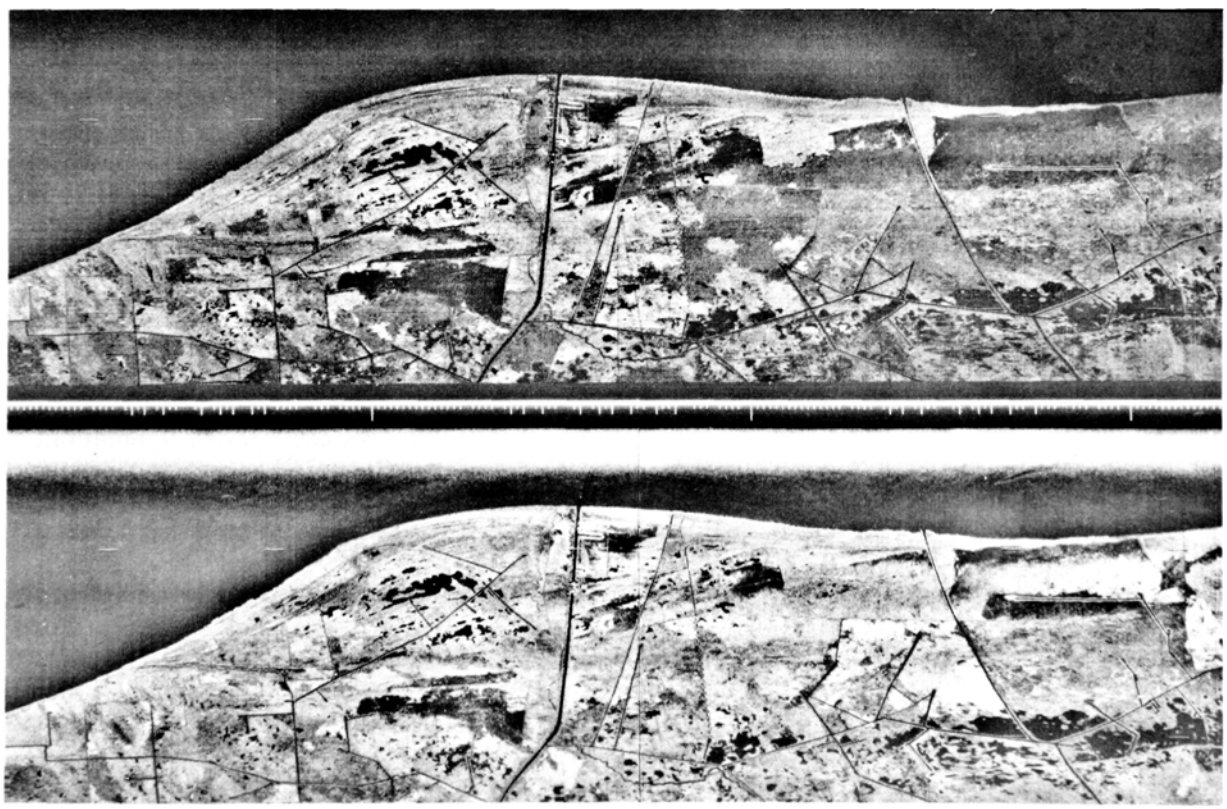
"Thermal" means having to do with heat. Accordingly, thermal infrared records the heat of terrain features. A bare rock surface is hotter in the bright sun than green grass. Thermal infrared photographs the hotter feature as brighter. This infrared image is a photograph of an image that appears on an electronic tube something like a television tube. This tube and the total infrared sensor system are in an airplane. The sensor scans the terrain by swinging from side to side as the airplane flies ahead.



The scanner, therefore, "paints" the ground in narrow strips. These strips are photographed all together to make an image like a photo from a strip camera. The imagery can be used to detect fire when concealed by smoke, as in a forest fire. It has many other potential uses, such as mapping seismic fault lines, identifying minerals, crop diseases, soil moisture content, cool underground springs, and heat from vehicles. Most military uses are classified.

(2) Radar

Radar imagery, particularly Side-looking Airborne Radar (SLAR), is similar to thermal infrared in many respects. The radar "looks" out from each side of the airplane in a narrow beam. Then the airplane flies ahead, and the radar takes another look sideways. These "looks" (or side scans) are added to each other on the radar display tube. A picture is taken of this tube and this picture is your SLAR imagery. Again, like IR, the terrain covered is in a strip like the photo from a strip camera.



Side-looking Airborne Radar (SLAR) Images

(3) Satellite Transmitted

Photos of the earth are transmitted from satellites. These are not direct photos but are photos of a cathode ray tube, like a television screen. The satellite contains a video tape recorder like a television camera. When the camera is turned on a photo of a portion of the earth is made on video tape. This video tape is transmitted to the earth and reconstituted on a TV type screen and photographed.

MAPS

A topographic map is the most important tool of a terrain analyst. You will see in chapter 5 how you can use "topo" maps for analyzing drainage, slope, settlements, and many other aspects of terrain. So it's important to have topographic maps that are as recent and accurate as you can get.

There are also other kinds of maps. A planimetric map is one that does not show relief. They are used especially for mapping manmade features such as city streets, where it is important to show a lot of detail without the "clutter" of contour lines.

Another kind of map is called thematic. These are maps that are designed to show just one feature or "theme," so they are often called special purpose maps. Examples would be maps of average rainfall, location of certain minerals, and distribution of population. The factor overlays that you will be making (see chapter 5) are a kind of thematic map.

TEXT

The third major source of data is words--printed, typed, written or spoken. Printed words (or text) that are available to everyone are called "open literature." This is the kind of material that you can get from a library, bookstore, or magazine stand. The term refers especially to scholarly writing such as books and articles in recognized journals. The open literature of geography contains a lot of information that is valuable for terrain analysis because it is carefully done, usually well illustrated, and easy to obtain.

There are also many other kinds of text that can be useful to you. Travel accounts, guidebooks, industrial advertising, and chamber of commerce publications can all tell you something about an area. You can even learn a good deal about local business and industry from a telephone directory.

Military intelligence reports are another essential source of information, but they have to be handled more carefully than open literature because they are usually classified. Their scope varies from an entire country, as in the NIS (National Intelligence Surveys) produced in Washington, to special intelligence reports of a local area which would be typed in the field with just a few carbon copies.

A good source of data, although not always reliable, is government reports of various kinds. Most governments publish statistics on climate, streamflow, population, agricultural produce, industrial production, and a variety of other subjects. Keep in mind, however, that in some countries these figures may be "slanted" to support some governmental policy, while in others it simply may not be possible to get reliable figures. For example, where a population lives mainly by subsistence farming, most of the produce may never be sold and so no record of it is made.

SECTION 2. WHERE TO GET IT

MILITARY INTELLIGENCE SOURCES

In the field your first source for data is military intelligence. It is MI's job to get and process the data that you will use in terrain analysis, especially data from aerial reconnaissance. When you need photos or other imagery of a certain area, you can request them from MIBARS (Military Intelligence Battalion, Aerial Reconnaissance and Surveillance). If you are attached to a division headquarters, you should have close relations with the division MI company. Requests for data should go through your detachment commander.

AERIAL PHOTO AGENCIES

In addition to the imagery that you can get from MIBARS, there are many sources of aerial photography that can be used in peacetime. The U.S. Department of Agriculture maintains a library of aerial photographs covering most of the United States from which photos can be ordered:

Western Aerial Photography Laboratory
Administrative Services Division
ASCS-USDA
2505 Parley's Way
Salt Lake City, Utah 84109

You can obtain a map showing the "Status of Aerial Photography in the United States" by writing to:

National Cartographic Information Center
USGS National Center
12201 Sunrise Valley Drive
Reston, Virginia 22092

This map shows areas that have been photographed either by government agencies or commercial firms, and tells where you can obtain prints.

Most of the states also have agencies that maintain photo libraries. All of these sources make a charge for furnishing photographs.

Air photos are available for purchase from commercial aerial survey firms in the United States and some other countries. The cost is often higher than that of photos from government agencies, but the photos may have larger scales than are otherwise available. Some of these companies are listed in the USGS map described above, while others are given regularly in the journal "Photogrammetric Engineering and Remote Sensing."

MAPPING AGENCIES

Maps for the U.S. Army are produced by the Topographic Center of the Defense Mapping Agency (DMA). Other major elements of DMA are the Hydrographic Center, which mainly produces charts for the Navy, and the Aerospace Center, which is concerned with aeronautical and space navigation charts. So most of the maps you will be using come from the DMATC. To obtain all necessary information about maps of the world, request a copy of "Department of Defense, DMA Catalog of Maps, Charts, and Related Products" from:

Defense Mapping Agency Topographic Center
Washington, D.C. 20315

This very extensive catalog is published in four parts. Part 3, Topographic Products, has six volumes, each dealing with a portion of the world. It contains indexes of all DMA maps and other products available. It also contains instructions on how and where to order maps and products, for example, aerospace, hydrographic, topographic and air target material products, city maps, trig lists, map gazetteers, and digital topographic data. Since the names and locations of map depots change from time to time, up-to-date ordering information should be obtained from the above address.

Nearly all foreign governments also maintain one or more mapping agencies. Although DMATC maps cover all parts of the world, you may be able to get more up-to-date maps through local sources when you are overseas. The Library of Congress maintains a list of these sources, "Published Sources of Information about Maps," and "Selected List of Map Publishers and Sellers," which you can obtain from the Geography and Map Division, Library of Congress, Washington, D.C. 20540.

In addition to DMA, there are many other government agencies, both in the United States and abroad, that produce maps. Usually these maps are for special purposes. For example, the U.S. Forest Service and its counterparts in other countries issue maps showing cover type and other aspects of forest stands. Some of these are very useful in terrain analysis. You can also get government maps showing transportation routes, mining activity, recreational areas, and other information about the terrain. Some governments put out maps showing types of land use.

Private mapping agencies are also active in some countries. All European countries are covered by road maps that are distributed (for a small charge) by gasoline vendors. Automobile clubs are active in many countries and some of them produce good road maps. The maps that are sold in bookstores frequently give detailed information about city street patterns.

WRITTEN MATERIAL

A good place to start getting information about an area is the local library, either in a town or on an Army post. You will probably find travel accounts and perhaps scientific works about the country, state, or locality you are concerned with.

Geographical publications are especially useful. Some of the leading ones written in English are:

National Geographic Magazine
(the well-known magazine published in Washington, D.C., with excellent illustrations and frequent map supplements)

The Geographical Review
(a scholarly journal produced quarterly by the American Geographical Society, Broadway at 156th St., New York, NY 10032)

The Geographical Magazine (an illustrated monthly with articles by specialists for the general reader, published by New Science Publications, 128 Long Acre, London WC 2E9QH, England)

SOURCES OF CLIMATIC DATA

Fortunately there is no lack of good climatic data for most of your needs. The U.S. Government and most foreign governments have extensive data collection and summarization programs. Weather data are widely disseminated and are seldom if ever classified. Cooperation and exchange of weather information and data are normally restricted only in wartime.

The Air Weather Service (AWS) of the U.S. Air Force has the responsibility of providing you with any and all data you will require--both stateside through the Environmental Technical Applications Center (ETAC) and overseas through the Weather Wing or detachment in your theater of operations. (See sections 2-19 and 2-20 of FM 30-10.) Requests for ETAC's support are made by standard military letter and addressed to: USAF ETAC, Scott AFB, IL 62225. A concise statement of the problem in terms of either the environmental factors involved or of the climatological information desired is all that is needed. If the problem cannot be adequately defined or the request properly stated, then Air Weather Service staff meteorologists are available to assist. The request must state the date the solution or information is needed and the priority of the program or project requiring support. A staff mete-

orologist can be contacted by phone before writing the formal letter. Remember that the Air Weather Service does have the mission to supply Army elements with climatic data and even analysis.

Probably a majority of the data you will require for your studies and climatic summaries already exists in published form and in the open literature. It will be found in any good library in your area of operations in official government publications. It will also occur in a wide variety of climatic and geographical textbooks and even in some travel guides. It is good practice to get started looking for materials for your climatic summary or study while waiting for officially responsible agencies to supply you with what you need. Contact your local National Weather Service office or U.S. Air Weather Service officer and see what they might have on hand that they could lend or supply. Then try large public or university libraries for additional sources, and consider the possibility that what you need may already exist in an appropriate published form so that all you need to do is copy it.*

For some foreign countries and areas remember that a greater concern for weather data may rest with an agency outside of the meteorological service of that country, such as a hydrological (irrigation/flood warning) service, an agricultural bureau, or even an association of airlines at some major airport. Unusual sources of good data can sometimes be found, such as records at a resort hotel, a marina, a TV station, or a mine at a lonely location.

Another source of data which requires more experience to use is cloud photography and other types of imagery taken from satellites by the Defense Meteorological Satellite Program (DMSP) for use of military personnel. Global DMSP data are received and processed at the Air Force Global Weather Central (AFGWC), Offutt AFB, Nebraska.

Conventional weather maps produced in the major capitals of the world, and river stage data taken at various gaging stations on a stream, are other sources of usable data. Governments below the national level also take and keep weather data--although these are generally for special studies and are of shorter durations. It is a good rule never to take "no data available" as an answer without digging just a little bit further.

**See especially section 23 of the National Intelligence Surveys (NIS), completed for most countries of the world. These climatic sections do not get out of date.*

CHAPTER 3

MANAGE THE FILE OF DATA

After you collect the information (data), you need a place to store it and you must be able to find it when you need it. No matter how impressive the data may be, it's worthless if you put it somewhere and can't find it or can't tell what it is when you do. So you must file it, label it, and be able to find it again and recognize it. Keep your filing method simple enough that it works. The very sophisticated systems for titling, plotting, and handling photography described in TM 30-245, Image Interpretation Handbook, may not be suitable for field conditions.

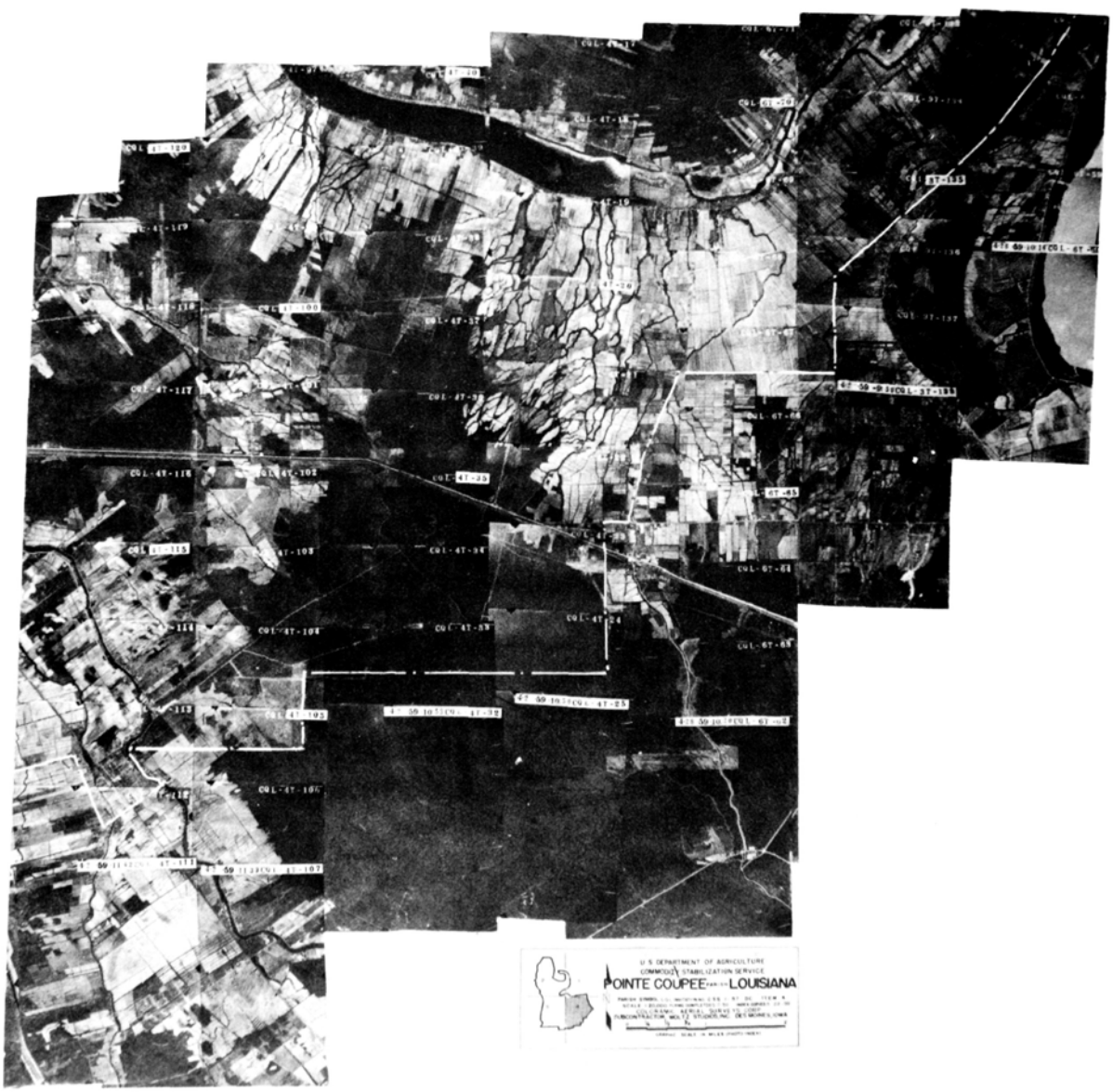
So: 1. KEEP IT SIMPLE
2. KNOW WHERE IT IS
3. KNOW WHAT IT IS

Almost all data you collect will be in the form of photos, maps, or documents and books, occasionally supplemented by non-photographic remotely sensed imagery. The data is stored and retrieved either (1) manually (by hand), (2) by automation using machines to do part of the job and manually to take care of the remainder of the job, or (3) by automation using machines to do all of the job.

SECTION 1. FILE PHOTOS

The simplest ways to manage aerial photo files are with either photo indexes or map overlay plots. Titles are important on all three--the photos, the indexes, and the plots.

Photo Index Mosaic. An uncontrolled photo index mosaic is the fastest way to show photo coverage providing you have a copy camera available. You lay the photo prints from each flight line over each other by matching detail. Staple them in place. Add a title and a legend and draw the map area corner ticks. (See TM 30-245, page 5-16). Have it "shot" and reduced on the copy camera. If no copy camera is available, make an index plot of the photos.



Index plot of Photographs. Drawing details on plots is time-consuming, so be sure you have enough time to draw the details you need. Use a plotting template on an overlay, over a map, usually a 1:250,000, and draw the outline of the area covered on the map by the photo. (See TM 30-245, page 5-16.). If flight lines are regular, you may plot only every fifth photo, as well as the first and last photos of the flight line. For examples of plots of oblique, strip, and panoramic photos, see TM 30-245, pages 5-17 and 5-23.

Titles of Photos. There are many systems of standarized titling. (See TM 30-245, chapter 4.). Some titles are brief and some are detailed.

The title is exposed directly on the film, in the corner of each film frame, as the photo is taken. It appears as a small rectangular box or "block". This block contains three columns of dots which are in binary code. When translated by means of a computer, the code tells the following information about each photo frame:

(1) Date (of photo)
(2) Photo-taking unit
(3) Sortie number
(4) Camera type, or sensor
(5) Barometric altitude
(6) Heading of the airplane
(7) Drift
(8) Roll
(9) Pitch
(10) Time (GMT)
(11) Latitude of the airplane (when the photo was taken)
(12) Longitude of the airplane (when the photo was taken)
(13) Radar altitude
(14) B/N (bombadier/navigator mode of operation)
(15) SLAR (side-looking airborne radar) mode
(16) ELRAC (electronic reconnaissance accessory set)

Other photo titling methods, such as alphanumeric data blocks, are discussed in TM 30-245.

Should you acquire photos with no titles, you will have to title them manually. On the film leader, write the name of the area covered by the photos. The minimum to write on each film frame or print is the roll number, date, and the frame number. Additional data may be written elsewhere, such as on the film roll can, the package of prints, or the photo data card.

Photo Data File Cards. If you are required to store a large amount of photography and sensor imagery, you may have to use a card file to control or search for photos.

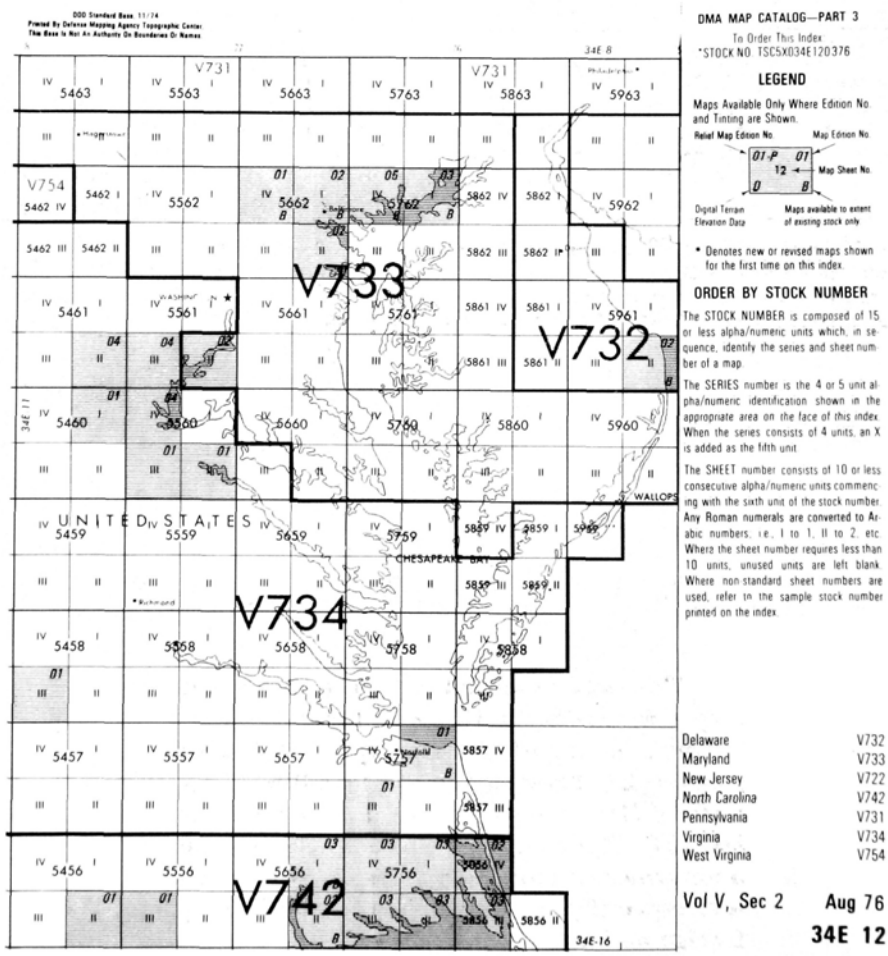
Depending upon the size of your collection of photos and sensor imagery, you may need a cross reference file on 3x5 cards. For example, suppose a request is. "What is all the latest coverage you have over Tan An?" Then you need a file by date of coverage and by the area of Tan An. Other cross references can be by country, province, source, type of imagery, or scale.

SECTION 2. FILE MAPS

Map Indexes. The indexes of foreign maps that you will use most frequently are those by the Defense Mapping Agency Topographic Center (DMATC), formerly known as Army Map Service and later as the Army Topographic Command (TOPOCOM). These are described in TM 5-248.

DMATC maps, however, do not provide complete coverage, especially within the United States, Puerto Rico, and the U.S. territories. DMATC is responsible primarily for foreign maps, and the U.S. Geological Survey (USGS) is responsible for domestic maps. (See chapter 2.) So you will need USGS maps for complete United States coverage. The USGS maps are indexed by a different system than those of DMATC. USGS indexes maps by standard quadrangles of 7-1/2 minutes, published at a scale of 1:24,000, and by 15 minutes, at a scale of 1:62,500 or 1 inch to the mile.* Most USGS maps of the U.S. are published at those scales in addition to 1:250,000 and 1:1,000,000. Alaska is published only at 1:63,360 and 1:250,000. Puerto Rico is published only at 1:20,000, 1:120,000, and 1:240,000.

* *1 Inch to the mile is actually 1:63,360, but the difference is negligible at this scale.*



USGS indexes are by state and each quadrangle has a name, not a number like DMATC maps. The name is usually a prominent feature such as the largest city or town in the quadrangle, and the names of adjacent sheets are shown in the margins. You must have an index to know the names of USGS sheets that are more than one sheet removed from the sheet you have.

NATIONAL TOPOGRAPHIC MAPS

Series	Scale	1 inch represents	Standard quadrangle size (latitude-longitude)	Quadrangle area (square miles)	Paper size E-W N-S width length (inches)
7½-minute	1:24,000	2,000 feet	7½ x 7½ min.	49 to 70	[1] 22 x 27
Puerto Rico 7½-minute	1:20,000	about 1,667 feet	7½ x 7½ min.	71	29½ x 32½
15-minute	1:62,500	nearly 1 mile	15 x 15 min.	197 to 282	[1] 17 x 21
Alaska 1:63,360	1:63,360	1 mile	15 x 20 to 36 min.	207 to 281	[2] 18 x 21
U.S. 1:250,000	1:250,000	nearly 4 miles	[3] 1° x 2°	4,580 to 8669	[4] 34 x 22
U.S. 1:1,000,000	1:1,000,000	nearly 16 miles	[3] 4° x 6°	73,331 to 102,759	27 x 27

[1] South of latitude 31° 7½-minute sheets are 23 x 27 inches; 15-minute sheets are 18 x 21 inches.
[2] South of latitude 62° sheets are 17 x 21 inches.
[3] Maps of Alaska and Hawaii vary from these standards.
[4] North of latitude 42° sheets are 29 x 22 inches. Alaska sheets are 30 x 23 inches.

The only other index of complete world map coverage is the U.S. Coast and Geodetic Survey's index of aeronautical charts. (See chapter 2.) These indexes are numbered by a still different system from that of USGS or DMATC. The charts can serve as a useful base upon which to plot other maps to show coverage, especially of foreign maps (published by foreign nations).

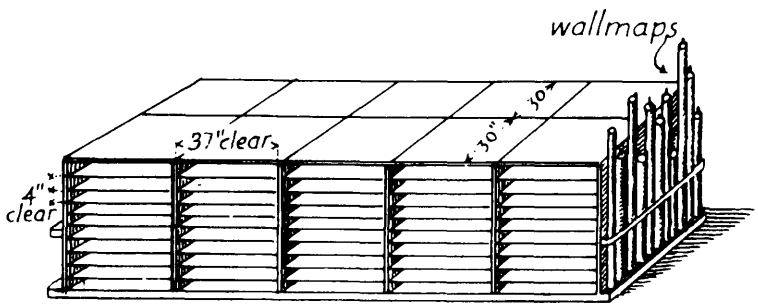
Map Plots. Maps are easy to plot. Simply draw the outline of the map coordinates on a smaller scale map or on an index of another map series. You can use an overlay to avoid marking up a base map or the index. Map overlay plots are a good way to compare the coverage of different maps of the same area.

Map Titles and Files. If maps which you are filing do not have a title in the lower right-hand corner, you may need to write one in order to find it easily when searching the map file. Maps are best filed in folders of strong (wrapping type) paper 24" x 36". They can be easily and quickly made in the field with masking tape or staples, and can hold 30 or more maps.

A title of the contents should be written on the lower (front) right-hand corner. These folders can be numbered in order to return them to their proper place in the file. A good idea is to include a second copy of the map index in each folder to indicate its contents. Keep the master copy of all indexes together in a binder.

Maps can be grouped in folders regionally by countries, provinces, or by some other geographical breakdown. If the map is too large for the folder, it is better to fold the map once or twice than to roll it. A rolled map is difficult to identify, space consuming to store, and a pain to unroll to look at.

Two map folders fit nicely side by side in a standard map file (42" x 54"). The map file comes in five-drawer sections. Map files can be easily improvised from open-end wooden cases, and the top can be used for spreading out maps.



SECTION 3.
PLOT REMOTELY SENSED IMAGERY

Infrared (IR) imagery, described in TM 30-245, pages 2 through 25, is produced by an airborne scanning unit combined with the forward motion of the aircraft. The result is an effect of "painting" narrow strips on the ground. These strips are added to each other as the aircraft moves forward and the total ground coverage is similar to that of visual strip photography.

Side looking airborne radar (SLAR) imagery is produced by a method similar to the method used to produce IR imagery. The radar "looks" out from each side of the airplane in a narrow beam. Then the airplane flies ahead and the radar takes another look sideways. These "looks" (or side scans) are added to each other on the radar display tube. A picture is taken of them, like taking a picture of your TV screen. This picture of the radar is your SLAR imagery. So you have a photograph of a recording display in both cases, SLAR and IR, but of two different types of energy. In the case of SLAR, the energy is a radio wave and in the case of IR, it is a heat wave.

Since the ground coverage of SLAR and IR is similar to that of visual strip photography, you plot all imagery about the same way. Simply plot the width of ground covered by two parallel lines on an overlay over a base map. Use symbols and annotations as indicated in FM 30-245, pages 5 through 17. Frequently the plot will "run" from one topographic sheet onto the next. You will need many large-scale maps, or better, plot to a small-scale one such as 1:250,000.

CHAPTER 4

USE THE DATA FILE

SECTION 1. ANALYZE SOURCE MAPS

INTRODUCTION TO MAP READING

As a terrain analyst, you will read maps to extract information for terrain studies. You will also use a map as a base upon which to add this information to compile your data overlays or special purpose overlays.

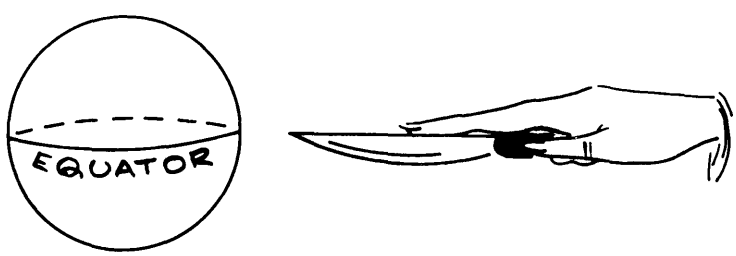
To best understand and use the map information, refer to the legend, which contains symbols of terrain and manmade features shown on the map.

Always look at the legend before using the map. For more details regarding map symbols, refer to FM 21-30, Military Symbols, May 1970, and FM 21-31, Topographic Symbols, June 1971.

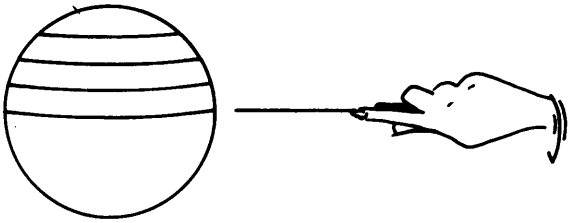
MAP PROJECTIONS

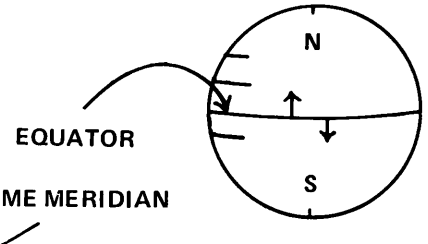
The earth is a globe and a map is flat. There is no way to flatten a globe without stretching or tearing. If you stretch, you distort the areas or shapes of areas to be shown. As long as the area is small, the distortion is not great, as on a city or county map. But when the areas are of continental size, the distortion may be serious. When continents are shown, each with its correct area, the shape is badly distorted.

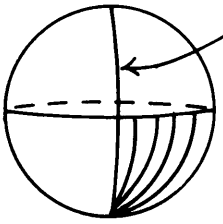
This distortion is a result of "projecting" the shape of the globe, a sphere, onto a flat surface. The first step in making a map projection is to determine geographic coordinates. For a global (worldwide) projection you would mark a sphere where it would slice in two, in the middle, like an orange. This mark is the equator.

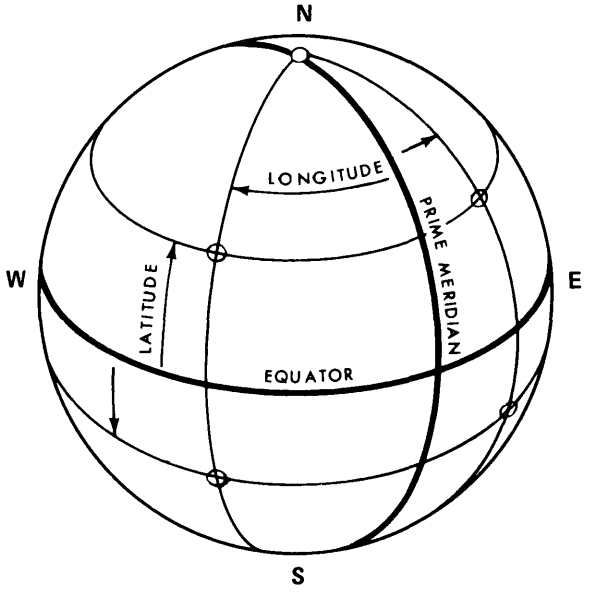


Then imagine that you cut the sphere into a number of other horizontal slices of equal distances apart, like slicing an egg. Call these marks "latitude" lines north and south of the equator. Then divide the equator into 360 degrees of "longitude" where each division is sliced through the North and South Poles of the sphere. Let's call the first slice of longitude the prime meridian and number all others east or west of it. The lines of longitude and latitude form the geographic coordinate system described in detail in FM 21-26, chapter 3.







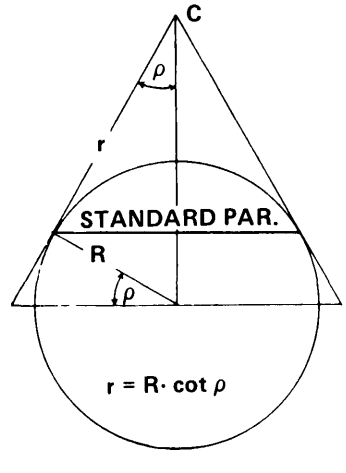


Here is part of the Geographic Coordinate System.

There are many ways to show this coordinate system on a flat paper. One of the most frequently used methods is a conic projection. Imagine that the cartographer (mapmaker) places a cone of paper, like a dunce cap, on a transparent globe. He puts a light bulb in the center of the globe and traces the grid shape and continent outlines on the paper hat. He then unwraps the cone and this is his map of that area. Of course the map is not actually made in this way, but this comparison shows the theory of the conic projection.

More complete details of types of conic projections are presented in TM 5-241-1, Section II and TM 30-245, chapter 5.

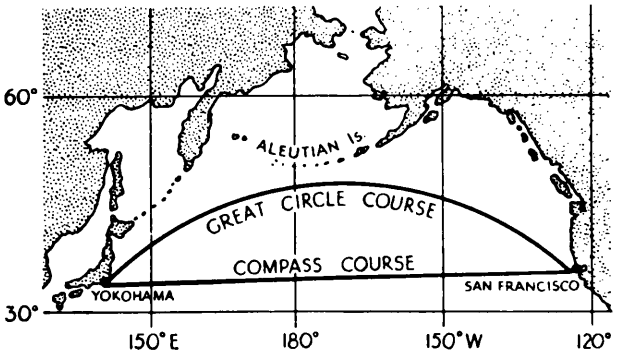
Generally the disadvantage of a conic projection is that the larger the distance between two points on the cone, the larger the distortion and error will be. As a compromise solution to this problem the cartographer uses many differently shaped cones, one for each belt around the earth. This produces a projection called "polyconic", in which the longitude and latitude lines have pronounced bends.



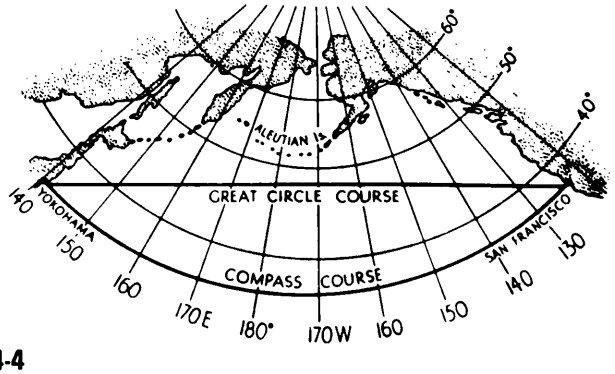
Geometry of a conic projection.

The projection used for a map depends on (1) the part of the world to be mapped, including both size and location, and (2) the purpose for which the map will be used. Every advantage gained for one purpose (say consistency of scale) must be at the expense of some other factor (such as accuracy of shape).

For navigation, neither shape nor scale is as important as the ability to plot compass courses as straight lines. This is the advantage of the projection known as Mercator, which has been used for centuries in navigational charts. It is easily recognized because the parallels and meridians are all straight lines, and the parallels get progressively farther apart toward the poles. This produces serious distortion of areas in the higher latitudes, but it does not affect the maps usefulness for navigation. For example, if you were to fly from San Francisco to Yokohama and headed due west using a Mercator chart, your compass course would look like this:

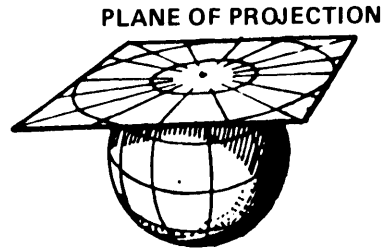


A "great circle", which is the shortest distance between two points on the globe, appears longer on a Mercator projection. So a gnomonic projection was designed in which every great circle appears as a straight line. Gnomonic projections are used to lay out long sailing and flying routes. For descriptions and uses of other map projections, see TM 30-245, chapter 5.



The projection most used by the Army is a modification of the Mercator projection called Transverse Mercator, designed for areas between 84° north and 80° south, where practically all the inhabited land of the earth lies. (See section II, TM 5-241-1 and chapter 3, FM 21-26.)

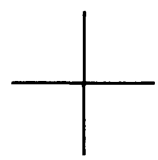
For areas in high latitudes, a Polar Stereographic projection is used. These are the North and South polar regions. In this case a plane is tangent to the sphere at the pole and detail is projected onto it.



POLAR CASE

GEOGRAPHIC COORDINATES

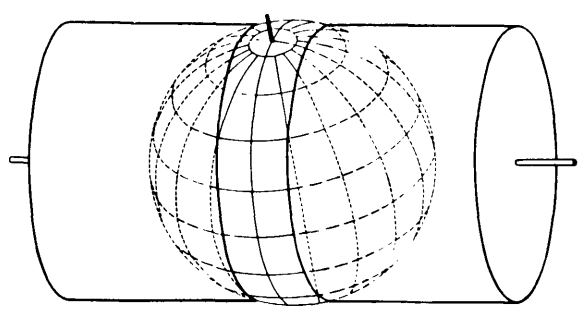
Let's go back to page 4-2 where we divide the earth into meridians and parallels. We label the parallels in degrees, minutes and seconds north or south of the Equator and the meridians in degrees, minutes and seconds east or west of the prime meridian. Now we can locate any point on the earth by longitude and latitude. (See TM 5-241-1.)



76°30'10" WEST LONGITUDE

MILITARY GRIDS

Soldiers in the field soon found that giving orders by longitude and latitude to designate exact locations and directions was most cumbersome. To confuse the situation even more, the length of a degree of longitude varies with distance from the Equator. So military grids were designed. Almost every general staff designed its own, however, and soon there were dozens of grids and endless confusion. This all led to adoption by the U.S. Army of the Military Grid Reference System for identifying locations on military maps. This system uses the UTM (Universal Transverse Mercator) grid between 80°S and 84°N latitudes; for the polar regions (north of 84°N and south of 80°S) we use the UPS (Universal Polar Stereographic) grid.



Using the Military Grid Reference System, you will not identify points by latitude and longitude but rather by a series of numbers and letters that designate squares of various sizes on the earth's surface. The largest of these squares are 100,000 meters on each side. They are designated by two letters which place the square within a "grid zone" that is 6 degrees wide (in longitude) and 8 degrees high (in latitude). For example, Fort Belvoir is in 100,000-meter square UT, within grid zone 18S. You can find this information in the lower margin of a map of the Fort Belvoir area (in the Indian Head sheet).



Grid zone

100,000-meter square

GRID ZONE DESIGNATION: 18S 100,000 M. SQUARE IDENTIFICATION UT	TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS SAMPLE POINT: ALEXANDRIA CHAPEL
IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 4264000	1. Read letters identifying 100,000 meter square in which the point lies: UT 2. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: 08 Estimate tenths from grid line to point: 2 3. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: 67 Estimate tenths from grid line to point: 3 SAMPLE REFERENCE: UT0826 73 If reporting beyond 18° in any direction, prefix Grid Zone Designation, as: 18SUT082673

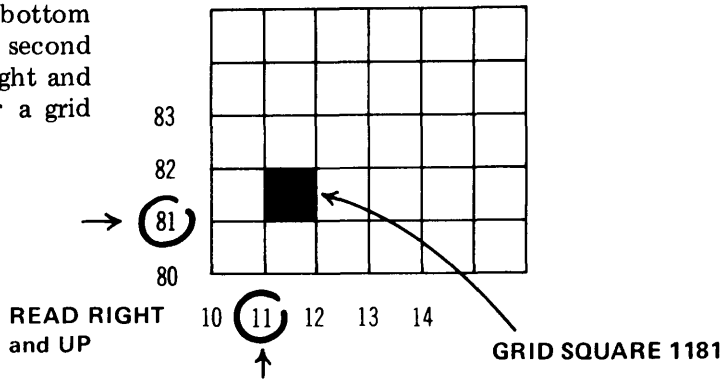
These are 1,000-meter grid squares

Reference to nearest 100 meters

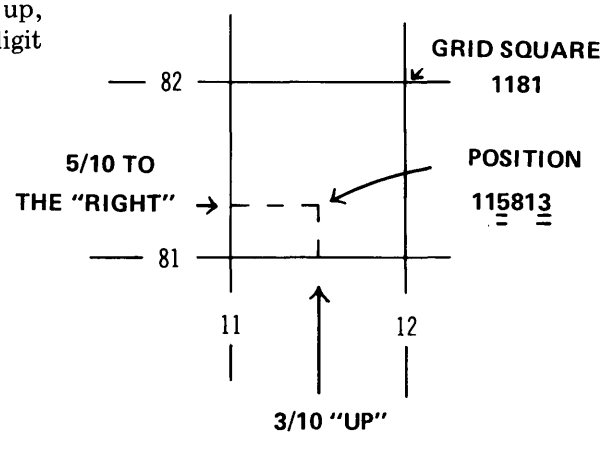
How the Indian Head, MD, VA sheet fits into the

Military Grid Reference System

When you are finding a position on a large-scale topographic map, you are more interested in the 1,000-meter squares, which are called "grid squares." These are identified by a 4-digit number. You get the first two digits by reading the numbers on the bottom of the grid from left to right and the second two by reading up, i.e., you read "right and up." This gives you the number for a grid square.



Now to find your location inside the grid square (to the nearest 100 meters), you need two more digits, one for the horizontal axis and one for the vertical axis. So within the grid square, you estimate how many tenths of the way you are over to the right, and how many tenths of the way up you are. Suppose you are 5/10ths to the right and 3/10ths up, then you insert these to make a six-digit number, such as:

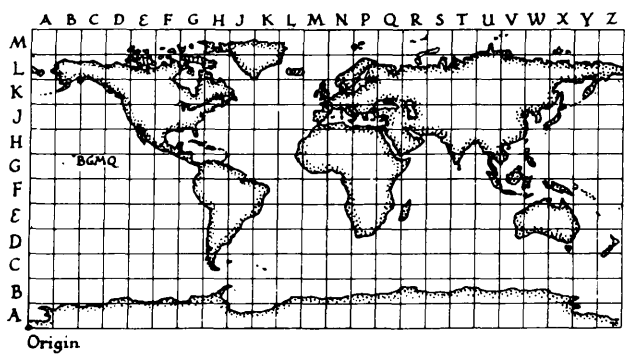


This is just a summary of how we use the Military Grid Reference System. For more information about how it is derived and its worldwide application, see FM 21-26, Map Reading.

WORLD GEOGRAPHIC REFERENCE SYSTEM (GEOREF)

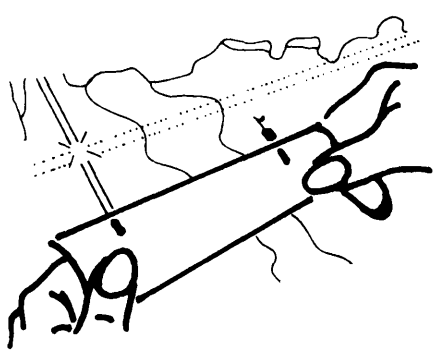
This is a worldwide position reference system used primarily by the U.S. Air Force. It uses geographic longitude-latitude in degrees and minutes with a simplified scheme of reference. The world is divided in 15° bands of longitude, lettered A to Z (with I and 0 omitted). Latitude is also divided into 15° belts lettered A to M beginning at the South Pole. Thus you have 288 quadrangles each identified by two letters. Each quadrangle is subdivided into one-degree squares and marked A to Q. Thus four letters will identify a 1° quadrangle, for example BGMQ. Further details are in FM 21-26.

The GEOREF system is used for air navigation and global reference. It uses degrees and minutes but records them by letters and numbers starting from the 180° meridian and the South Pole.



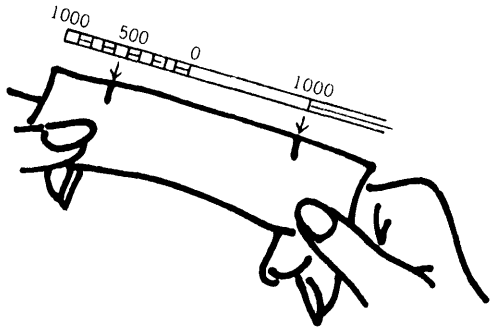
SCALE AND DISTANCE

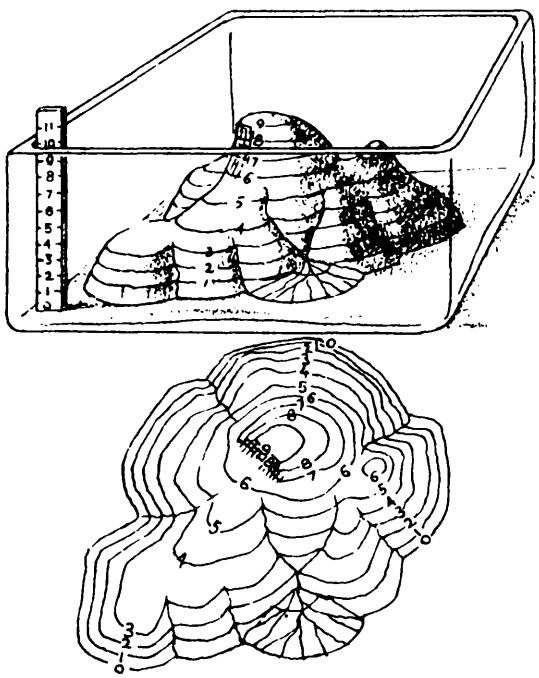
A map is drawn to scale. The scale is printed at the bottom and top of the map like this: 1:50,000. It means that 1 foot on the map equals 50,000 feet on the ground. At the bottom of the map, you'll see also one or more bar scales. Topographic maps used by the Army generally have bar scales in three different units.



Here's how to use the bar scale to measure distance on the ground. Take a piece of paper and mark on it the distance between two points on the map.

Then put this paper, with the two marks on it, next to a bar scale and read on the bar scale what the distance represents. For more details, see FM 21-26, chapter 4.



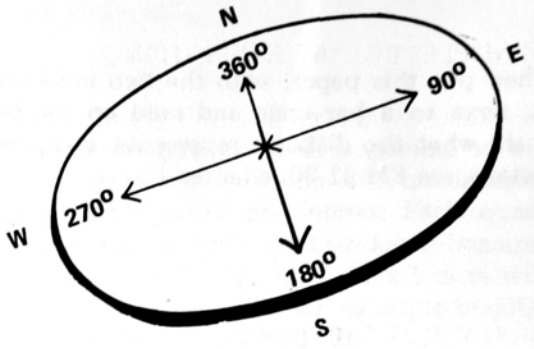


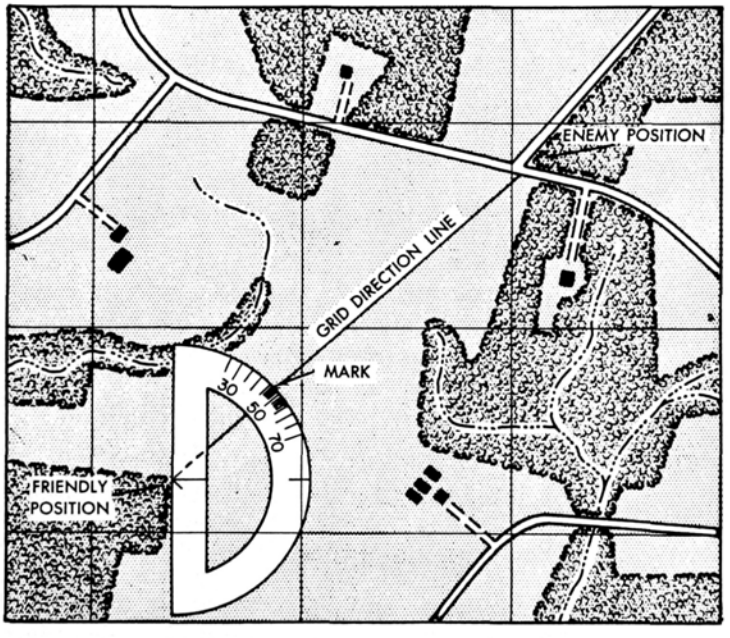
ELEVATION AND RELIEF

How high is the hill and what's its shape? Elevation is the height above a reference plane, usually mean (average) sea level. Relief is the configuration of the terrain. Of the many ways to show relief, the most common way is by contour lines. A contour line is an imaginary line on the ground connecting all points of equal elevation. The spacing and arrangement of contours show the various shapes of the hills and steepness of slopes. Descriptions and illustrations of slopes and shapes such as valley, water basin, ridge, spur, saddle, depression, cut and fills, and cliff, are shown in FM 21-26, chapter 6. Also described and illustrated are other methods of depicting relief such as hachures, shaded relief, and form lines.

DIRECTION AND LOCATION

How to find your location on a map was described on a previous page. Azimuth is read in degrees from north. The compass, like a circle, is divided into 360 degrees. North is 0 or 360°; east is 90°; south is 180°; and west is 270°.





To plot (or measure) the azimuth on a map you will use a protractor. Techniques are covered in great detail in FM 21-26.

PRINCIPLES OF LAND NAVIGATION

Land navigation is the ability of a soldier to find his way cross-country, determining his direction with a compass, the stars, or the sun, and by terrain association, dead reckoning, and map reading. How to do it is described in FM 21-26, chapter 5.

ANALYTICAL PHOTOGRAMMETRIC POSITIONING

This involves the use of geometry and mathematics to determine the position of points on aerial photos involving scale, parallax, and relief displacement. Techniques are described in TM 30-245.

USE OF THE PLANIMETER

A planimeter is an instrument used to measure areas of irregular shapes on maps or photographs. The type that you will use is called a "polar planimeter." This instrument is anchored at one end, and you trace the area's outline with the movable point on the other end. Detailed instructions are furnished with the instrument by the manufacturer.

FOREIGN MAPS

Not all of the maps you will use in terrain analysis will be produced by the U.S. Government. In studying foreign areas, you will often need to use locally produced maps, either because they show details that are not on the maps made in the United States or because they are all that will be available in some situations.

Your biggest problem in using these maps will be one of language. You should have some sort of table of equivalent terms for the language your map is printed in. Sometimes this is given in the margin on an English-language map of a foreign area, or places will be labeled in both the native language and in English. You may have to learn an alphabet that is new or partly new to you, such as Greek or Russian, but you will find that with a little concentration this is not so hard to do.

It pays to learn what common terrain features are called in various languages. For example, in Central Asia a mountain pass might be shan-hou in Chinese, hotol in Mongolian, la in Nepalese and Tibetan, pereval in Russian, or an in Kashmiri. A river would be ho, gol, khola, chhu, darya, and chu in these same languages.

The Army has compiled a summary of the characteristics of the maps of most countries of the world, which you will find useful in any terrain study of a foreign area. This is TM 5-248, Foreign Maps.

SECTION 2. INTERPRET IMAGERY

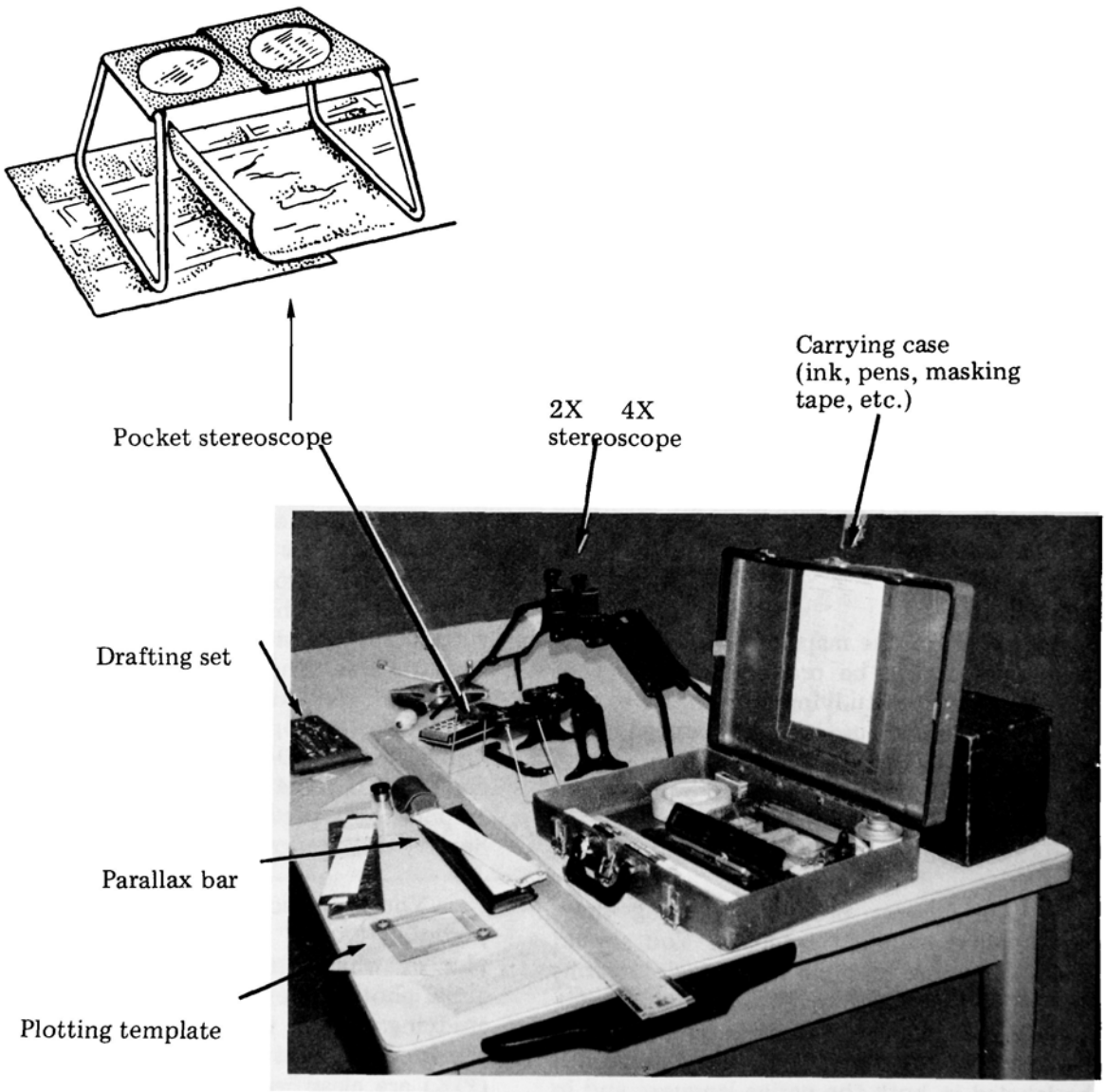
AERIAL PHOTOGRAPHY

Aerial photographs are taken from airplanes with cameras pointed at the ground. The photographs are frequently called air photos. There are many types of cameras and photos, such as high obliques, low obliques, vertical, panoramic, and strip, and many different scales. The interpretation techniques and instruments used range from very simple to extremely sophisticated. These are described in TM 30-246, FM 21-26, chapters 8 and 9 of FM 30-245, and the Manual of Photographic Interpretation by the American Society of Photogrammetry.

You will also make use of photo interpretation "keys." These show typical examples of what terrain features look like on aerial photos. They are essential when you are studying an area that cannot be checked on the ground. Most photo interpretation keys (PIK) are classified, for a listing of them see Appendix A of FM 30-10.

HEIGHT AND DISTANCE DETERMINATION FROM AERIAL PHOTOGRAPHY

Although many extremely sophisticated instruments have been developed to measure distance on aerial photography, some of them operated automatically by computers, the terrain analyst will most frequently use basic and simple techniques. Some of your tools will be the same as those used in photointerpretation and drafting, such as the 2X pocket stereoscope with parallax bar, tube magnifier with a measuring base, drafting tools, plotting template, and photointerpreter's slide rule.



The Terrain Analyst's Office Equipment

PHOTOINTERPRETER'S SLIDE RULE

This slide rule was designed especially to permit rapid calculations of (1) dimensions of objects on photos, (2) scale of photos when altitude and focal length are known, (3) altitude required for a desired scale with a particular focal length, (4) ground covered by any scale of photography, (5) percent of forward overlap, (6) ground distance between adjacent flight lines, (7) exposure interval to meet photo overlap required. You will need to be able to do the first two of these operations on the slide rule; the others are mainly for flight planning. See section 3-10, page 3-63 of FM 30-245 for examples of operation.

PHOTO MOSAICS

You will only need to prepare uncontrolled mosaics, that is, mosaics that are not adjusted to exact measurements. The photos are simply overlapped by matching images and are stapled or glued together. Details are described in TM 5-240, chapter 9.

DRAFTING PRINCIPLES FOR OVERLAY PREPARATION

Overlays are prepared for color separation by pen and ink drafting or scribing techniques described in TM 5-240, chapter 8.

PHOTOGRAPHIC TECHNIQUES IN RECONNAISSANCE

It is often valuable to obtain ground photos using handheld cameras to gather terrain data when on reconnaissance. Their use for this purpose is explained in TM 11-401, TM 11-401-2, FM 5-36, and FM 30-10.

NONPHOTOGRAPHIC IMAGERY

Radar and infrared imagery is mostly supplemental to aerial photointerpretation. For information concerning its use, see TM 30-245, TM (C) 30-245A, Remote Sensing, by the National Academy of Sciences, and Remote Sensing for Environmental Analysis, by J. Estes and L. Senger.

Imagery from satellite transmissions, described on a previous page, is of very small scale (about 1:1,000,000) and still experimental. Its use in terrain analysis is limited to icepack reconnaissance, snow cover, and shoreline measurement. For more information, see the two books on remote sensing listed above.

SECTION 3.
INTERPRET WRITTEN INFORMATION

WHAT TO USE

In chapter 2, we talked about the variety of sources that you can draw on for terrain information. Written sources (in contrast to maps and photographs) are especially diverse since they can be anything from tourist advertising to scientific articles. The important thing to remember is that you should be alert to use any source that can fill in pieces of the "jigsaw puzzle" that we call terrain. You will find travel magazines such as the National Geographic or similar periodicals from other countries especially useful because of the illustrations and maps they contain.

HOW TO EVALUATE IT

Drawing on a variety of sources does not mean you should not be critical of them. On the contrary, you should continually question the accuracy of the written matter that you use, whether it is books, magazine articles, brochures, or whatever. Ask yourself what its purpose was, and whether the author was trying to sell something or had a personal "ax to grind." What do you know about the author? Is he an authority in his field or someone who just visited the area briefly in order to get a quick story? Finally, how recent is the information? If it is 10 or 20 years old, what changes might have occurred in the meantime?

WHAT TO DO WITH IT

There are several ways to handle information from written sources:

1. If you find it to be unreliable and not worth keeping, you should make a note of the source (on a 3x5 card or in a notebook) with your opinion of it so you will not waste time on it again.

2. If you find worthwhile information in it, you should make notes on the card or in your notebook. You can either extract data then and there, or you can write down the kind of data for future reference.

3. Instead of an intermediate file of notes, you can copy the data that you might need directly onto a map overlay or photograph. Remember to show in the margin, or by a symbol of some kind, where the information came from.

CHAPTER 5

ANALYZE TERRAIN FACTORS

INTRODUCTION

Having acquired and organized the data that you need for the area you are studying, your next task will be to interpret the individual features of the terrain. We divide them into natural and cultural (or manmade) features. The distinction is not clearcut, of course, since many features have both natural and manmade elements. Examples are a planted forest or a reservoir made by enlarging a natural lake. In general, though, we think of the natural features, or "factors," as being surface configuration, soils and other surface materials, vegetation, drainage or hydrological features, and climate, while buildings, factories, mines, transportation routes, cities and other settlements, and farming enterprises are considered to be cultural.

The first six parts of this chapter take up terrain factors that are primarily natural, although any and all of them can be changed by human activities. Section 7 lumps together those factors that are chiefly manmade, especially settlements and means of transportation. Any one of these is a big subject in itself and you will have to look in the various references listed in the Appendix for more detailed information about them.

SECTION 1. PREPARE CLIMATIC SUMMARIES

WEATHER VERSUS CLIMATE

Weather is the state of the atmosphere commonly thought of as the here, now, and today. It can be unique or very commonplace. It can be described in simple terms (stormy, clear, rainy); or it can be measured by complex instruments either continuously or at regular intervals. The sum total of the weather records at a place becomes the climatic record of that place. Climate, then, is a summary of weather, and it is normally expressed in terms of means, extremes, and frequencies. The uniqueness of today is usually lost as the weather record takes its place as part of the total climatic record. But the prediction of both the weather of tomorrow and the longer period averages and extremes for a place is important to many military field operations. (See section II of chapter 3, FM 30-10.)

CLIMATIC DATA AND ANALYSIS

In chapter 2, you learned something about the variety of sources for climatic data. The presentation of climatic data can range from simply classifying the climate of a place (figure 2-1 of chapter 2, FM 30-10) to providing very detailed and even special purpose statistics for particular users (figure 2-6 of chapter 2, FM 30-10). A general purpose study of the outstanding characteristics of the climate of a place is called a climatic summary. Here is an example of one.–

EXAMPLE OF CLIMATIC SUMMARY

CLIMATIC SUMMARY FOR THE MONTH OF JULY - 3d CORPS AREA

1. GENERAL CIRCULATION

Generally air flows from the west and northwest. Occasionally warm, dry continental air from Russia causes a relatively intense, dry heat with temperature 90°F or more.

2. TEMPERATURES

Afternoon temperatures generally are in the 70's and morning temperatures are in the 50's. There are occasional periods of hot, dry spells that last more than a week with temperatures in the 90's. The highest temperature ever recorded was 101°F.

3. THUNDERSTORMS

Occur frequently. They usually develop during the day and reach maximum intensity in the late afternoon and evening.

4. SURFACE WINDS

Average windspeed is 5 MPH. The most predominant direction is northeast, with a mean speed of 8 MPH. Calms are frequent, occuring 25.2 percent of the time, and usually in the early morning. Calms or near calms often last the whole day.

5. CLOUDINESS

Mornings frequently are clear. Clouds develop by noon and cloud cover reaches a maximum in the late afternoon, decreasing to nil just before sunset.

6. VISIBILITY

Normal visibilities are 7 to 13 miles and occasionally further. Occasionally haze may reduce visibility to about 3 miles.

7. PRECIPITATION

Thunderstorms are the usual cause of precipitation. Occasionally a southwesterly wind will cause continued drizzle and low, overcast skies for one to three days. This is the only time low visibilities occur. Occasional haze may reduce visibility to about 3 miles.

The format of a climate summary is variable both in scope or number of weather elements covered and in the details presented. The manner of presentation (maps versus tables; graphs versus statistics) also varies with the needs and desires of the particular user. This variation should present no special problem to the skilled and experienced terrain analyst if he has a wide range of formats to choose from. He soon learns from experience--not only what is good, but what is better and best. Imagination and ingenuity are important ingredients in preparing a climatic summary or study--along with the necessary communication with a user. Contact with the user should take place before and during, as well as after, preparation of the climatic summary.

Your personal collection and retention of many different formats for preparation and presentation will aid greatly in this phase of your operations. Being as precise as possible in any statements you make during the compilation and analysis of the climatic data will generally aid users and commanders in making the right decisions based on this part of your work. Don't oversimplify the atmospheric conditions nor provide too many details unless specifically called for by your user's need.

WEATHER AND THE TERRAIN

Day to day forecasts are not the responsibility of a terrain analyst, as the Army in the Field gets these from the Air Force. However, a study of climatic records is in itself a kind of long range forecasting, since a knowledge of what the weather of a place has been in the past can give some idea of what it is likely to be during the same seasons in the future.

Since most terrain factors are affected in some way by the weather, it is important for you to understand what these relationships are in whatever area you are analyzing. An area with marked seasonal variations in rainfall, for example, will have large differences in soil trafficability, degree of difficulty in crossing streams, and perhaps in the amount of concealment provided by vegetation between one season and another. So it is part of your job to know what the weather is usually like at the time of year that your "customer" is concerned about, and how the weather is going to affect the various terrain factors. The commander who asks you for a terrain study will want to know both how the weather elements that are likely to occur will affect his operations, and how these same conditions may affect the enemy's course of action.

Although this may seem like a tall order, these effects will have to be taken into account as you prepare the overlays for each terrain factor.

SUMMARY OF PROCEDURE

1. Find what stations have taken observations in or near your area.

2. Assemble whatever records you can obtain from Air Weather Service or other sources.

3. Prepare tables of average and extreme temperatures and rainfall for each month.

4. Mention any special weather conditions that are likely to occur and when (thunderstorms, fog, wind, frost, snow, etc.), with data when possible.

5. Note any climatic disasters which the area has experienced (floods, tornadoes, etc.).

6. Prepare graphs which might help the user understand the climatic picture.

SECTION 2. ANALYZE DRAINAGE FEATURES

RELATIONSHIP TO MILITARY OPERATIONS

From ancient times, rivers (and all watercourses) have been obstacles when they lie across the path of movement. Today, with the concept of rapid mobility, it's vital for commanders to know what streams exist, where they are, their size, and how much water they are likely to have at each season of the year.

By drainage, then, is meant the various types of watercourses (perennial or intermittent), their bottoms and bank conditions, flooding potential, lakes (including evaporation basin areas, or dry lakes), and wet areas such as marshes, swamps, and bogs. The term includes also the underground zone called the water table, and surface springs and seeps. The study of all of these aspects of water (other than the oceans) is called hydrology.

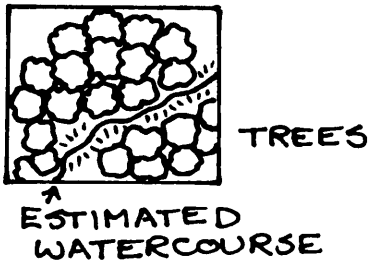
Rivers more than 150 meters (500 feet) wide are major obstacles to military operations. But width of a watercourse is not its only serious aspect. Key terrain adjacent to a river, which allows the enemy to direct small arms fire or artillery fire, or terrain capable of accommodating friendly forces, can be just as important. Floods can immobilize large-scale operations unless some information prior to the event is made available to the commander. Lakes, especially if numerous, are also major obstacles to rapid movement, as are large swamps and marshes.

WHAT YOU NEED TO KNOW

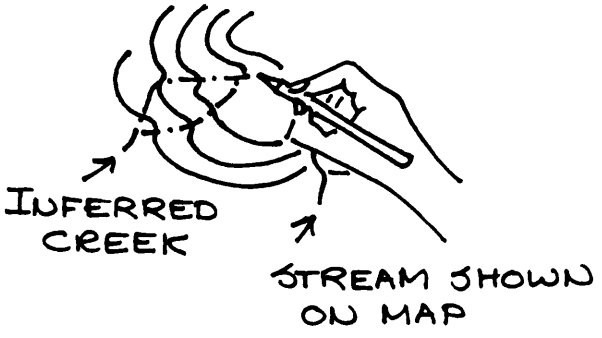
In some parts of the world, the density (or number) of creeks, rivers, and streams is so great per square mile that it's tough going in those areas, even walking. An overlay showing the density of an area's streams quickly suggests to a commander whether he will have a problem getting troops and equipment across the area, or a part of the area. Your job, then, is to plot all watercourses (wet or dry) in an area of operations, provide some basic data about them, and interpret their possible effects on military operations.

In other words, drainage isn't just identifying major rivers. These are shown on topographic maps and are evident in most aerial photos. It is the total number of watercourses — their widths, bank conditions, bottom characteristics, etc., — that you're interested in, large and small. Many of these are not even shown on maps.

Fortunately, drainage is easy to see on most maps and photos. Maps usually show only those watercourses that the map maker thought important enough to show. But your job is to show many more. To do this, you can place an overlay over a topographic map and by connecting indentations in adjacent contour lines estimate the positions of watercourses not shown on the map. This simple effort, then, allows you to imagine just how rough the terrain is.

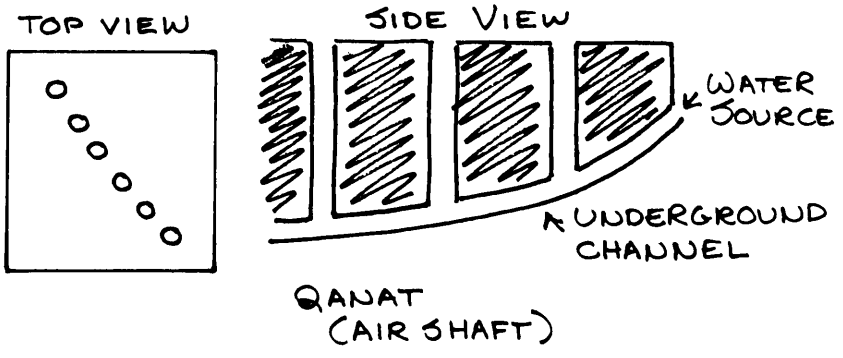


Sometimes aerial photos of densely wooded areas aren't too helpful in showing watercourses in the area. Your best bet, then, is to connect depressions in the vegetation canopy (the tops of the forest cover) by a line which probably is close to the actual location of the hidden watercourse.



In more open areas, by tracing lines of trees or other vegetation, you'll be able to locate watercourses approximately if they are not shown on available maps. For example, on the llanos (plains) of South America, thin lines of darker vegetation usually follow watercourses which may not be shown on maps.

In extremely dry lands, there is no vegetation to guide your eye. However, in some countries, such as Iran, a line connecting man-made holes in the ground may provide some idea of the underlying watercourses. These holes are openings to the surface from underground galleries or tunnels (called qanats) in which water flows; the holes permit air to reach the galleries in which workers keep the tunnels open.



So, having examined your map or photograph, you have some idea of where the watercourses are. If the contours tend to be "bumpy," you probably will suspect that the area has more creeks than are shown on the maps. But if the contours are smooth, there are few drains or watercourses in the area.

Place a mylar or other transparent drawing material over the map or photo. Using a black-lead pencil, lightly trace all the watercourses. If you get confused as to the direction of streamflow, use arrows to show directions.

Once you've traced all watercourses onto the overlay, study it carefully. From this overlay and other sources of information, such as the topographic map or photos of the area, consider the following:

1. Terminal points and identification of streams with gap widths greater than 3 meters. (For meanings of these terms, see the glossary at end of this section.)

2. Terminal points and identification of stream segments with widths greater than 3 meters.

3. Alignment of normally dry watercourses.

4. Alignment of streams with gap widths less than 3 meters.

5. Gap widths, by classes, of streams with gap widths greater than 3 meters.

6. High and low water depths of streams greater than 3 meters wide.

7. Bank heights and slopes above mean water.

8. Structures.

9. Obstacles.

10. Areas subject to flooding.

11. Navigation aids.

12. Location of stream cross-sections.

13. Water bodies.

14. Navigation channels.

15. Location of gaging stations.

16. Location of water sample sites.

17. Wet area.

Certain kinds of data about watercourses can be shown best by tables. The following data can be obtained from photoanalysis, inspection of topographic maps, or from pertinent reference sources. Many lend themselves to brief descriptions, as in the following examples.

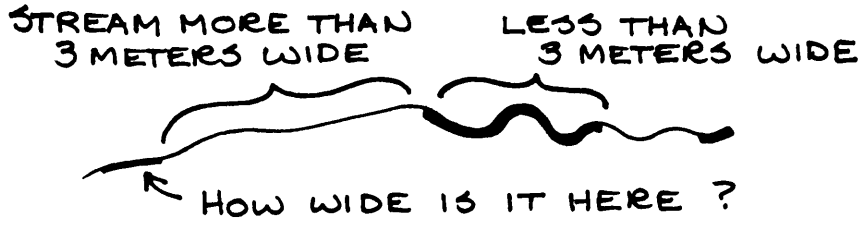
1. Water gap widths	15-25 meters
2. Icing conditions	Begins in November; up to 3 feet thick; irregular over lower river
3. Bank and bottom materials	Sand with boulders; clay, soft
4. Water quality	Unfit in upstream area
5. Representative cross-section of stream	(Sketch, with scale)
6. Layout of significant structures	(Sketch with scale)
7. Description of obstructions	(Sketch, with scale)
8. Classification of watercourses and water bodies	(Perennial or intermittent)
9. Description of wet areas	(Brief description of area, surface, periods of dryness, vegetation)
10. Water velocity	(If known, state. If not, attempt to estimate, give season of occurrence)
11. Tidal influence	(Wave action; heights. How banks, stretches affected; effect on ford site)
12. Vertical and horizontal clearances	(Bridges, towers, transmission lines)

Assuming that you can estimate answers (by studying photos or maps) or can obtain answers from pertinent sources such as hydrologic reports, pencil the data onto the overlay at points where it is relevant. For example, if you can measure stream bank heights at point X, pencil the heights next to point X on the overlay.

Careful study of your annotated overlay will suggest broad groupings of related data. Stretches of rivers (or creeks, dry washes, or wadis) having widths less than 3 meters can be grouped under the heading, "Less than 3 meters wide." Streams over 3 meters (or whatever width you deem most significant for the area) can likewise be grouped.

With a lead pencil mark on the overlay those stretches of streams 3 meters or less in width; use a heavier stroke of the pencil if these are the sections that are most important to you.

Prepare a legend or table showing the various symbols used and their meanings. In this case, a thicker pencil stroke indicates streams 3 meters or less in width.



The other categories of information listed above are also grouped by you, marked on the overlay, and tabulated according to symbol. For example, stream banks less than 10° can be identified on the overlay by a symbol and the symbol shown in your legend.

GENERAL INFORMATION ABOUT WATERCOURSES YOU NEED TO CONSIDER

Before preparing your overlay, study the following list. Then, as you prepare the overlay, fill in as many of these spaces as possible, as in the examples given. Use whatever references you can find to obtain answers not obtainable from photos or maps. This is merely a checklist to orient your thoughts about the drainage in any area of interest.

	Example
1. Rivers and Streams	
a. Name or other identification and location	Podunk Creek
b. Channel characteristics (form, length, profile gradient of stream bed)	Winding; 10 kilometers; falls 10 ft. in 1 km.
c. Bottom characteristics (composition, depth, firmness, unusual conditions)	Rough gravel bottom; depth more than 3 meters
d. Flow characteristics:	
(1) Measurements and periods of occurrence at low, high, and mean water of depth, width, volume of discharge, and velocity (minimum, maximum, and mean)	
(2) Special phenomena (crosscurrents, undertows, eddies, floods); periods; area covered; destructive effects. Tidal effects at low, high, and mean tides.	Subject to floods in June; tides average 1 ft. twice a month

e. Physical and chemical characteristics of water (turbidity, color, odor, taste, temperature, chemical composition, bacterial pollution, seasonal variations)	Stinks at low tide. Polluted (human) near Podunk City
f. Bank characteristics (composition, stability, height, and slope	Sandy clay slopes, 5—10%, except near trees lining bank
g. Regulatory structures (levees and dams)	No dams but several locks
h. Islands, bars, shoals, and rapids (name, size, surface roughness, elevation, and pattern)	Rapids (covered by June floods) only upstream from Podunk Bend
i. Ice (earliest, latest, and mean freezing and breakup dates, extent of frozen surface; thickness of ice; carrying capacity; and frequency and location of ice jams)	Never freezes
j. Kind and prevalence of animal and vegetable life	Vegetation is seasonal. Muskrats along lower course
k. Type and location of crossings	Fordable anywhere below Podunk Hollow
l. Utilization of watercourse (for water supply, irrigation, disposal of waste)	Drinking water (Podunk City) and washing cars
m. Accessibility for military water supply (relation of road nets to potential water points, off-road approaches, intake problems)	Approaches generally good everywhere except in June floods; then, west banks are inundated along entire stretch
2. Lakes	
a. Name or other identification, and location	Lake Podunki
b. Length, width, depth, and surface area at low, high, and mean water; periods of occurrence of each	High winds in December cause flooding along west banks
c. Gage locations and periods of record, zero gage elevations, mean and extreme gage heights, and periods of occurrence	
(d) Shore characteristics (composition, stability, height, and slope	Shoreline of lake is marshy most of December

(e) Physical and chemical characteristics of water (turbidity, color, odor, taste, temperature, chemical composition, bacterial pollution, seasonal variation)	Reportedly murky except in December
(f) Bottom characteristics (composition, depth, and firmness of material, unusual bottom conditions, profiles)	Chiefly mud except sandy beach on east side
(g) Regulatory structures	None
(h) Islands, bars, and shoals (name, size, surface roughness, elevation, and pattern)	Shoals (shallow) near Goo Creek
(i) Ice (earliest, latest, and mean freezing and breakup dates; extent of frozen surface; type and thickness of ice; and carrying capacity)	Freezes first week in December. Can be crossed by horses. Thaws in early February
(j) Kind and prevalence of animal and vegetable life	Some growth of algae in late summer
(k) Type and location of crossings	
(l) Utilization of water body (for water supply, irrigation, disposal of waste)	Bathing and fishing
(m) Accessibility for military water supply (relation of road nets to potential water points, off-road approaches, intake problems)	Accessible year-round except in December when shoreline is marshy
3. Marshes and Swamps	None in area, except seasonally (December) along shore of Lake Podunki
(a) Information in 2 above, as applicable	
(b) Seasonal variations (months when variations in extent and wetness are greatest and least)	
(c) Cross-country movement under various seasonal conditions	
(d) Existing or potential causeways	
(e) Special conditions (quicksand, permafrost)	

If part of your drainage study concerns data on ground or surface water other than is listed above, follow the outline below. Provide answers from any source. Again, this is a checklist to guide your thoughts in making a drainage study.

Special water supply studies are made by engineers, assisted by geologists and hydrologists. The information required in terrain intelligence studies includes the following:

1. General	
a. Normal level of water table and variations	3 feet along all creeks. Wells in granite (found in northeast area) are dry or poor in quantity (1 gal/minute). Elsewhere water table is commonly 10 to 50 feet below ground surface. Yields up to 60 gal/minute
b. Yield of springs and wells and variations	
c. Potability and contaminations	Potable except in vicinity of Podunk Hollow
d. Underground flow in dry watercourses	
2. Surface supplies	
a. Total drainage area	25 sq. mi.
b. Rainfall and runoff data	Not available
c. Sources and kinds of possible contamination, including sewage or industrial wastes	Podunk Hollow is contaminated by natives
d. Chemical and bacteriological analyses	
3. Wells	One well (50 feet deep, cased) in Podunk Hollow
a. Rainfall data	
b. Reports of available well logs and test data	
c. Physical, chemical, and bacteriological analyses	
d. Existing water supply system	
(1) Source of supply	One well in Podunk Hollow
(2) Quantity provided; ultimate capacity	Reportedly 60 gal/minute

(3) Treatment methods — Untreated

(4) Distance from supply to proposed military user point

(5) Pressures

(6) Chemical and bacteriological analyses

ESTIMATING STREAM VELOCITY

Sometimes it is possible to make a rough estimate of the rate of streamflow from aerial photographs. If you have two consecutive photos and the lapse time between them, you can measure the speed of an object (a log, perhaps) afloat in the stream. This will tell you about what the speed of the current is. You can also make rough estimates of the rate of flow by the appearance of rapids and the topography through which a stream flows. If the valley is flat and the stream has many meanders (large, looping curves), the streamflow is probably not more than 3 miles per hour and may well be less than this speed. If the stream is flowing through a steep-sided canyon and has many rapids, its velocity might be as much as 15 miles per hour.

In the field, you can measure a stream's rate of flow by the following simple method, called the chip method. Pace or tape off a distance (usually 50 feet) beside any stream. Mark the distance with a stake or stone at each end. Have someone (or yourself, if alone) drop a chip or small twig into the water at the upstream stake or stone. You (standing at the downstream stake) mark the time required for the chip to reach the downstream stake. Usually, a stopwatch is used to mark the time.

Here are the calculations:–

Distance = d

Time of start = t_1

Time of stop = t_2

Then, $t_2 - t_1 = t$

$$\frac{d}{t} = \text{feet per second (fps)}$$

For example, d = 50 feet

$t_2 - t_1$ = 10 seconds

So, $\frac{d}{t} = \frac{50}{10} = 5$ fps

SUMMARY OF PROCEDURE

1. Collect all possible sources of information about drainage in your area: topographic map, air photos, reconnaissance data, streamflow records, use data (navigation), irrigation, recreation, etc.

2. Trace onto an overlay those drainage lines shown on the topographic map, and note whether perennial or intermittent.

3. Study air photos to locate drainage channels not shown on the map, and enter on overlay.

4. Accentuate streams 3 meters or less in width.

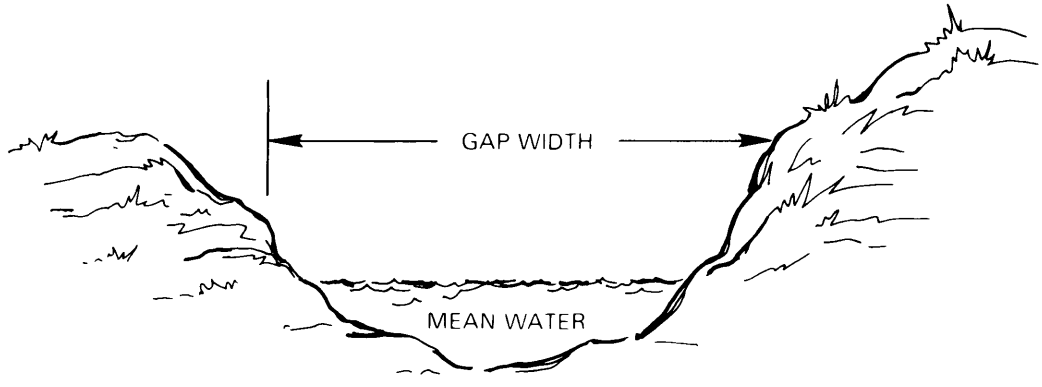
5. Note other pertinent details on the overlay, such as stream banks with less than 10° slope.

6. Estimate rate of streamflow where possible on overlay and note.

7. Tabulate available information about both surface and subsurface water, according to example given in text.

EXPLANATION OF TERMS USED

Aqueduct	A large pipe or conduit made for transporting water from a distant source.
Drainage canal/ditch	An artificial waterway used for removing surface water from an area.
Flood plain	The lowland that borders a river, usually dry but subject to flooding.
Gap width	The horizontal distance across a watercourse, bank to bank, measured at the first slope break above mean water level.



Hydrology	The study of water occurring in streams, lakes, underground, and as snow.
Inland waterway	A river, canal, lake, or inland sea which is used as an avenue of transport.
Intermittent stream	A stream that flows only part of the time.
Irrigation canal/ditch	An artificial waterway used for transporting water.
Lake	A water-filled hollow, more or less extensive, in the earth's surface; may be salt or fresh water.
Marsh	An area of saturated ground dominated by grasslike aquatic plants.

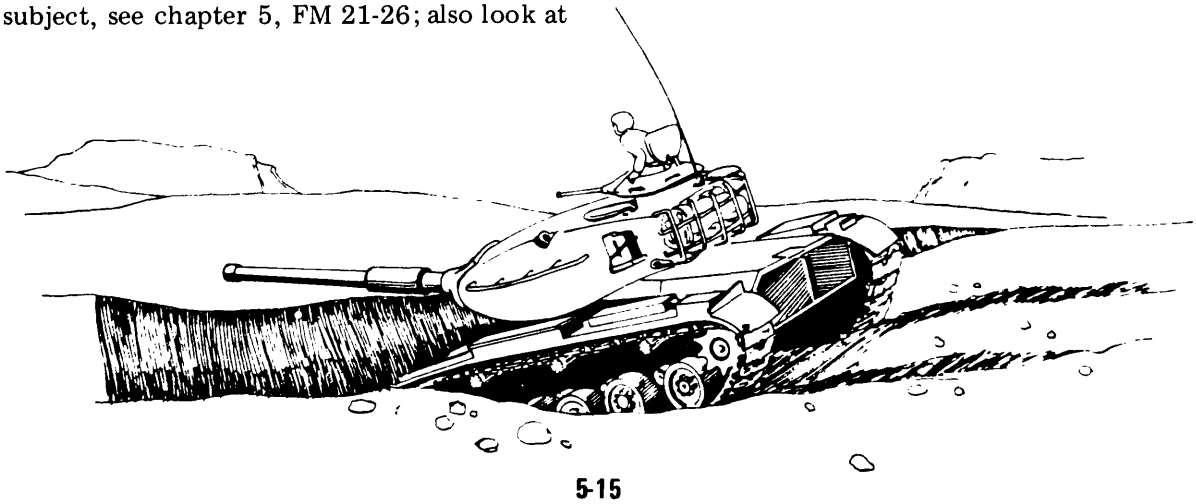
Meander	One of a series of winding or looping bends in a stream.
Navigation channel	A waterway improved by locks, levees, etc., to permit navigation.
Perennial stream	A stream that flows throughout the year.
Reservoir	An area of water storage often artificially created by building a dam at a suitable retaining point across a valley
Spring	A natural flow of water from the earth's surface occurring where the water table meets the surface.
Stream	A flow of water, of any size, running on the surface of the earth.
Swamp	An area of saturated ground dominated by trees and shrubs. (Sometimes used as equivalent to marsh.)
Well	A hole or shaft sunk into the earth to tap an underground supply of water.

SECTION 3.
ANALYZE SURFACE CONFIGURATION

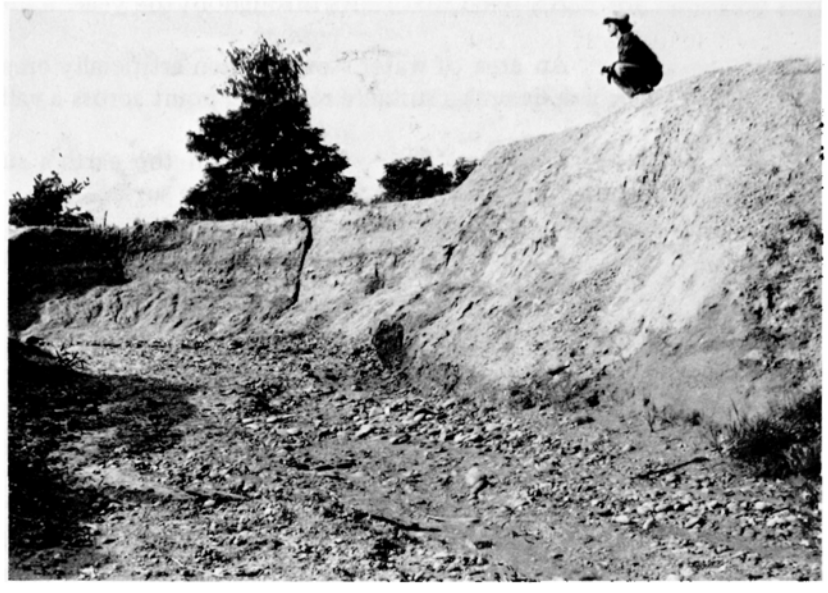
LANDFORMS AND RELIEF

By "surface configuration," we mean the shape of the earth's surface. This includes the hills and valleys, mountains and plains, and all other natural irregularities, both major and minor. The surface features that make up these irregularities are called landforms. They are shown on a topographic map by contour lines, so first of all you should know how to read contours on a map. For a review of this subject, see chapter 5, FM 21-26; also look at the special symbols for landforms like depressions, cliffs, and sand dunes in FM 21-31.

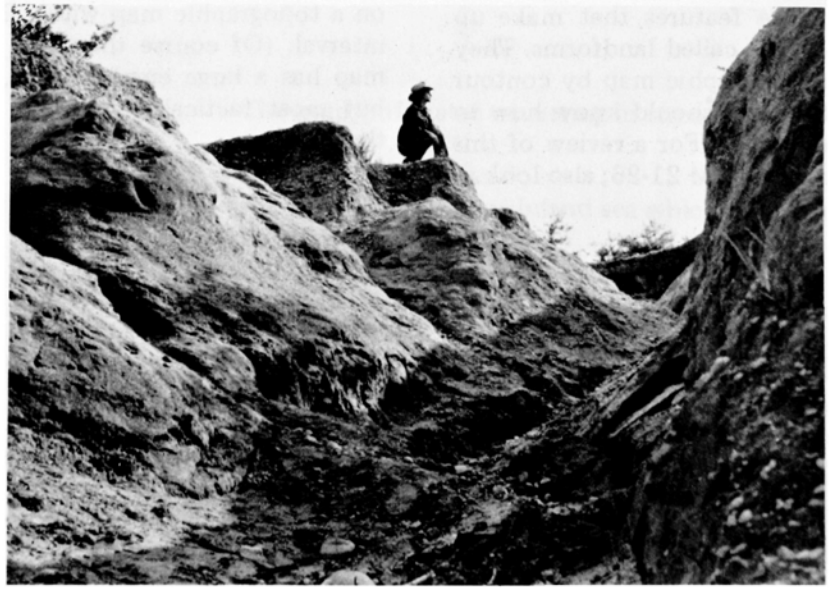
Contour lines don't tell the whole story, however, because some features are too small to appear on the contour map. A straight-sided gully 20 feet wide and 6 feet deep—like you might find in Arizona after a cloudburst—can stop a tank but it won't show up on a topographic map with a 20-foot contour interval. (Of course they will appear if your map has a large enough scale, say 1:10,000, but most tactical maps have a smaller scale than this.)



These features that may be important but don't show on your topographic map are called microrelief features (see photos). So you must either study the terrain on the ground or use large-scale imagery to locate them unless your map has them identified by special symbols (some of these are shown in FM 21-31). In contrast, the features that you can discover from a topographic map are called macrorelief features.



Microrelief features (above and below) produced during one season. An abandoned gravel excavation area in Maryland, near Washington, D.C.



To show surface configuration you should have an overlay for landforms (call it C-1) and a group of overlays for slope (C-2, C-3, etc.). These will provide the framework for all of the other terrain overlays—drainage (water features), rocks and soils, vegetation, and manmade (cultural) features. If you know what kind of landforms are in an area, what their shape and arrangement are, what is the vertical difference between the highest and lowest elevations (called local relief), and how steep the slopes are, you will have the information that you'll need first in order to answer terrain intelligence questions.

HOW TO MAKE A LANDFORMS OVERLAY

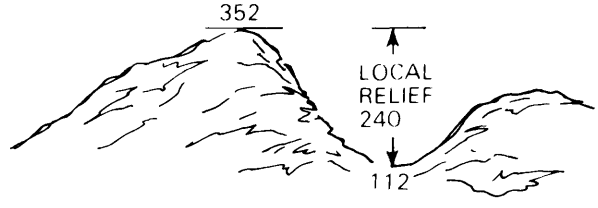
To prepare a landforms overlay you should first find out what kind of area you are dealing with. Was it glaciated in an earlier geological period, like much of the northern United States and Europe? If so, you might expect certain kinds of hills called "drumlins," or microrelief features known as "kames" and "moraines." Is it a desert? If so, you might find flat-topped plateaus called "mesas" and usually dry, sandy watercourses known as "washes" in the western United States and "wadis" in North Africa. If it is a limestone region, you might expect to find sinkholes, caverns, and underground rivers typical of "karst" topography. So knowing something about your area can help a lot in recognizing its landforms.

The landform overlay can be prepared directly from a topographic map base. Here is how to go about it:

1. Place a transparent sheet over the base and draw lines along the breaks between major landforms—mountains, hills, and plains.

2. Outline any prominent obstacles such as isolated hills or depressions. Use a special symbol for cliffs and escarpments. Don't show rivers or other water bodies because they will appear on your drainage overlay.

3. Mark the elevation in meters of conspicuous high points in the area. Then show the elevation of the lowest points. By subtracting the lowest elevation from the highest, you can find the local relief of the area; enter that figure in the margin.



4. Study any photographs that you have, or visit the area in person, to find and measure microrelief features that aren't on the base map. Mark and label on the overlay any that might have some military importance.

5. Put a legend in the margin, or label all features directly on the overlay.

SLOPE

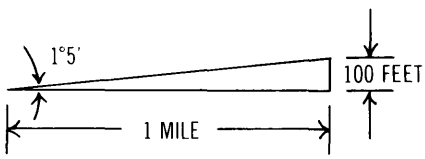
Slope is the inclined surface of a hill, mountain, or any other part of the earth's surface. Slope has always been most important to military movement. If the slope is steep enough, it is virtually impassable even to foot troops. Fortresses were frequently built on top of steep slopes for this reason.

Slope can be expressed in many ways:

1. With topographic maps, the easiest method is feet per mile or meters per kilometer. For example, if a map has a scale of 1:62,500 and a 20-foot contour interval, the number of contour lines in 1 inch, multiplied by 20, gives the number of feet per mile.

2. With the Abney level, slope is read in degrees above horizontal. One degree is about 1 unit high in 57.3 units horizontal.

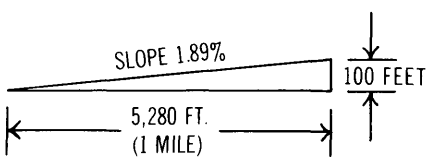
For rough calculations, 1°5′ is about 100 feet per mile.



3. In engineering, slope is most commonly expressed in percent. This is the ratio of vertical to horizontal distance multiplied by 100. For example:–

Vertical distance = 100 ft
Horizontal distance = 1 mile or 5,280 ft

So: $\frac{100}{5280} \times 100 = 1.89\%$ slope

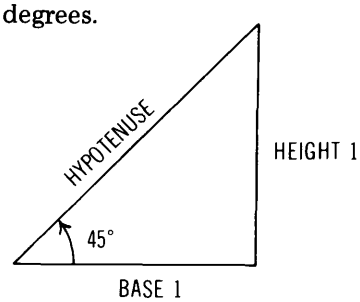


Note that the same units (feet, meters, or whatever) must be used for both vertical and horizontal distance. So, in this example, one mile horizontal distance must be converted to feet because the vertical distance is measured in feet.

Regardless of the kind of units, if you measured a vertical distance of 1 and a horizontal distance of 1, you would have a slope of 100%.

$\frac{1}{1} \times 100 = 100\%$ slope

The vertical distance is the same as the height of a right triangle. The horizontal distance is the same as the base. The slope is the same as the hypotenuse. The angle made by the hypotenuse and the base in this case is 45 degrees.

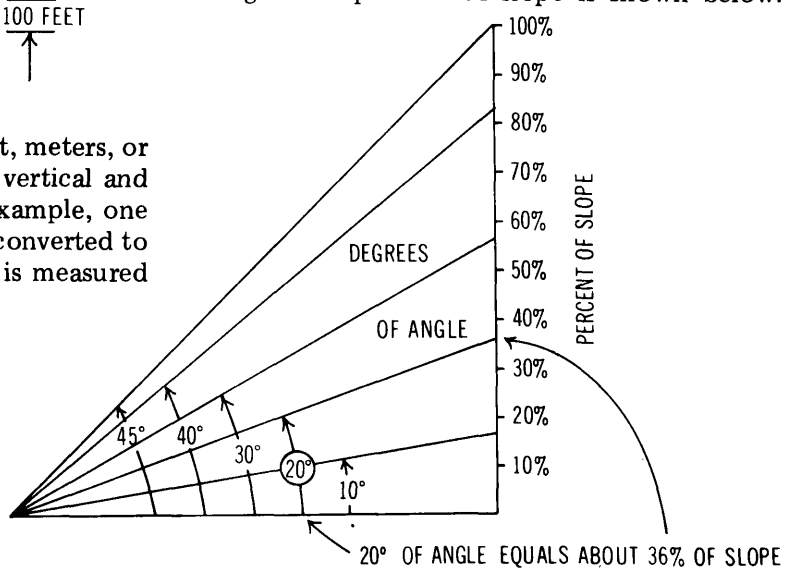


To write this in a formula:

Vertical distance = VD
Horizontal distance = HD

So: $\frac{VD}{HD} = \%$ slope

The relationship between degrees of an angle and percent of slope is shown below.



A comparison of slopes expressed in percent, degrees, and feet per mile:-

Percent	Degrees	Feet per mile	
1	0°34'	52.8	
2	1°09'	105.6	
3	1°43'	158.4	
4	2°17'	211.2	
5	2°52'	264	(See example below)*
6	3°26'	316.8	
7	4°00'	396.6	
10	5°43'	528	
15	8°32'	792	
20	11°19'	1,056	
30	16°42'	1,584	
50	26°34'	2,640	
100	45°	5,280	
200	63°26'	10,560	

*5% slope = 2°52' = 264 f.p.m.

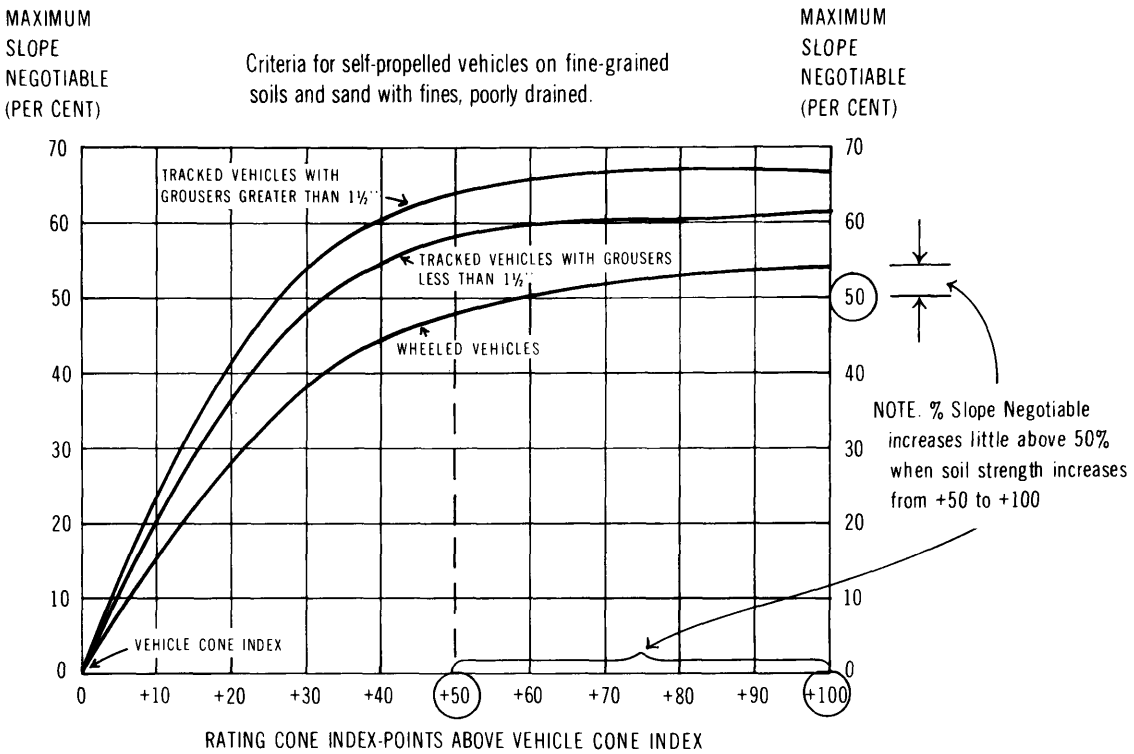
4. Other ways to express slope are discussed in TM 5-236.

WHICH SLOPE SHOULD YOU SHOW ON A SLOPE MAP?

Basically you need to know which slopes will not obstruct any off-road vehicle. You also need to know which slopes are too steep for any vehicle to climb, and those slopes which are a barrier to certain kinds of vehicles. Listed below are critical categories of slope for the major classes of vehicles, as given in FM 30-10.

Slope Categories	Effect on Movement
A. 0-15%	No hindrance for any off-road vehicle
B. 15-30%	Difficult for wheels/easy for tracks
C. 30-45%	Too steep for wheels/slow for tracks
D. Over 45%	Difficult to impossible for tracks

These slope categories may be used as practical values for military operations. The graph below can be used to find the limits of climbing ability for various types of vehicles when you know the soil strength. Soil strength is measured by rating cone index points: the higher the index numbers, the greater the soil strength.



Here's an example of how the graph can be used: if the rating cone index is +40 and the vehicle is wheeled, the graph shows that the maximum negoitable slope is about 44%.

HOW TO MEASURE SLOPES

You intend to make an overlay showing all slopes between 0 and 15%. Let's say you have a map at a scale of 1:50,000 with a 20-foot contour interval. You want to know (a) how much horizontal distance on the ground is there between the 20-foot contours, and (b) how much ground distance lies between two index contours. (These are the heavier contour lines, generally every fifth one.) First, determine the horizontal distance covered on the ground, then how much the ground distance measures on the map.

If you know that:-

Map scale = 1:50,000
VD (vertical distance) = 20 ft and 100 ft
Slope = 15%

Find:

HD (horizontal distance on ground)

Use the formula:-

$$\% \text{ slope} \times 100 = \frac{VD}{HD}$$

or

$$HD = \frac{VD \times 100}{\% \text{ slope}}$$

$$HD \text{ (ground)} = \frac{(20 \text{ ft})(100)}{15} \text{ for a 20-ft contour interval}$$

$$= 133.3 \text{ ft for a 20-ft contour interval}$$

$$= \frac{(100 \text{ ft})\ (100)}{15} \text{ for five 20-ft contour intervals,}$$
$$100 \text{ ft VD}$$

$$= 666.6 \text{ ft for five 20-ft contour intervals}$$

Now determine the ground distance represented by 1 and 5 contour intervals (20 ft each) on the map. How much does 133.3 ft and 666.6 ft ground distance each measure on the map at a scale of 1:50,000?

Remember:- 1 unit on the map = 50,000 units on the ground
map units : ground units = map distance : ground distance

So, $1{:}50{,}000 = X$ (map distance) : 133.3 feet

$$50{,}000X = (1)(133.3 \text{ feet})$$

$$X = \frac{133.3 \text{ ft}}{50{,}000}$$

$$= 0.0026 \text{ ft or distance on the } 1{:}50{,}000 \text{ map between 2 contour lines}$$

For 5 contour intervals

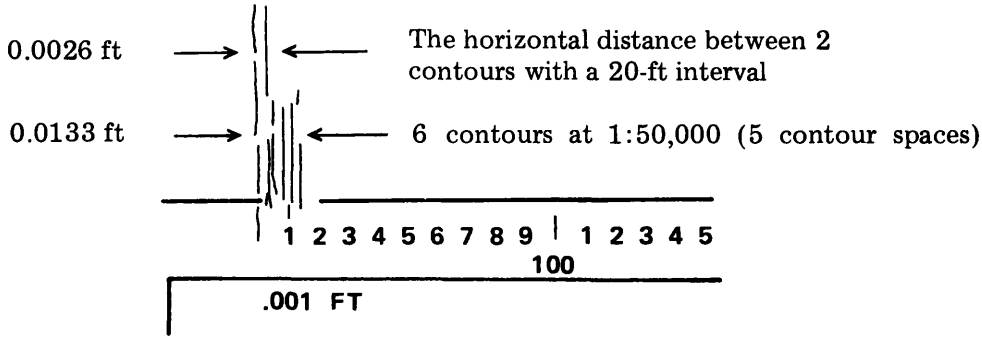
$$X = \frac{666.6 \text{ ft}}{50{,}000}$$

$$= 0.0133 \text{ ft}$$

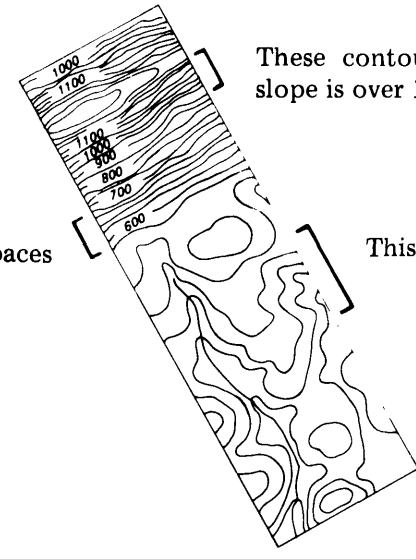
Now taking these lengths,

0.0026 ft (horizontal distance of 20 ft @ 1:50,000)
0.0133 ft (horizontal distance of 100 ft @ 1:50,000)

and using a scale graduated in thousandths of a foot, draw their spacings:-



These groups of 6 lines are the spacings of 5 contour intervals on a slope of 15%. If contours are spaced farther apart than this, you have less than 15% slope and you are in the 0-15% slope category. If the 5 contour intervals are spaced more closely, you have a slope of more than 15%.



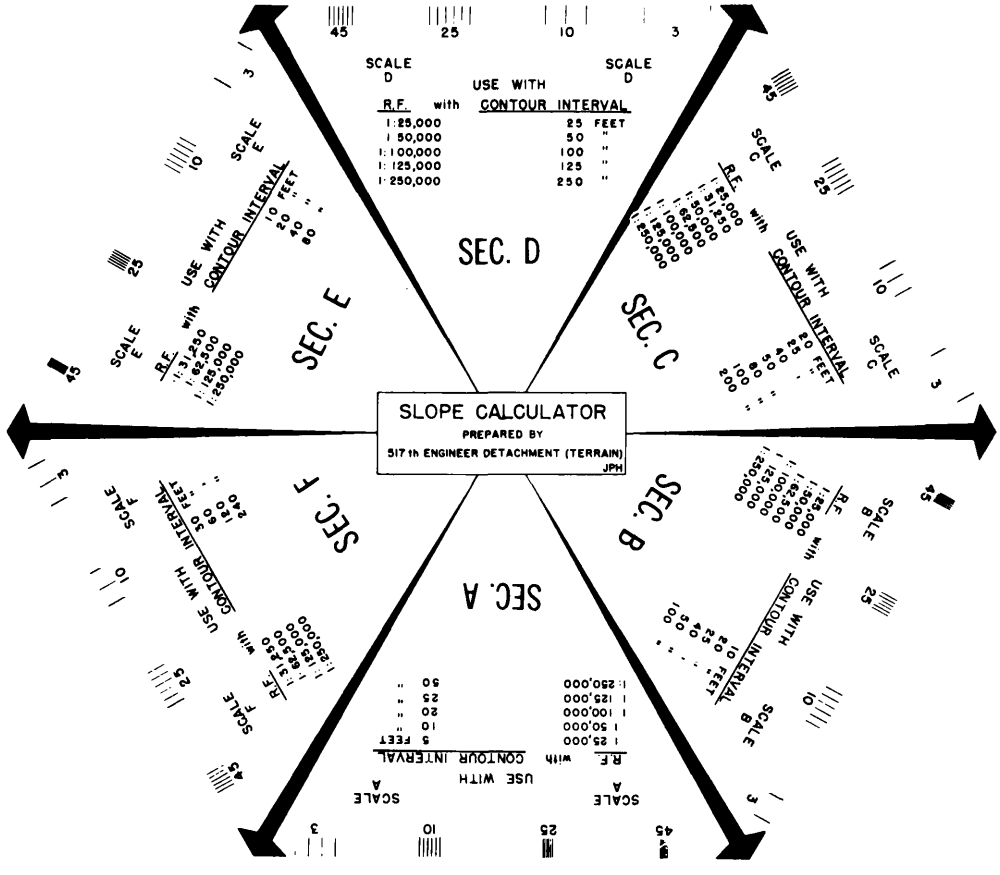
These contours are closer and therefore the slope is over 15%

These are 15% slope spaces or contour density

This slope is less than 15%

The spacing between contours is called "contour density." Compute and draw the contour densities that you need for vehicle movement requirements on a piece of translucent material, and you have constructed a slope template or slope calculator. You may read from it contour densities for slopes of 30%, 45%, or whatever values you have constructed.

Many slope calculators have been made by various terrain detachments. These calculators show different contour densities to be used on maps at various scales with various contour intervals. They are usually reproduced by the photo lab on transparent plastic. An example of six different slope calculators combined into one is shown below.

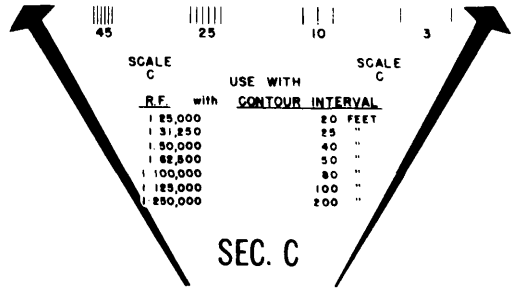


Each section, A through F, is actually a separate calculator.

Select one section for an example.

To measure a 45% slope:-

Use this contour density on section "C", because you are given a map with:
an RF of 1:25,000
and
a contour interval of 20 ft



HOW TO DRAW SLOPE CATEGORIES ON A MAP OVERLAY

1. Make a slope calculator as described above, or select a readymade one.

2. Gather all supplemental data about slopes from your file. Slope can be most easily determined from a contour map. If possible get other information from reconnaissance, reports, and aerial photos. Details of this data are listed in FM 30-10, p. 4-5, and in EIG 31, pp. 4, 7, and 8.

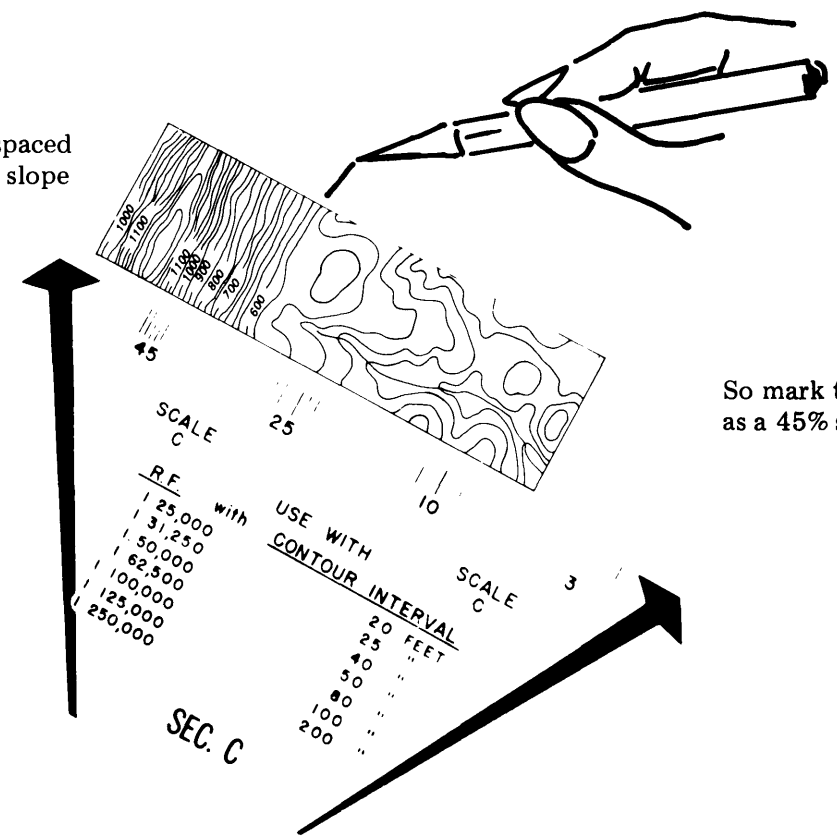
3. Select your base topographic map and tape a new clean overlay on top of it.

4. Draw the neat line and tick marks.

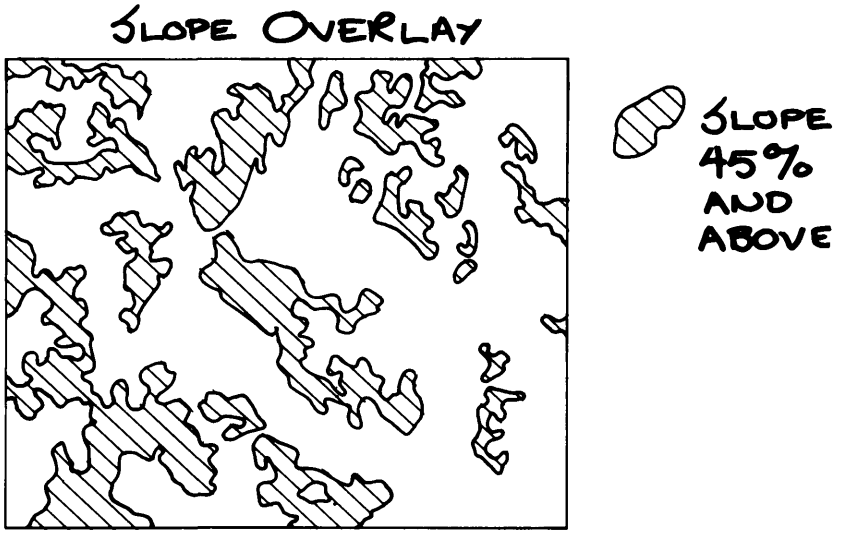
5. Write the title, scale, north arrow, and all necessary legend.

6. Select the required categories of slope. For example: 0-15%, 15-30%, 30-45%, and 45% and over.

7. Then, while moving the slope calculator over the contours on the topographic map, first match the 45% slope with those contours which are spaced that closely (or closer), and mark it on the overlay.



8. Continue until you have outlined all areas that are 45% or steeper. Label them in the legend. You have now completed a slope overlay showing areas that are too steep for any vehicle.



9. If available, use aerial photos and other data to check your results.

10. Use a new overlay and repeat the procedure for slopes of 0-15%. This overlay is the opposite extreme of the 45% slope map, since a slope of 0-15% can be climbed by any off-road vehicle. Make a third overlay for slopes of 15-30%, and a fourth for 30-45%.

11. Mark on the overlay any microrelief features, like stream banks and low escarpments, which appear on the photos but not on the map. If you can get into the field, check your map on the ground.

EXPLANATION OF TERMS USED

Abney level	A handheld device for finding degree of slope on the ground.
Contour density	The spacing of contour lines on a map.
Drumlin	A smooth oval hill of glacial origin.
Gradient	Degree of slope expressed as a fraction in which vertical distance is the numerator and horizontal distance is the denominator.
Index contour	A contour line shown more prominently than the adjacent ones, usually every fifth one.
Karst topography	A type of landform developed in a region of easily soluble limestone rock. It is characterized by large numbers of depressions of all sizes, sometimes by great outcrops of fluted limestone ledges, sinks, and other soluble passages, almost total lack of surface streams, and large springs in the deeper valleys.
Landform	The physical expression of the land surface.
Local relief	The difference in elevation between the highest and lowest points in a given area.
Macrorelief	Large features of relief.
Mesa	A plateau or flat-topped mountain bounded on at least one side by a steep cliff.
Microrelief	Small features, 2 meters or less in height, that will affect military movement but usually do not show on a topographic map, e.g., pits, small mounds, swales.
Moraine	An accumulation of loose material deposited by a glacier.
Percent of slope	Slope expressed as the ratio of vertical to horizontal distance multiplied by 100.
Relief	The irregularities of a land surface.
Representative fraction	The ratio between map or photo distance and ground distance expressed as a fraction in the same units.
Scale	The ratio between the distance on a map and the corresponding distance on the ground.
Slope calculator	A device for finding areas within a given class of slopes on a topographic map.
Slope map	A map (or overlay) showing areas within certain ranges of slope.

SECTION 4. ANALYZE GEOLOGY AND SOILS

GEOLOGY

The study of the materials that make up the earth—their composition and how they came to be the way they are—is called geology. So actually geology includes soils as well as rocks, but in practice the study of soils is considered a separate science and it will be covered under another heading in this section. In terrain analysis, you need to know something about the kinds of rocks in your area and their arrangement. You should be able to put them into a simple classification and to make an overlay that will show where they are in relation to each other.

By understanding the kinds of rock formations in your area, you can infer something about their importance for military purposes. For example, suppose you've concluded that a limestone formation underlies most of the area. You also know that the rainfall is heavy most of the year. You've discovered (either by reading or by careful study of aerial photographs, maybe even a topographic map) that there are many depressions in the same area. You rightly conclude that: (1) the area has many sinkholes (places where the ground has collapsed, a result of underground erosion by acidic ground water), (2) that soils are deep and mostly clay, (3) that because of the evident structure in parts of the area, shallow wells to obtain drinking water are possible, (4) that potential rock quarry sites will probably produce only inferior quality crushed rock, and (5) that in rainy weather vehicles would have difficulty in cross-country movement due to the deep sticky clays that can be expected.

If a rock formation—say a granite—has a pattern of fissures or joints crossing it and they are close together, engineers setting up a quarry operation would expect the rock to crush easily. But if the rock formation is made of lava, which is very fine grained, you'd expect it to be hard to crush even if it is jointed.

If you recognize many joints in an area or many faults (longer joints along which the rock formations have slid or moved) would you expect energy to travel through the rock formations quickly? For example, if a seismic sensor (a device that detects movement or energy in the subsurface) is placed in an area of severely jointed rock, would it perform well? No, because the energy being transmitted through the ground would have to cross the joints or fissure before being picked up by the sensor's receiver.

A CLASSIFICATION OF ROCK FORMATIONS

If the area you're studying is in a cold region, most of the rock formations will not be deeply weathered, so they won't have thick soils. Of course, if the rocks are covered by soils or gravels carried in by ancient streams or glaciers, these soils aren't derived from the local rock formations.

By weathered, we mean the tendency for rock formations to break down into soils. Some rocks, because they're badly fractured or are naturally soft, weather (form soils) very deeply.

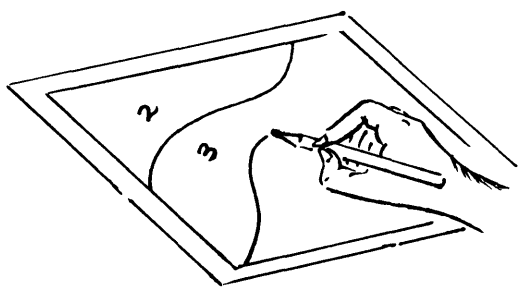
The igneous rocks, such as granite or basalt, in colder regions can be labeled as hard. In very warm areas, such as Venezuela, these same rocks might be deeply weathered and easy to drill. They would have deep soils developed over them or be less resistant than in colder regions. They could be labeled moderately hard.

Hard, angular-breaking sandstones, limestones, or thick-bedded shales can, in colder

areas, be classified as hard. If your study shows them, however, to have deep soils (be deeply weathered), to be densely jointed, or to form soft, low, rounded hills or rolling topography, classify them as soft.

Metamorphic rocks, such as schists or gneisses, can be hard or soft. If you suspect that they outcrop often or tend to form ledges and cliffs, and appear to have thin soils, classify them as hard. If they form very low topography, appear to be deeply weathered with thick soils, call them soft.

A good idea is to imagine the problems you'd have operating a diamond drill in your area. Imagine how easy or how difficult it might be to drill holes in the various rock formations. This helps to conceive just how soft, hard, or moderately hard the rocks are.



1. Once you've identified the types of rock formations in an area, trace the edges or boundaries of each rock type on a photograph with a grease pencil or with a suitable pen.

2. Label each rock formation. For example, rock unit 1 is sandstone, rock unit 2 is shale, etc. Then briefly describe them. It will look something like this:-

Rock Unit

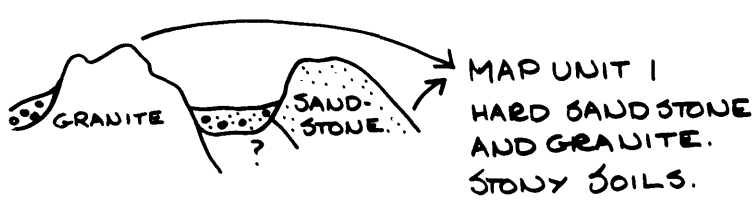
1 Sandstone, hard; forms cliffs and ledges, estimated between 10-20 feet; forms bouldery, sandy soils on lower slopes.

2 Shale, moderately hard; forms rounded low hills and broad flats; forms deep sticky (when wet) soils except on hilltops. Has thin sandstone beds locally.

Etc.

3. Now make an overlay from the photos or the photomosaics. Get a piece of stable mylar (which won't change scale with temperature changes), place it over the photos or photomosaic, and begin to trace. You're OK if the number of rock formations isn't too great, but if you identified many rock types in the area and you described each one, you must lump some of them. Lumping or grouping the rock formations means that you will reduce the total number so the final overlay won't be too crowded.

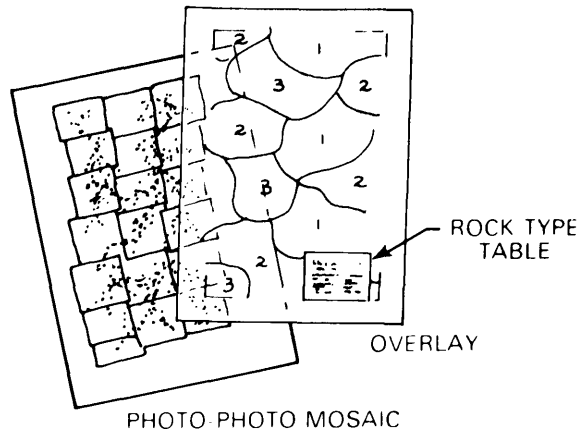
Here is where that simple rock classification system is handy. For example, suppose you have a hard sandstone and a hard granite in the area. Why not lump both as Unit 1? Of course, you wouldn't do this if you have identified only a few rock formations in your area.



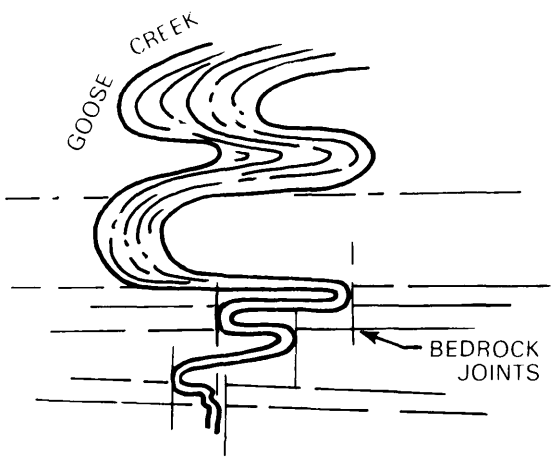
Soils that are deep and widespread must also be shown on the overlay. For example, a broad meandering (wandering) stream may have vast areas of sand and gravel—called alluvium by geologists. Draw the boundaries of this deposit and describe its composition.

If faults or fractures are evident in the photos, transfer them to the overlay. Joints are hard to see but careful study of the photos may suggest the most prominent orientation of an area's joints.

If the joints or fractures are very prominent, you must say so in the table describing the rock units. For example, under rock unit 2, shales—"Shales are densely jointed near Goose Creek Canyon."



You now have a rough Geological or Rock Types overlay and a brief description of the rock types.



5. The overlay now has the boundaries between various rock formations (lumped or not lumped) drawn in ink. You also should label in ink the areas of each rock unit. Place a typed or hand drawn table of the rock units in one corner of the overlay, usually the lower right. Check the corner tick marks and include on the overlay certain prominent cultural and/or geographic reference points for later rapid check with the photomosaic or other photos.

SUMMARY OF PROCEDURE

1. Determine what kinds of rocks are in the area, from geologic maps, photos, or field study.

2. Classify these rocks according to hardness and resistance to erosion. Include unconsolidated material like sand, gravel, and soil.

3. Trace the boundaries of the various rock types on a photograph, and label.

4. Make an overlay by transferring these boundaries to mylar at the scale of your topographic map.

5. Mark any faults, fractures, or joints on the overlay.

6. Put a legend or table of rock types in the margin.

SOIL

The analysis of soil for military purposes has two aims: (1) for engineering or construction use, and (2) for military operations. Knowledge of the characteristics of soil and its distribution on the landscape is basic to the engineer for siting and construction of roads, airfields. and foundations for buildings. Soil trafficability--the ability of a soil to permit the movement of a vehicle--is of utmost interest to tactical and strategic planners as well as commanders in the field. Knowledge of soil is also needed in order to plan field activities like digging foxholes, preparing gun emplacements, and building field fortifications.

Sources of information for evaluating soil conditions are many and varied. Field inspection or reconnaissance provides the best source, but rarely, if ever, can enough reconnaissance be done to provide all the information needed. Most of the time, the analyst will be asked to provide soil information for areas that he has no practical way to reconnoiter. The areas may be enemy held or they may be too remote.

If field reconnaissance is possible, you should make use of a cone penetrometer, which measures or provides an indication of the shearing resistance of the soil. A common tile spade and an earth soil auger are also very useful tools when doing field reconnaissance.

Topographic maps are a good source of indirect soil information. Topographic maps can be interpreted best by analysts who also have a good knowledge of geomorphic processes—who understand the relationship between landforms and soils. For example, areas on the map that indicate rugged, mountainous terrain more than likely will have stony, shallow soils. Flood plains and stream terraces, on the other hand, usually are covered by soils several meters in thickness. If an area is depicted as swamp or marsh, you can suspect that it will have soils containing a lot of organic matter and very low construction value and bearing strength.

Analysis of airphotos is perhaps overall the best method of obtaining soil information for large areas. You will need stereo pairs and a stereoscope for making good soil interpretations. For best results, the airphotos need to be of high quality and reasonably large scale, 1:20,000 or larger.

In using airphotos, a word of caution is in order. Remember that soils are three-dimensional; only the soil surface is revealed in an airphoto. Therefore, your interpretation of soils is limited to what you can deduce from clues that can be seen.

Other major sources of soil information include geologic, geographic, and agricultural soil reports. The Soil Conservation Service of the U.S. Department of Agriculture (USDA) has published soil reports, including detailed soil maps, for many of the counties in the United States. These reports are primarily tailored for agricultural users, but the more recently published ones deal also with engineering properties of soils. Anytime you require soil information for a specific tract in the United States, you should first determine the availability of a soil report covering that area. The Soil Conservation Office is located at most county seats.

Many foreign countries, likewise, have published soil reports that can be obtained if you are stationed overseas.

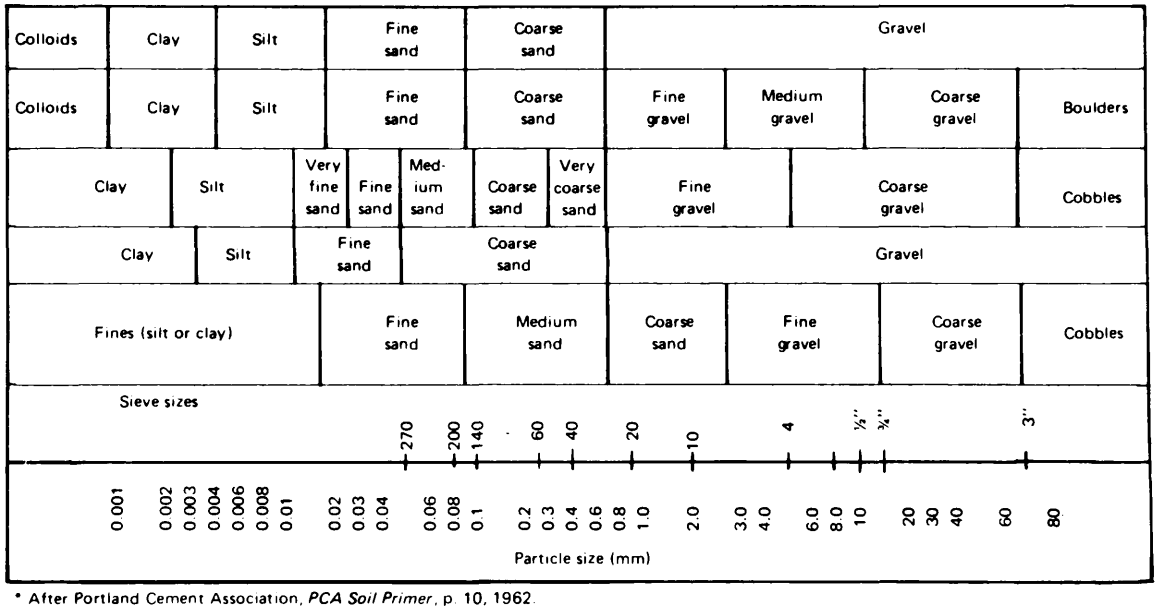
With experience and a sprinkling of common "horsesense," together with limited soil information, an analyst can put it all together and produce a useful product—whether the product is a soil factor overlay or an end product such as a cross-country movement study.

WHAT YOU NEED TO KNOW

The soil data elements needed to produce a soil factor overlay (soil data base) depend somewhat on the requirements of the user. Most of your information will be for "points" on the ground surface or "spot information." The trick for the analyst is to extend this information to cover all of the map area.

Following are the basic soil data elements that are most often required to adequately describe soils for terrain studies:

1. Soil Composition. This term refers to the types of materials that make up the soil. Terms such as clayey, silty, sandy, gravelly, and loamy are used to describe composition. The U.S. Army Corps of Engineers uses the Unified Soil Classification System (USCS) to classify soils. The Unified System combines grain size distribution with the Atterberg limits (plastic and liquid limits) to arrive at a soil classification that is useful for engineers. The size limits of the soil separates used in the USCS and the USDA classifications are not quite the same, as this chart shows:



* After Portland Cement Association, *PCA Soil Primer*, p. 10, 1962.

1 American Society for Testing and Materials

2 American Association of State Highway Officials soil classification

3 U.S. Department of Agriculture soil classification

4 Federal Aviation Agency soil classification

5 Unified soil classification (Corps of Engineers, Department of the Army, and Bureau of Reclamation)

UNIFIED SOIL CLASSIFICATION
(Including Identification and Description)

Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in and basing fractions on estimated weights)		
1	2		3		5		
Coarse-grained Soils: More than half of material is larger than No. 200 sieve size.	Gravels: More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.		
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		
		Gravels W/Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).		
			GC	Clayey gravels, gravel-sand-silt mixtures.	Plastic fines (for identification see CL below).		
	Sands: More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.		
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		
		Sands W/Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).		
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		
Fine-grained Soils: More than half of material is smaller than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.					Identification Procedures on Fraction Smaller than No. 40 Sieve Size		
					Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)
	Silts and Clays: Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight
	Silts and Clays: Liquid limit is greater than 50		MH	Inorganic silts, micaceous or diatomaceous	Slight to medium	Slow to none	Slight to medium
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		

2. Soil Depth (thickness of soil). This is the overall depth of the unconsolidated material (soil to bedrock).

3. Soil Moisture. Bearing strength of a given soil varies mainly with moisture content. Thus, knowledge of soil moisture provides a tool for predicting soil strength and forecasting soil trafficability. The analyst should be aware that moisture conditions vary from season to season and even from day to day.

4. Soil Horizonation or Layering. If a section downward through a soil is examined, a layering, often well defined, will usually be found. Such a section is called a "profile" and the individual layers are known as "horizons." Every well developed, undisturbed soil has its own distinctive profile. Generally, most soils have three distinct horizons. The topsoil or surface soil is called the A horizon; the layer just below the A is the B horizon or the subsoil; the C horizon, just below the B, is more or less the same as the "parent material." You should be acquainted with these terms because much of the source material, particularly agricultural soil descriptions, will use them.

The above items are the ones most commonly used in preparing a soil factor overlay. However, there are other data elements that can be used to supplement the basic information and may be needed for some end products. The following data element items may be required in addition to the basic list.

1. Depth to high water table.

2. Unique horizons, layers, or formations within the soil profile, such as caliche, laterite, permafrost zones, and hardpans.

3. Degree of stoniness of the soil.

4. Cone Index (CI)*. This is a field measurement indicating the shearing resistance of soil, obtained with a cone penetrometer.

5. Remolding Index (RI)*. A ratio that expresses the proportion of original strength that will be retained by a fine-grained soil or a sand with fines, poorly drained, after being subjected to vehicular traffic.

6. Rating Cone Index (RCI)*. The product of the measured cone index and remolding index for the same layer of soil. It expresses the soil strength rating of an area.

7. California Bearing Ratio (CBR)*. A test having the function of measuring the soil resistance to penetration prior to reaching its ultimate shearing value.

Except for special requests, it is unlikely that you will use data items 4 through 7 for making soil factor maps.

HOW TO PREPARE A SOIL FACTOR OVERLAY

A soil factor overlay is similar to preparing other factor maps. There is really no "cookbook" method of terrain analysis. You will learn by doing, and with experience your confidence and the reliability of your product will progressively increase.

Before starting the soil factor overlay, it is highly desirable to have the landforms, drainage, and geology factor overlays completed first. These overlays, together with topographic maps, air photos, field and laboratory data, are the basic tools for preparing the soil factor overlay.

* *See Student Pamphlets, "Soil Engineering," Section 1, Vols. I, II, and III, U.S. Army Engineer School, Fort Belvoir, Virginia.*

First you should separate homogeneous soil areas on the basis of composition (texture or grain size distribution and soil profile characteristics). The size of the areas will depend on complexity of the soil pattern and the scale of mapping.

In most parts of the world, distinctive soils are associated with distinctive landforms. Using landforms as a rough guide, the obvious soil groupings should be made first. For example, flood plain (bottomland) soils can best be delineated first. Bottomlands are easily separated from the uplands, based on topography. Another fairly easy separation are soils on very steep slopes; they are commonly shallow and often contain numerous rock fragments. Very poorly drained soils of marshes and swamps can also be separated using a topographic map. You should check the drainage factor overlay for confirmation of these areas.

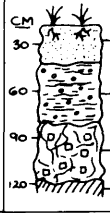
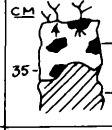
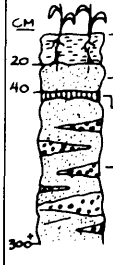
Having separated soils on the basis of composition and profile characteristics, you should next assign a "depth of soil" class to each delineated area. Soils are seldom uniform in depth, even over short distances of a few tens of meters. Thus a judgment will have to be made concerning the average depth of each area that you have drawn. Some areas may need to be subdivided. An example of a depth of soil code is shown below and in the sample of a soil overlay.

Depth of Soil (meters)	Code or Class
0 — 0.5	1
0.5 — 1.5	2
1.5 — 3.0	3
3.0 +	4

1:50,000

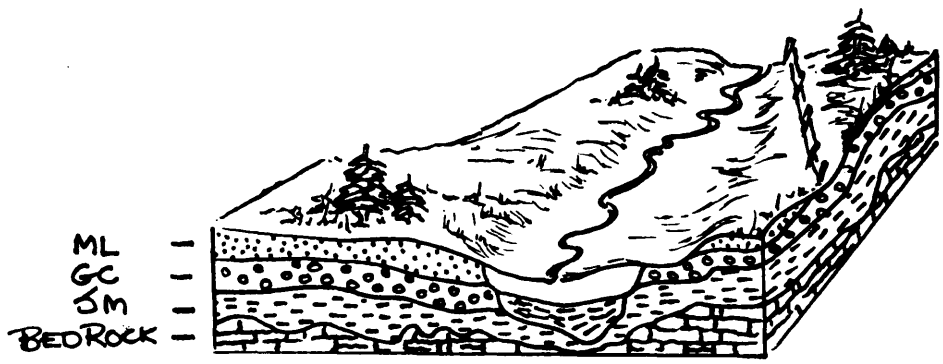
SOILS (SURFACE MATERIALS) DATA TABLE
- TO ACCOMPANY SOIL FACTOR MAP -

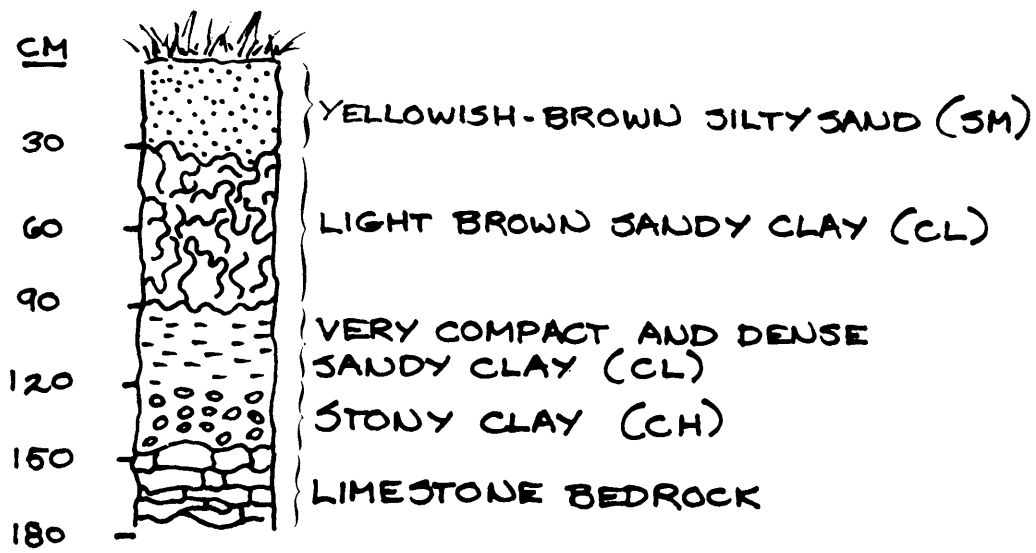
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JULY, 1972

FACTOR MAP UNIT (FIRST DIGIT)	COMPOSITION, UNIFIED SOIL CLASSIFICATION, HORIZONATION AND DEPTH	PHYSIOGRAPHIC POSITION	DOMINANT LAND USE	REMARKS
1	 DARK BROWN SANDY CLAY (CL); LIGHT YELLOWISH-BROWN CLAY (CH) WITH SOME GRAVEL; LIGHT YELLOWISH-BROWN CLAYEY SILT (ML) WITH SOME STONES; SANDSTONE BEDROCK	ROLLING UPLANDS	NATIVE GRASS USED FOR GRAZING	NO HIGH WATER TABLE. RCI IN SURFACE HORIZON ESTIMATED TO BE ABOUT 80 AT 30% MOISTURE CONTENT. SOIL WEATHERED FROM SANDSTONE
2	 REDDISH-BROWN SILT LOAM (ML), CONTAINS MANY ROCK FRAGMENTS; CHERTY LIMESTONE BEDROCK	STEEP HILLSIDE AREAS OF ROLLING UPLANDS	GRASS AND SCRUB USED FOR GRAZING	NO HIGH WATER TABLE. HIGH BEARING STRENGTH AT ALL TIMES. SLIPPERY AFTER RAINS.
3	 VERY DARK BROWN SILTY CLAY LOAM (ML-CL); DARK BROWN SILTY CLAY (CL); HARDPAN; STRATIFIED LAYERS OF GRAVELLY SAND (SW), GRAVELLY CLAYS (CL), AND SILT (ML)	FLOODPLAINS ALONG RIVER	CULTIVATED - MAINLY FEED GRAINS	GENERALLY HAS HIGH WATER TABLE MARCH-MID MAY. RCI LESS THAN 40 WHEN SOIL SATURATED.

Modification of soil depth ranges will sometimes be necessary depending on the objectives, scale of mapping, and the source data available.

In order to facilitate the preparation of soil reports requested by users and to more thoroughly document the soil information, a so-called Data Elements Table should accompany each overlay or series of related overlays. Each soil unit (compositional unit) should be briefly described as well as source information allows. A sketch of the soil profile helps users visualize each distinctive soil unit. The sketch can take many forms; two examples are given below.





The format of the Data Elements Table can be changed or expanded as requirements or objectives change. Different physical environments will, in fact, require different data. You should emphasize the soil characteristics or properties that are unique or overriding for each environment. In the Arctic, for example, you might emphasize the effects of climate on soil—frozen soil, permafrost, etc. Obviously, these data elements would not apply in tropical areas.

SUMMARY OF STEPS IN PREPARING SOIL FACTOR OVERLAYS

1. Select and assemble all relevant source information. Obtain landforms and drainage factor overlays, if possible.

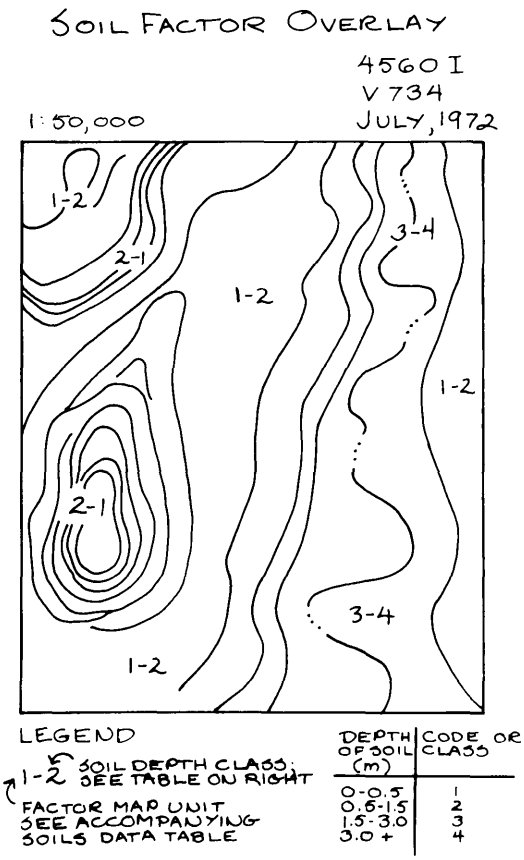
2. Study the relevant information for the area as a whole.

3. Develop a legend for the study area based on composition or soil characteristics and soil depth.

4. Evaluate the soil factors and place appropriate boundaries on the overlay, using the topographic map as a base. Avoid excessive cartographic detail. A soil map so detailed that it is difficult to read fails its purpose.

5. Prepare a supporting Data Elements Table with soil profile or landscape/soil cross sectional sketches.

6. Submit material for drafting and reproduction, or file manuscript.



EXPLANATION OF TERMS USED

Alluvium	A general term for material deposited by streams, including silt, sand, gravel, clay or boulders derived from decomposed bedrock but deposited elsewhere.
Basalt	A common name for a group of dark, fine-grained, heavy, very hard volcanic rocks. It rings when struck by a hammer.
Clay	Soil particles having diameters less than 0.002 mm.
Cone penetrometer	An instrument used to measure the ability of a soil to support traffic movements.
Dolomite	A kind of rock that looks like limestone but does not fizz in the presence of dilute hydrochloric acid. Occurs in thin to thick beds.
Fault	A fracture in the earth's crust along which rock formations have moved.
Geology	The study of rock formations: their composition and structure, how they formed, and subsequent changes.
Granite	A general term for any coarse-crystalled, light-colored igneous rock.
Gravel	Loose, coarse, granular material larger than sand grains, resulting from breaking down of rock.
Igneous rock	A rock formed by solidification of any molten material, either deep within the earth or thrown out by a volcano.

Joint	A break in a rock mass where there has been no relative movement of rock on opposite sides of the break.
Lava	Fluid rock, such as that coming from a volcano. Also the same material after cooling.
Limestone	A rock consisting chiefly of calcium carbonate, usually gray, hard, and resistant.
Metamorphic rock	A rock that has been changed chemically or physically.
Outcrop	Any exposure of bedrock.
Sand	Individual rock or mineral particles having diameters ranging from 0.5 mm. to 2.0 mm.
Sandstone	Common term for any rock that has visible grains of sand.
Silt	Individual mineral particles of soil that range in size between clay and sand (0.002 mm. to 0.5 mm. in diameter).
Sedimentary rocks	Rocks that were formed from sands, muds, or gravel deposited by rivers or streams, or from chemical deposition in the ocean or in shallow seas.
Weathering	The process by which rock formations break down to form soils or softer rocks.

SECTION 5. ANALYZE VEGETATION

RELATIONSHIP TO MILITARY OPERATIONS

Vegetation may be the most important terrain factor or it may be negligible. Its importance tends to be in proportion to its density. During World War II. in the desert campaigns of Egypt and Libya, the vegetation was so sparse that it provided no cover, concealment, obstacles, or construction material. On the other hand, in Vietnam it was of such importance, especially for concealing guerilla forces, that massive efforts were made to alter it by chemical sprays.

There are many ways by which the plant cover that we call vegetation can affect military tactics, decisions, and events. Probably the most important is concealment—that is, providing protection against enemy observation, either from the ground or air. It may also give protection from enemy fire, which is called "cover." As an obstacle to movement, it can slow down the advance of vehicles and sometimes troops, and it can limit the landing capability of helicopters and other aircraft. Some kinds may be used as construction material for roads, field fortifications, and camps.

In addition to the direct effects of vegetation, a skilled analyst can tell a lot about soils, drainage, climate, and the inhabitants of an area by studying its plant cover. We will not take up these indirect effects in this manual, but you will find it useful to keep them in mind during your study of vegetation.



WHAT YOU NEED TO KNOW

The most commonly needed information about vegetation is whether it consists of trees, shrubs, or non-woody plants like grass or crops. If trees, you must determine its spacing (canopy closure) and the height of the top of the canopy. This information can be obtained from air photographs. It is also important for many purposes to know the size of the individual tree trunks (stem diameter). This can usually be determined only by sample measurements on the ground. Other information that you need to know about the plants includes: Are they evergreen or deciduous (losing their leaves seasonally)? Do they have deep roots or can they be pushed over easily by a tank? (You might get a clue concerning this by looking at windfalls.) Does the ground cover last throughout the year or does it die back in the winter or the dry season? This kind of information usually comes from a general knowledge of the area and vegetation types that you are dealing with.



You do not need to know the scientific names of the plants in your area. You probably can recognize a pine or an oak or bamboo or a palm tree even if you do not know what species it is, and this should be recorded. If you do know the botanical name, so much the better. Local names of plants can also be useful, especially in foreign areas.

HOW TO PREPARE A VEGETATION OVERLAY

Most of your mapping will be done from air photographs. When the area you are working on is relatively simple, you can draw lines directly on the overlay as you study the photos. Otherwise you will draw lines on the photos with a grease pencil and later transfer them to the overlay.

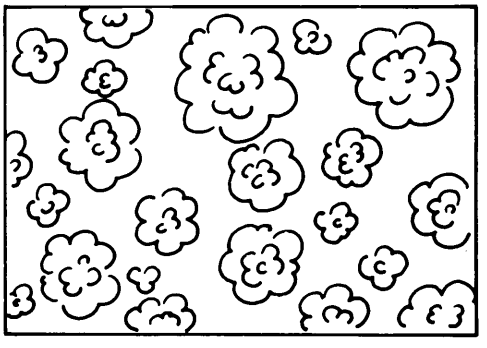
As in most aspects of terrain analysis, you should be able to use a stereoscope. (See FM 21-26, pp. 8-14 to 8-19, for more information about the use of stereoscopes.) By using the stereoscope, you can easily tell whether an area contains trees, shrubs, grass, crops, or a mixture of these. Having separated these areas by lines on your photo, see if there are any subareas that can be outlined. Within a forest, for example, stands of different ages can be very different in their appearance and effect on movement Mixtures of different species* are different from "pure" stands.



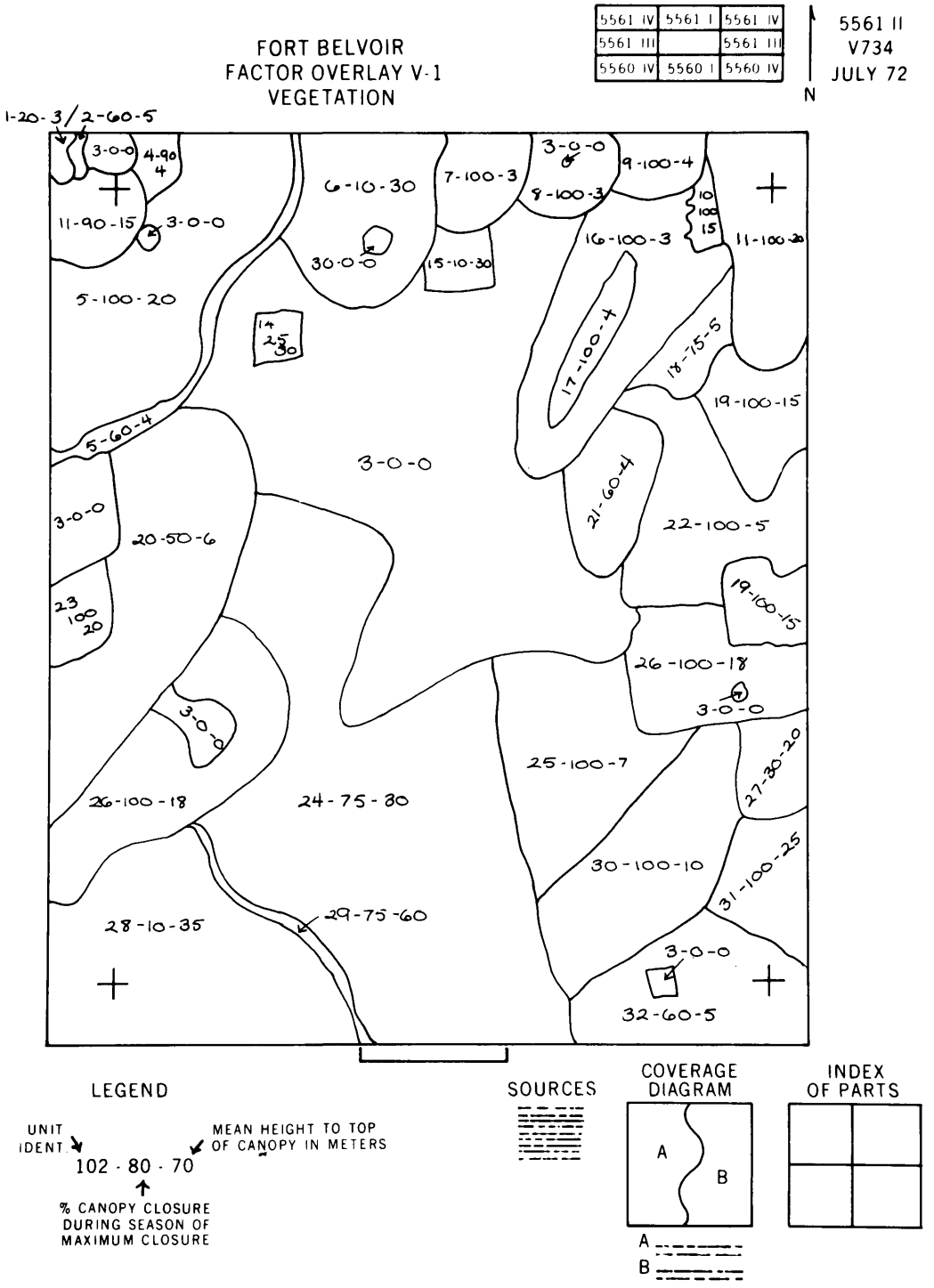
* *A "species" is a distinct kind of plant, like eastern white pine or Kentucky bluegrass. Note that the same word is both singular and plural.*

When you have drawn lines around each type on the photograph, your map will show areas in which the height, spacing, and most prominent species of plants are all more or less uniform. In order to find the height of trees that appear on a stereopair, you also should know how to use a device called the parallax wedge. Student Handout T. 133-253, Evaluation of Standing Timber, explains how to use this device on pages 48-49.

Having outlined the various types of vegetation that appear on the photograph and determined the height of the canopy top if trees are present, you should enter three numbers within each area that you have outlined The first number simply identifies the area, counting from the top lefthand corner of the photograph or map from left to right and top to bottom. The second number is a percent showing the degree of canopy closure. It can be estimated to the nearest 10 percent. For example, this stand would have about 40 percent canopy closure:



The third number is the average height of the canopy top in meters. If the area has no plants more than 2 meters high, the second and third numbers will be zeros. Your vegetation overlay, which you will label V-1, will then show a number of outlined areas each containing three numbers. After making the usual notes and explanations in the margins, your map will look something like this:


FORT BELVOIR
FACTOR OVERLAY V-1
VEGETATION
5561 IV
5561 I
5561 IV
5561 III
5561 III
5560 IV
5560 I
5560 IV
N
5561 II
V734
JULY 72
1-20-3/2-60-5
3-0-0
4-90-4
11-90-15
3-0-0
6-10-30
7-100-3
3-0-0
9-100-4
8-100-3
10
100
15
16-100-3
11-100-20
30-0-0
15-10-30
5-100-20
14
25
30
17-100-4
18-75-5
19-100-15
5-60-4
3-0-0
21-60-4
3-0-0
20-50-6
22-100-5
23
100
20
19-100-15
26-100-18
3-0-0
3-0-0
25-100-7
27-30-20
26-100-18
24-75-80
30-100-10
31-100-25
28-10-35
29-75-60
3-0-0
32-60-5
LEGEND
UNIT IDENT.
MEAN HEIGHT TO TOP OF CANOPY IN METERS
102 - 80 - 70
% CANOPY CLOSURE DURING SEASON OF MAXIMUM CLOSURE
SOURCES
COVERAGE DIAGRAM
A
B
INDEX OF PARTS
A
B

SUMMARY OF PROCEDURE

1. Study air photos and decide what kinds of vegetation are present (forest, grass, cultivated, etc.).

2. Outline each distinct type on the photo with grease pencil.

3. Transfer areas to overlay transparency V-1.

4. Number each area on the overlay.

5. Estimate canopy closure to nearest 10 percent and put second number in each area.

6. Measure average height of canopy top in meters and put third number in each area.

7. Identify each type in a legend and tell meaning of numbers.

8. Color code the various types and color them in (optional).

9. Prepare a card for each numbered area on the overlay and enter on it as much information as you can learn about the area.

ADDITIONAL VEGETATION DATA

Besides the information about canopy closure and height of the canopy top that are entered directly on your overlay, there is a lot more information that you will need in order to have a vegetation data base that can be used to answer many of the questions that will come to you. Your data cards should have spaces for the following entries:

Title, number, and scale of the base map.

Number of area on the overlay.

Source of data (if air photo, give the date of flight, scale, whether vertical or oblique, etc.; if ground reconnaissance, give date).

Principal species (give any names you can get, whether botanical, common, or local; if there is a common species that you don't know, enter it as "unknown").

Ground cover (if there is none, say so).

Depth and type of litter.

Canopy; maximum height, number of layers, height to first branches, crown diameters (number per hectare by classes).

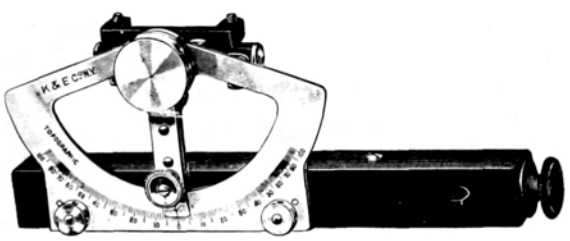
Stems; number per hectare by diameter classes.

Other comments; poisonous or edible plants present; state of foliage; difficulty in getting through brush; etc.

Some of the information called for on your data card can be obtained from air photos, while some of it can be learned only by inspection on the ground. Study the pamphlet "Evaluation of Standing Timber" and first consider what part of the world you are dealing with. You can tell a good deal from this fact alone. If it is tropical, you might have broad-leaved evergreen forests, kunai grass, and certain kinds of plantations. If it is subarctic, it may have stunted coniferous (cone-bearing) trees such as spruce or fir. Most conifers are evergreen, but a few lose their needles in winter; deciduous larch forests cover large parts of Siberia. In mid-latitudes like the eastern United States, you will find a patchwork of deciduous broadleaf, pine, pasture, and crops. So applying what you already know about the area will make it easy to eliminate many types that do not grow there.

Next use the air photos of your area to determine as much as you can about spacing, composition, and crown diameters. Lay out sample plots on your photos and count the number of each kind of tree per hectare. (A hectare is 100 by 100 meters, or 10,000 square meters, so on a photo with a scale of 1:10,000 a 1-hectare plot will be 1 square centimeter. On your 1:50,000 base map, a square 2 by 2 centimeters will inclose 100 hectares.)

In order to get data such as stem diameters, kind of litter, and ground cover under the forest, you will have to make a ground reconnaissance. If this isn't possible, you may be able to estimate some of these facts; for example, there is a definite relationship between stem diameter and crown diameter, which you can measure on a photograph. Sometimes, too, you can tell more about the interior of a forest by studying oblique photos than verticals. When you make a ground reconnaissance, take something with which to measure tree heights and diameters. You can make quick estimates with a forester's cruising stick. You will also need a clipboard for taking notes and measurements.



Abney Hand Level

But what if you can neither get into an area to study it on the ground, nor obtain photographs of it? There is still the possibility of getting vegetation data from topographic maps. Some maps, especially for certain European countries, give a fair amount of detail concerning the vegetation. U.S. topographic maps often have a green overprint that distinguishes forest from farm and pasture land. Such an overprint also shows orchards by a distinct pattern. If you know something about your area these overprints can tell you a lot about the vegetation. For example, if you know that the area was at one time all cleared for farms (as in Tidewater Virginia) which have been partly abandoned, you can tell that the forest will be dense and scrubby, hard to penetrate and affording good concealment in summer when in leaf but without many large, tall trees. (Remember the battles in "The Wilderness" during the Civil War when neither side could see the other until they were very close together.)

With your vegetation overlay (V-1) and data cards, you now have a good vegetation data base for your area. You can use this as a source for vegetation information that can be shown in other ways. You might want to prepare another overlay (call it V-2) showing the same areas as V-1 but containing different numbers to show crown diameters and stem spacing. Or you might prepare tables showing the number of stems or number of crowns per hectare in each diameter class. The interval that you choose for diameter classes will depend on the kind of forest you are studying, but it is not necessary to use a very small interval. In making a table of stem diameters, you might want to show only the number of stems above and below certain critical diameters, such as 5 centimeters (the smallest size that would be an obstacle for a truck) and 20 centimeters (the largest size a tank could knock down easily). A more detailed table of Stems per Hectare would look like this:-

VEGETATION DATA TABLE 1

STEM DIAMETERS AND HEIGHT OF CANOPY

Map Unit Identification No.	Mean Height (m)		No. in Each Stem Diameter Class per Hectare (cm)												Total Stems/ Hectare
	Top of Canopy	Lowest Branches	5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	
21	20	5	32	25	15	31	120	11			3		1			238
22	16	4	102	76	89	18	25	16	12							339
23	—	—														0
24	12	4	205	79	98	45	30		4		1					462
25	22	6	40	52	23	36	66	75	2	8		3				305

EXPLANATION OF TERMS USED

Broadleaf	Having leaves that are not needles or scales; includes all "hardwoods" such as oak, maple, and willow.
Canopy	A more or less closed layer formed by the leafy crowns of trees or shrubs.
Conifer	Cone bearing. (Used in referring to trees of the "softwood" group such as pine and spruce. Most, but not all, conifers are evergreen and needle-leaved.)
Crown	The entire leafy part of a tree or shrub, especially as seen from above.
Deciduous	Losing all of the leaves seasonally, either in the cold or dry season.
Evergreen	Having green foliage throughout the year.
Grass	As used here, any nonwoody vegetation in which grasses or grass-like plants are present.
Hardwood	In lumbering, any tree that is not a conifer. (Hardwoods are generally broad-leaved and may be deciduous or evergreen.)

Hectare	10,000 square meters, or 2.47 acres.
Litter	The accumulation of dead leaves and other organic material on the floor of a forest.
Savanna	Grassland with scattered, widely spaced trees. (Savannas are most extensive in the tropics, but as used here they are not limited to tropical regions.)
Shrub	A low plant (not more than 5 meters high) with woody stems branching near the base.
Species	A kind of plant that can be distinguished from all others on the basis of inherited characteristics.
Tree	A woody plant with a single main stem, more than 5 meters high.
Woodland	A stand of low trees with crowns that are widely spaced enough to allow considerable light to reach the ground layer.

SECTION 6. ANALYZE BEACHES AND OTHER COASTAL FEATURES

BEACHES AS A TERRAIN FACTOR

Military landings on a coast are nearly always made on some kind of beach. Occasionally an invasion is made directly at a port—like the Inchon landing in Korea—but usually this is too risky. Many coastlines have alternating beaches and rocky shores, but the latter are hazardous both for boats and personnel and are easy to defend.

Therefore the analysis of coastal features must be centered on beaches, although the adjacent terrain, both coastwise and inland, is highly important in planning a landing. A lot of specialized terms are used in describing coastal features; since it is important to use them correctly, the most common ones are explained here and at the end of the section.

Because beaches are linked with a special kind of operation (amphibious landings), it is useful to have special factor overlays for beaches and nearby areas in your data base. On this overlay, however, you will show not only the "natural" features of beach, cliffs, headlands, etc., but also manmade objects such as piers and jetties. These are an important part of the beach terrain and often change it significantly.

WHAT YOU NEED TO KNOW

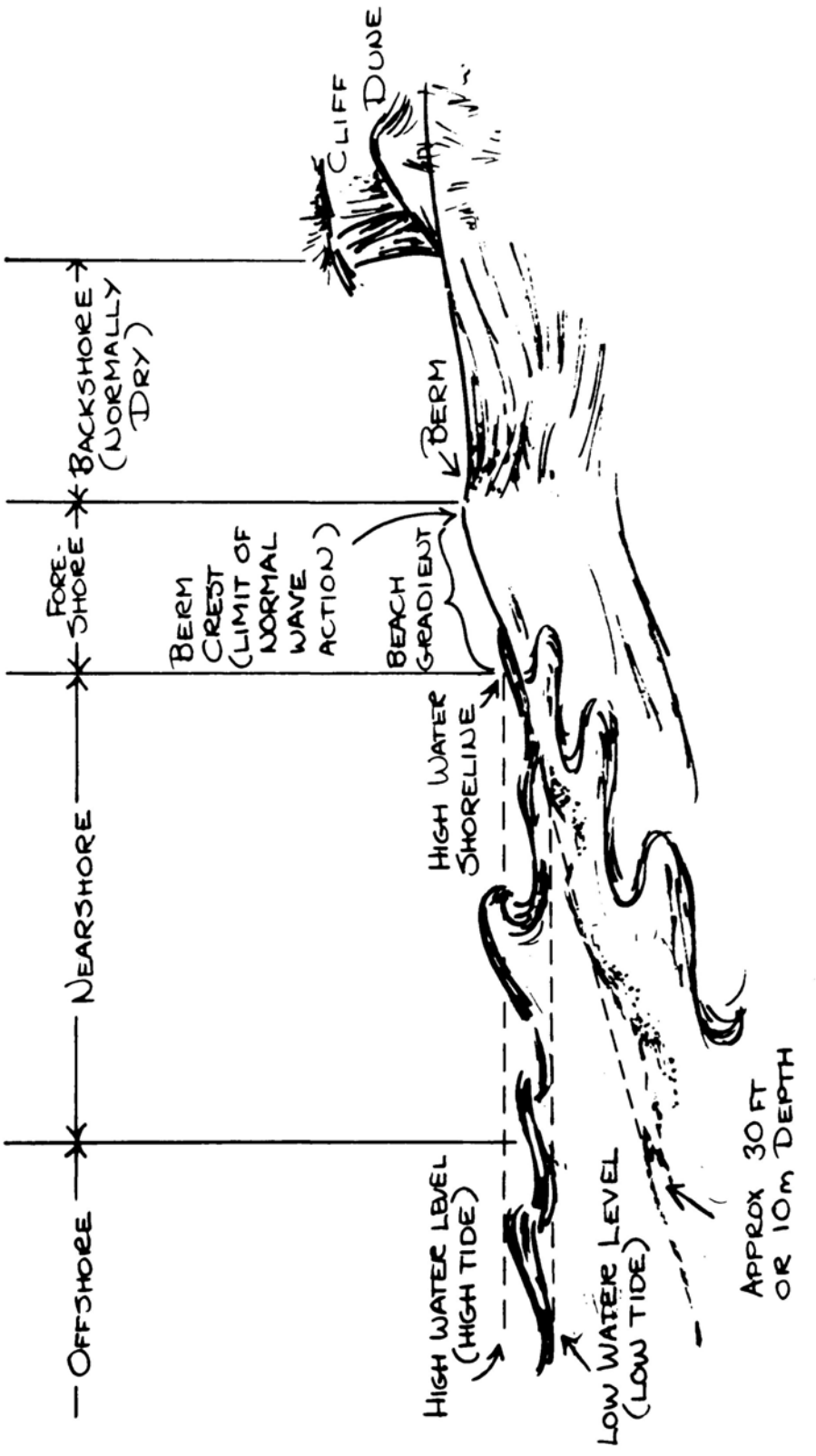
Some kinds of information about the coast will appear on other overlays—soils, vegetation, climate—to be combined with your beach data on the amphibious (Zones of Entry) special purpose overlay. In order to have what you need for this operational map, you must pay special attention to certain things about the beach. This information can be divided into several groups that we'll discuss separately starting from the direction of the ocean.

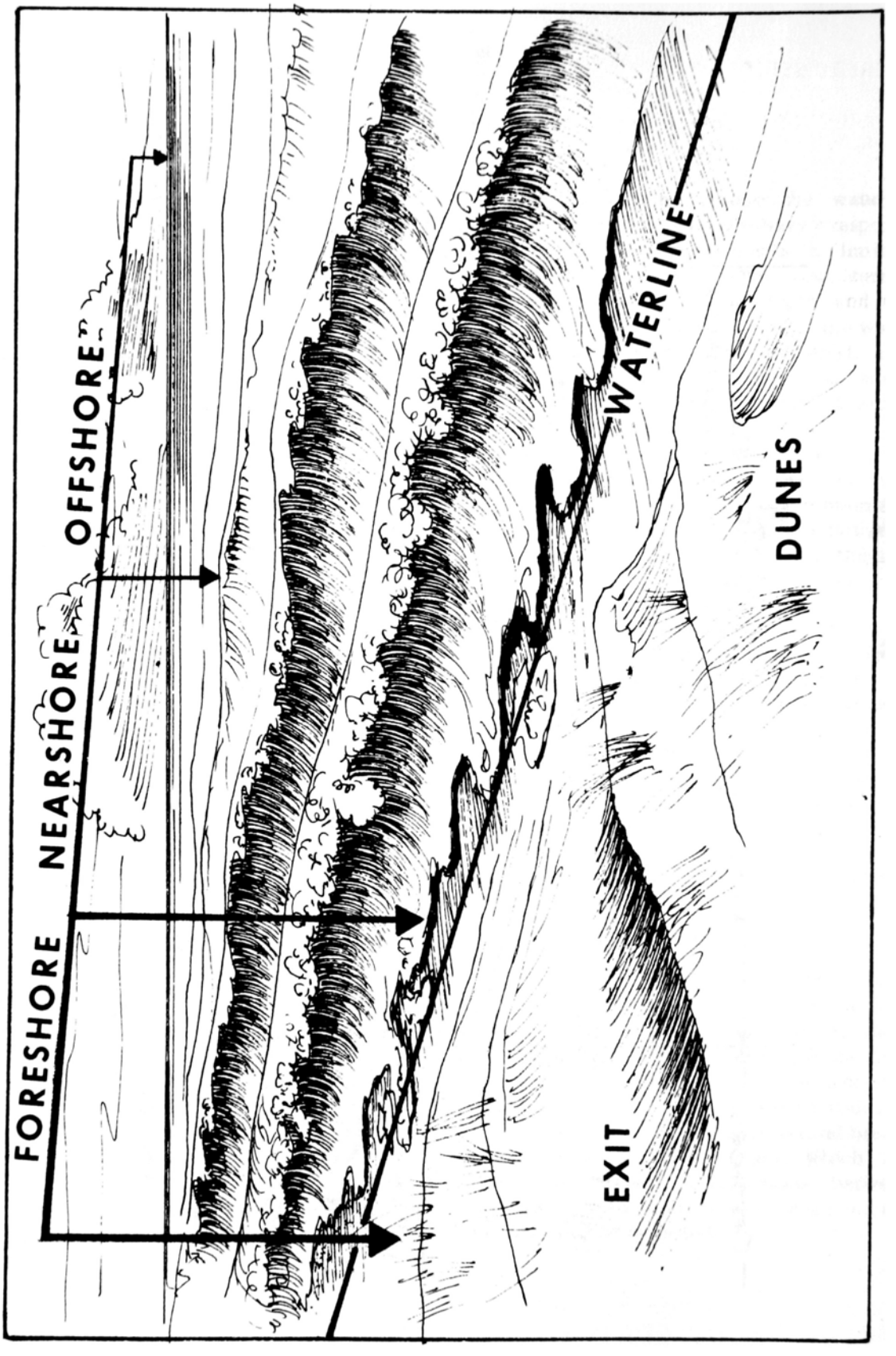
Nearshore Zone. Where the water is deeper than 30 feet, it is the Navy's responsibility. The 30-foot depth marks the limit of the "nearshore zone" where your terrain study begins. Between this depth and dry land, it is important to know what the waves are like, what kind of currents exist, how steep the bottom is, what it consists of, and if there are any underwater obstacles either natural or manmade.

Tides. Tides vary in height and time according to the shape of the ocean basin and the season of year. You must find out how high and how low the tide can be in the area you are studying.

Beach (or Shore). This is the zone from the waterline (usually the mean low tide) inland either to the line of permanent vegetation or the place where there is a marked change in the terrain. It consists of a foreshore, or zone of normal wave wash, and a backshore which is dry except during storms or unusually high tides. You will need to know the length and width of the beach, its gradients, its material and firmness, and the presence of obstacles such as rock outcrops or structures.

Adjacent Terrain. A beach may be backed by any of a variety of terrain types, such as tidal wetlands, sand dunes, lagoons, steep cliffs, and hills. Because a landing force must be able to move inland quickly, it is necessary to have a complete record of such terrain. Of special importance are roads or natural breaks in otherwise difficult terrain, which are known as "exits." Connections between beach exits and inland towns or road and rail networks should be noted.


OFFSHORE
NEARSHORE
FORE-SHORE
BACKSHORE (NORMALLY DRY)
BERM CREST (LIMIT OF NORMAL WAVE ACTION)
BEACH GRADIENT
BERM
CLIFF
DUNE
HIGH WATER SHORELINE
HIGH WATER LEVEL (HIGH TIDE)
LOW WATER LEVEL (LOW TIDE)
APPROX 30 FT OR 10m DEPTH


FORESHORE
NEARSHORE
OFFSHORE
WATERLINE
DUNES
EXIT

WHERE TO GET IT

Much of the information that you need can be found on a topographic map. This will give you good data especially on the location of beaches, lagoons, marshes, and roads leading inland from beach exits. Be sure to note the date of the map, however, as these features all tend to change both from natural and human causes.

If possible, you should look at photographs as well as maps of the area. These will serve as a check on the accuracy of your map and may also reveal obstacles that are too small to appear on the map

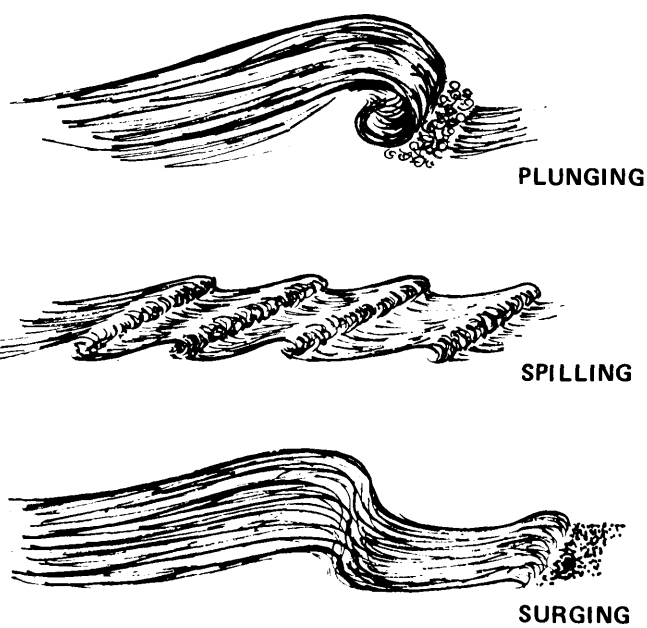
Some of the data that you need, such as beach gradients and wave type, can be found only by observing on the ground. Adequate measurement of gradients can be made with an Abney level or other hand-held instrument. In observing waves, you should note the type (surging, spilling, or plunging), the directions of approach, the height and period (interval between waves), and any persistent gaps in the breaker lines.

Times of high and low tides can be found in published tide tables, and other information such as maximum height of tides can be seen by looking at the beach.

Since beaches are often used for recreation, you can often get useful information from travel folders and other published material. Information about uses of a coastal area—fishing, swimming, excavation of sand or gravel, landing of lighters, etc.,—can tell a lot about the nature of the terrain.

THE FACTOR OVERLAY

On your beach overlay, mark the location of beaches, obstacles of all kinds, exits and roads leading to the interior, lagoons and marshes, high ground, and location of man-made objects. Show the prevailing direction of waves by arrows, and enter notes on the type of waves, time of high and low tide, and any other data that cannot be shown by symbols.



If there are offshore reefs, which are common in tropical regions, show the location of any breaks in the reef.



SUMMARY OF PROCEDURE

1. Study a topographic map to find the location of beaches, major obstacles, and roads leading inland from the beach.

2. Determine from photographs (or on-site reconnaissance if possible) the types of waves, beach gradient, minor obstacles, and changes that may have occurred since your map was made.

3. Get information on high and low tides from published tide tables.

4. Make an overlay showing all information discussed in this section.

5. Enter other data such as tides in the margins.

EXPLANATION OF TERMS USED

Many of the words in this list have other meanings in addition to those given here. This list gives only the more important words and the meanings that you will use in describing beach terrain.

Atoll	A ring-shaped coral island or islands enclosing a lagoon.
Backshore	That portion of the beach lying between the foreshore and the coastline and covered by wave uprush during exceptional storms only.
Bar	An offshore ridge or mound submerged at high tide, of sand, gravel, or other unconsolidated material, especially at the mouth of a river or estuary or lying parallel to and a short distance from the beach.

Barrier Beach	A beach separated from the mainland by a bay, lagoon, or marsh.
Beach	(n.) The zone which extends landward from the waterline to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation. In amphibious operations, that portion of the shoreline designated for landing of a tactical organization.
Beach Face	The section of the beach normally exposed to the action of wave uprush.
Beach Length	The distance along the beach at the water's edge at high water and/or low water between the ends of the beach. USABLE BEACH LENGTH is the overall length minus any unusable parts, that is, separated or obstructed portions.
Beach Ridge	An essentially continuous mound of beach material that has been heaped up by wave or other action. Ridges may occur singly or as a series of approximately parallel deposits behind the beach.
Berm	A nearly horizontal portion of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms; others have one or several.
Bottom	The ground or bed under any body of water; the bottom of the sea.
Breaker	A wave breaking on the shore, over a reef, etc. Breakers may be (roughly) classified into three kinds although there is much overlapping: spilling breakers, plunging breakers, or surging breakers. Spilling breakers break gradually over quite a distance; plunging breakers tend to curl over and break with a crash; and surging breakers peak up but then instead of spilling or plunging, they surge up the beach face.
Cape	A relatively extensive piece of land jutting seaward from a continent or large island, prominently marking a change or notably interrupting the coastal trend; a prominent feature such as a peninsula or headland.
Coast	A strip of land of indefinite width (may be several miles), which extends from the shore inland to the first major change in terrain features.
Cove	A small sheltered bay or bay-like recess in the coast.
Dune	A ridge or mound of loose, wind-blown material, usually sand.
Escarpment	A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion or faulting.

Estuary	(1) That portion of a stream influenced by the tide or body of water into which it flows; (2) an arm of the sea at the lower end of a river.
Exit	Any natural or artificial feature of the ground by means of which troops and/or vehicles can pass from the beach into the hinterland.
Foreshore	The part of the shore, lying between the crest of the berm and the ordinary low-water mark, which is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.
Hook	A spit or narrow cape, turned landward at the outer end, resembling a hook in form.
Inlet	A narrow channel connecting two water bodies, especially in coastal area.
Jetty	(1) (U.S. usage) On open seacoasts, a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel. (2) (British usage) Jetty is synonymous with "wharf" or "pier."
Lagoon	A shallow body of salt or brackish water that is partly or completely cut off from the sea by a barrier beach or similar depositional feature. Also the inner body of water enclosed by a barrier reef or atoll.
Landing Beach	That portion of a shoreline usually required for the landing of a battalion landing team. (JCS definition)
Mean Sea Level	The plane or surface midway between mean high and mean low water. Frequently abbreviated to Sea Level.
Nearshore (Zone)	That part or zone of the sea approach lying between the 30-foot depth line and the mean low water shoreline (tidal) or mean water level (nontidal).
Offshore	The comparatively flat zone of variable width, extending from the 30-foot depth line to the seaward edge of the continental shelf.
Promontory	A high point of land extending into a body of water; a headland.
Reef	A chain or range of rock or coral, elevated above the bottom of the sea, generally submerged and dangerous to surface navigation.
Scarp	An almost vertical slope along the beach caused by erosion by wave action. It may vary in height from a few inches to several feet, depending on wave action and the nature and composition of the beach.

Seawall	A structure separating land and water areas primarily designed to prevent erosion and other damage due to wave action.
Shingle	(1) Loosely and commonly: any beach material coarser than ordinavy gravel, especially any having flat or flattish pebbles. (2) Strictly and accurately: beach material of smooth, well-rounded pebbles that are roughly the same size. The spaces between pebbles are not filled with finer materials.
Shoal	A detached elevation of the sea bottom composed of sand, gravel, or similar material (but not rock or coral) which may endanger surface navigation. Verb: to become shallow gradually.
Spit	An elongated deposit of waterborne sediment which extends from the shore, terminates in the water, and which is exposed at least at low tide.
Surf	The wave activity in the area between the shoreline and the outermost limit of breakers.
Tidal Flats	Areas bordering the oceans which are covered and uncovered according to the state of the tide.
Tide	The periodic rising and falling of the water that results from the gravitational attraction of the sun and moon upon the rotating earth.
Waterline	A juncture of land and sea. This line migrates, changing with the tide or other fluctuation in the water level. Where waves are present on the beach, this line is also known as the limit of backrush.

SECTION 7. ANALYZE MANMADE FEATURES

What if some magic carpet set you down on 10 different spots on the earth's land surface, each one chosen absolutely at random? The chances are that in maybe six of these places, after you picked yourself up and looked around as far as you could see in every direction, you would sight no evidence that other human beings exist—no houses, roads, or the like. You would see only trees, or snow, or mountains, or steppes, or an ocean vista across a beach—and any good terrain study of the place you are standing would have to consider only the "natural" factors of slope, soil, drainage, geology, and vegetation.

But what about the other four sites? What about certain "unnatural" characteristics of the landscape which would probably be sticking up there in front of you—a roadway, a canal, a rice paddy, a hedgerow, a house? Or even some city where there is not a sign of any "natural" terrain features. Certainly, if you are to make and interpret terrain maps you cannot ignore the "cultural," the manmade features. In fact, since wars tend to center around people even more than real estate, the chances are much greater than four in ten that the terrain maps which a military commander requires to do his job must contain clear and useful information on the manmade landscape.

RELATIONSHIP TO MILITARY OPERATIONS

The military importance of manmade terrain includes the street-by-street warfare in strongly defended cities, the critical communitcations of roads and railroads, and all the other elements of manmade landscape which provide obstacles, cover, concealment, or "key terrain." The most important of these features (or "cultural terrain," we might call them), in relation to military operations, are:- (1) settlements and buildings; (2) transportation routes; (3) military installations; (4) air landing zones and terminals. For many purposes, too, the following might be included: (5) manufacturing facilities; (6) utilities; (7) terrain effects of agriculture, mining, and recreation. Details of the importance of these features are described in FM 30-10.

REQUIREMENTS AND SOURCES OF INFORMATION

You need to know how to do at least the following three jobs:

1. Make an analysis and study of manmade features.

2. Prepare overlays and special purpose maps.

3. Write descriptive paragraphs in the terrain study.

Data sources should include all the information stockpiled in your data base file—topographic maps, aerial photography, intelligence reports, reconnaissance reports, card files, etc. However, in preparing overlays for large urban centers especially, it is likely that many other kinds of map sources may have to be consulted. If available, use even such out-of-the-way items as subway engineers' maps, tourist guidebooks, and real estate developers' planning maps (these are just a few examples). Sources of useful information range from G-2 or military intelligence channels to libraries, governmental offices, private industry and commerce, research organizations, university departments, and knowledgeable people. The particular need and the time available determine the extent and type of sources you will use.

BUILDING AND SETTLEMENT FEATURES

What is a settlement? It is often described by geographers as "the buildings and structures whereby people attach themselves to the land." In other words, while New York City is a settlement, so also is the temporary camp of a band of roving bushmen in the Kalahari

Desert. In some parts of the world, the rural settlement pattern is a dispersed one, with each farm family living on its own land, the residence separated from similar residences of farm neighbors. Almost all the rural parts of the United States follow this pattern, the only exceptions being a few religious communities and some ethnic minorities such as the Pueblo Indians.

In most of the world, the pattern of a compact or agglomerated village, the houses of neighbors built closely to each other forming a nucleus surrounded by all farmland, is much more the rule than the exception. Agglomerated settlements are much easier to identify from reconnaissance and from aerial photographs than dispersed settlements. In highly industrialized regions, where formerly distinct towns become swallowed up as suburbs of expanding cities, you may find it a problem to draw firm settlement boundaries. You may also find that, for a city map to be useful—for Civil Affairs purposes, for example—it should contain popular or local names of neighborhoods and small divisions, which seldom appear on official maps.

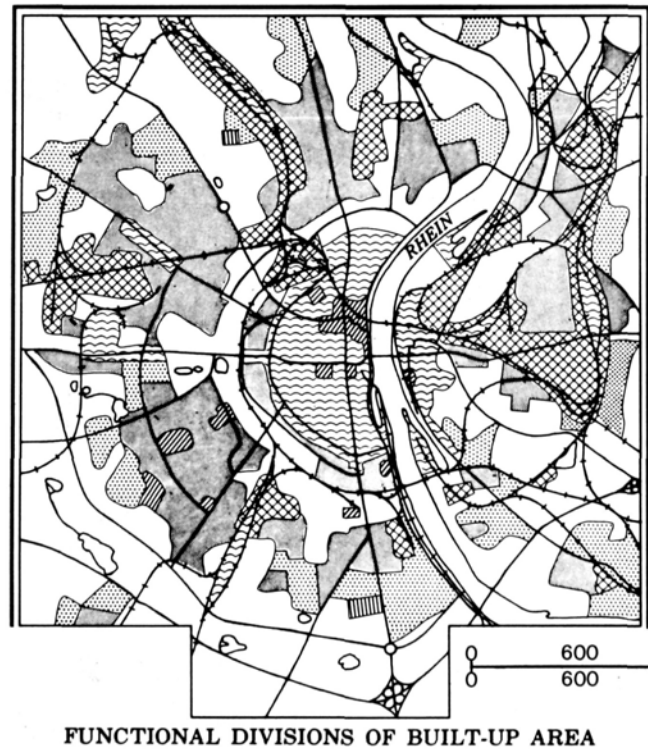
HOW TO MAKE AN URBAN ANALYSIS

1. Use all the data sources described above.

2. Select an appropriate base map and tape a sheet of mylar on it.

3. Add the title, map neat lines, tick marks, scale, and legend.

4. Check the dates of your data. Use only current sources.



LEGEND

FUNCTIONAL DIVISIONS OF BUILT-UP AREA

Industrial

Commercial

(including port areas and freight)

Governmental and institutional

Including local governments, courts, schools, churches and hospitals

Residential

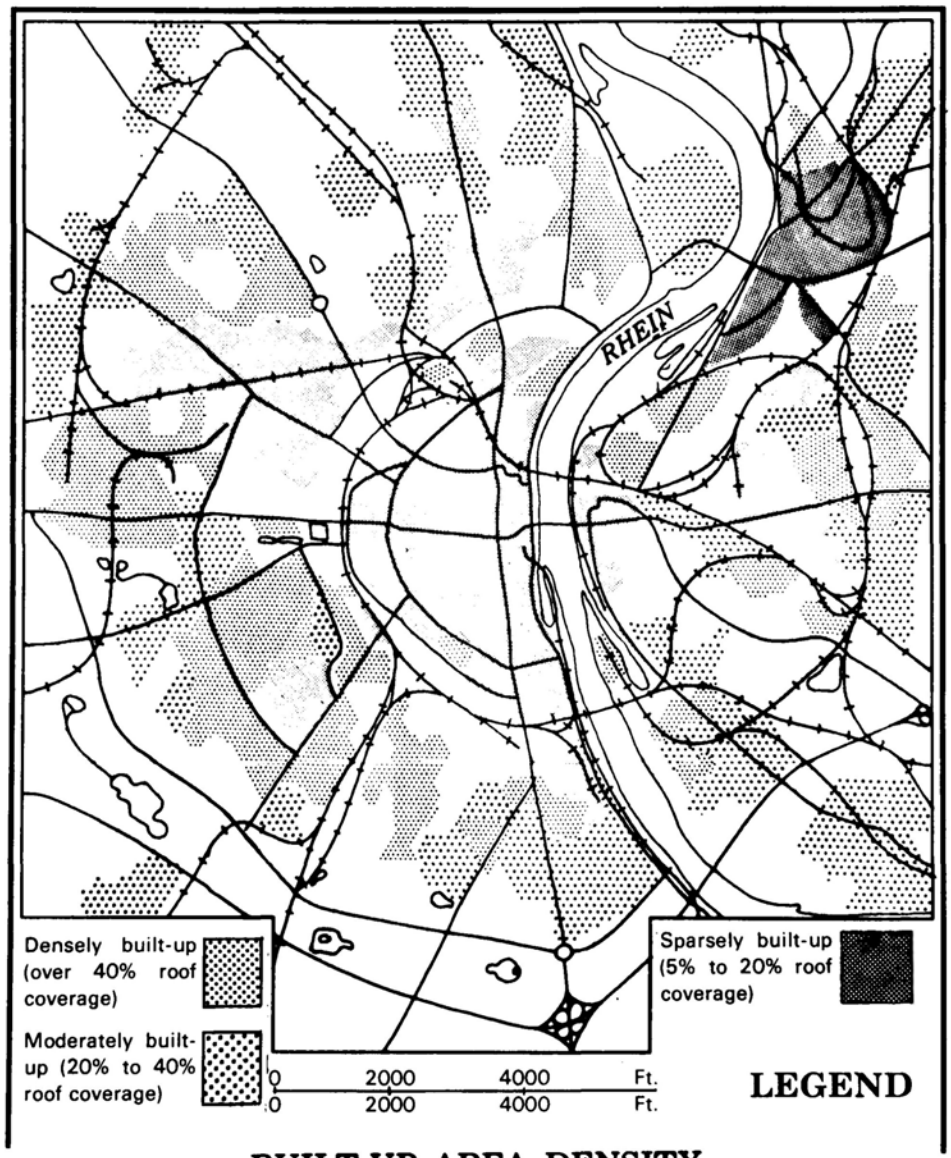
High density

Low density

Military

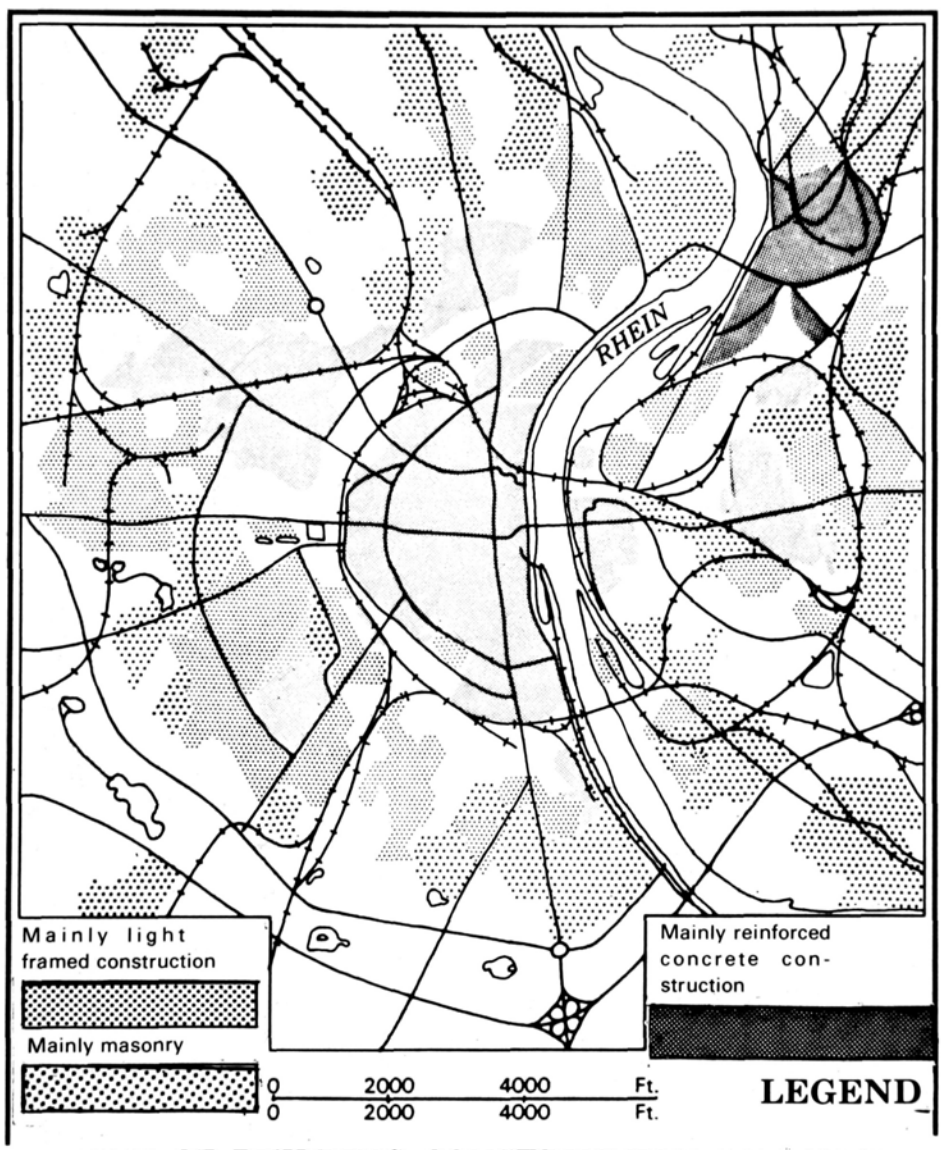
5. Draw on the overlay the information you have obtained. Usually when making a general built-up areas map, you will draw detail in this order; first, the through routes (highways, railroads, and the best routes for convoys); second, boundaries outlining the built-up or settled areas; third, the important landmarks, key installations, and prominent buildings. In addition, it is often necessary to show the sub areas of a city, outlining areas that are predominantly industrial, commercial, and residential. Also, open areas such as parks should be shown. An example of such an overlay is on page 5-57.

If you have the time and resources, make an overlay showing relative built-up area density. This is the percentage of the total area that is covered by roofs (see FM 30-10). You can divide the city into areas with 5 to 20% roof coverage (low density), 20 to 40% (medium density), and over 40% (high density). Here is a density map of Cologne, Germany.



BUILT-UP AREA DENSITY

Another useful kind of urban analysis overlay is one showing distribution of different kinds of building materials in an urban area. Again, Cologne is used as an example.



TYPE OF BUILDING CONSTRUCTION PATTERN

Much of your mapping of built-up areas will be at sufficiently large scale that every separate building appears distinct in the base map or aerial photograph. Strategic and important buildings usually need to be located on your overlay. In fact, a "Location of Key Installations" map is likely to be one most frequently requested by a commander. Key installations may also be listed, together with their military grid coordinates, to accompany such a map.

All the standard map symbols (see FM 21-31) may be utilized in an urban area map to show the various types of buildings and structures such as schools, docks, racetracks, and reservoirs. Of special military interest are lofty structures, whether church steeples, factory chimneys, water towers, or whatever, that can find use as landmarks or as observation posts. The overlay should give the height of such landmarks, both the peak (as air navigational hazard also), and the effective height level for observational purposes. The distribution of below-ground level space, suitable for shelter and/or storage, is another feature that might be required in an urban map. Floor area or storage capacity of buildings may also be significant.

TRANSPORTATION ROUTES

Mobility has always been critical to the success of an army, and to insure it requires detailed knowledge about routes: their locations, condition, and capacities. We make a fundamental distinction between rail and nonrail routes.

In showing a railroad network on an overlay, it is necessary first of all to identify the owners or operators of the trackage, who may be one or more companies or the government itself. Appropriate initials are placed on the map together with symbols showing the system end points. A railroad system may be made up of many segments, which are portions wherein the characteristics of gage and track are uniform.

There are standardized symbols for representing the different gages, the number of tracks, the locations of sidings, yards, stations, bridges, tunnels, cuts and fills, and other details about railroads (see FM 21-31). There are, in fact, upwards of 40 different symbols that you might find useful in preparing a railroad factor overlay. Such maps will also show the location and amount of maximum gradients whenever the grade exceeds 2%. Also, wherever the radius of curvature is 200 meters or less, the location and amount of curvature is recorded on the overlay.

Likewise, roads, streets, tracks, trails, and other nonrail routes must be accurately represented on a factor overlay for manmade features. The road shown on the map will, of course, be identified by the name or route number, if these are known. Unnumbered routes, secondary roads, tracks, and trails are seldom provided names on medium-scale maps, although finding their local or informal names and showing them on the overlay might be a good idea for some purposes. FM 21-31 recognizes about seven classifications of roads, with a distinctive symbol for each. Your transportation factor overlay might usefully include also the average dates of passability of secondary roads and tracks which do not have all-weather surfaces.

AIR TERMINALS, MILITARY INSTALLATIONS, AND OTHER MANMADE FEATURES

The location and characteristics of airports, heliports, and prepared landing strips are of special importance in military mapping. Your overlay should show them by the standard symbols, as given in FM 21-31. Useful data will include runway length, surface, elevation, and directional orientation. In addition, emergency runways should be plotted, as well as the positions of aeronautical lights, visual ground signs, and obstructions to flight.

Your terrain overlay files will also certainly include the locations and descriptions of another kind of manmade feature: the

existing military installations. These include, where known, missile sites, artillery emplacements, communications centers, posts and barracks, etc. Paramilitary installations and police stations should be included, where appropriate.

On large to medium-scale overlays, the manufacturing zones of built-up areas are designated by a distinct color tint or pattern. Individual factory buildings or complexes may also be shown and identified, especially on large-scale or city maps. In the industrialized countries, manufacturing facilities tend to be large and centralized, but in some other parts of the world they may be small and scattered, perhaps even spread through areas that are predominantly rural. Here the terrain analyst faces a special challenge requiring some knowledge of the country he is studying and its economy.

Utility and communications lines and systems can be very important in military operations, especially where such operations occur in the midst of large civilian populations normally serviced by these systems. Energy functions may involve hydroelectric, coal, oil, natural gas, and even nuclear fission facilities, along with their various production, processing, and storage plants, wells, tanks, yards, and pipelines. Cartographic symbols for these factors are contained in FM 21-31.

SUMMARY OF PROCEDURE

1. Assemble all available source data for manmade features in your area.

2. Prepare a transportation overlay showing:-

Location of roads with width, type of surface, and number of lanes.

Location of railroads with number and gage of tracks, sidings, and special facilities.

Location of bridges, with type of construction.

Location of airfields and type of facilities.

Location of unimproved roads and trails if significant.

Location of canals and facilities for waterborne traffic.

3. Prepare a built-up areas overlay showing:-

Boundaries of settled areas.

Important landmarks and prominent buildings with height.

Key installations (radio stations, telephone exchange, power plants, government buildings, etc.)

Open areas (parks, cemeteries)

Subareas (residential, industrial, commercial)

4. If time and data are available, prepare specialized overlays such as.-

Built-up area density

Kind of building materials

Storage capacity of build ngs

Shelter areas below ground

Kind of industrial plants

5. Prepare an energy overlay showing:-

Production sources (oil and gas wells, coal mines, hydroelectric dams)

Refineries and power generating plants (thermal, hydroelectric, nuclear)

Electric transmission lines

Oil and gas pipelines

Storage facilities, with capacity

EXPLANATION OF TERMS USED FOR MANMADE FEATURES

Agglomerated settlement — The form of rural settlement in which farmers' houses are clustered close together in a hamlet or village.

Dispersed settlement — The form of rural settlement in which each farmer lives on his own land, some distance apart from his neighbors.

Density of settlement — The ratio of roof area of buildings to total ground area, including streets and small open spaces. The recognized categories of density are—

Open	5% or less
Sparse	5 - 20%
Moderate	20 - 40%
Dense	40% and over

Gage — The distance between the two rails of a railway. Different gages exist in different parts of the world, and in some cases a single country contains railroads using different gages. Gages are classified as –

Broad	5 ft or more
Standard	4 ft 8½ in
Narrow	3 ft 6 in or less

Radius of curvature — On a railroad, the radius of the circle that would result if the curve at its sharpest point were extended to make a full circle.

Urban area — In the U.S. (according to the Census Bureau), a town or city containing 2,500 or more people if incorporated, and nonincorporated areas with a density of 1,000 or more inhabitants or 100 or more dwelling units per square mile. Other countries have different standards for distinguishing urban from rural areas.

CHAPTER 6

PREPARE SPECIAL PURPOSE MAPS

INTRODUCTION

The primary aim of terrain analysis, as stated in chapter 1, is to answer questions that are asked by military commanders. These questions are generally quite specific: "What is the best avenue of approach to move a company of infantry to Hill 861?" "Where can I find material with which to build a road from X to Y?" "What is the best place within Area Z to land helicopters?"

The answer that you give to a commander's question will be in the form of a terrain study. Sometimes there may not be time to write a report, or the question may not be complex enough to require it. Most often, however, your study will be in the form of a written report containing one or more map overlays. It may also include annotated photographs, either ground or aerial, and tables of numerical data such as average precipitation or bridge measurements. Of course the commander's decision will depend not only on the terrain analyst's report but also on other factors such as disposition of the enemy's forces and the logistical support he is receiving. But the terrain study is one essential part of the intelligence on which the commander will base his decision.

SPECIAL PURPOSE MAPS

The factor overlays that you have learned how to prepare will not in themselves answer the commander's questions. But once you have these overlays they will enable you, as a terrain analyst, to answer questions quickly. Therefore we make a distinction here between factor maps or overlays, which are an important step in the analysis, and special purpose maps or overlays which are designed to answer specific questions. Many kinds of special purpose maps can be made, of which the most important are:

Cross-country movement
Lines of communication
Zones of entry
Observation and fields of fire
Cover and concealment
Terrain masking and nap-of-the-earth flying

MILITARY ASPECTS OF TERRAIN

Each of these special purposes requires the analyst to consider all of the military aspects of terrain. These are:

Key terrain
Obstacles
Cover and concealment
Observation and fields of fire
Avenues of movement



They are not all of equal importance for each special purpose. For determining the best places to conduct an amphibious landing ('zones of entry), the first thing you will want to know is, where are the obstacles? You will determine this from your landforms map and perhaps also from the manmade features map. The first will show where the beaches are backed by difficult cliffs and where there are dangerous rocks and headlands, and the second will show such obstacles as jetties and seawalls. But a landing requires rapid movement inshore, and for this you must know the key terrain to be secured, places where the enemy can be concealed, and the best avenues for moving inland. You must also determine where the attacking force can obtain the best observation points and fields of fire, which in this case will coincide in part with the location of key terrain. These will require use of your vegetation, surface types, and manmade features overlays. Notice, then, that the "military aspects of terrain" can be determined from your individual factor maps, but these must be applied to the particular problem at hand.



PREPARING SPECIAL PURPOSE MAPS

You, the analyst, will perform the tasks listed below only after you have completed the steps outlined in chapters 2 through 5, that is, collect, file, and process data, then interpret features to build up a file of factor overlays and information. If you do not have this built-up file, nor the time to make it, then you must improvise.

How do you make the maps? All terrain analysis maps are made by basically the same technique. The only differences are the geographic location you are working on and the terrain element you are studying (slope, soil, drainage, etc.). Here's how:–

1. Go to your map and overlay file and remove the base map of your subject area with all of the corresponding pertinent overlays.

2. Tape each overlay over the map in turn and tape a clean, new transparent sheet on top of the overlay you are analyzing.

3. Write the appropriate title, legend, and scale; draw tick marks; label them; draw the map neatline corners.

4. Get your card file, tabular data list, and manual of related specifications for the information that has been requested.

5. Draw, or outline, on the clean overlay the required information by combining information from the base map and data overlays and card-tab data.

6. Label the areas or items.

7. Reproduce and/or deliver this special overlay as appropriate.

SECTION 1. PREPARE CROSS-COUNTRY MOVEMENT (CCM) MAPS

This is sometimes called an "avenues of approach" map. It tells the best routes by which various kinds of vehicles can get to an objective when they cannot use prepared roads. It also (and equally important) shows what part of the terrain cannot be crossed by these vehicles.

Some vary elaborate "models" have been devised to do this with computers, but these may not be available in the field when the commander needs them. In that case, it will be up to you to give him the information he needs.

To make this map, you must consider five terrain elements: (1) weather and climate, (2) landforms and slope, (3) soils, (4) vegetation, (5) drainage. Consider the interrelationship of these elements. For example, a soil may be suitable for a track vehicle when dry, not at all when wet, but excellent when frozen hard if the slope is not over 15 percent and the tree stem spacing is over 5 meters.

Use this procedure:-

1. From your reference file, remove the basic data overlays (factor overlays) for slope, soils, vegetation, and drainage, and data for weather and climate.

2. Place the landform overlay over the base map on a light table, and tape a new clean sheet over the two. Mark any obstacles, such as cliffs or deep ravines, that will be a barrier to movement.

3. Next, using your slope overlays, determine the area in which conditions are extreme for the vehicles that are to be used. Show those slopes where movement is most difficult (over 15%) and least difficult (0-15%). Outline and label them as "poor" and "good." Label the remaining areas as "fair."

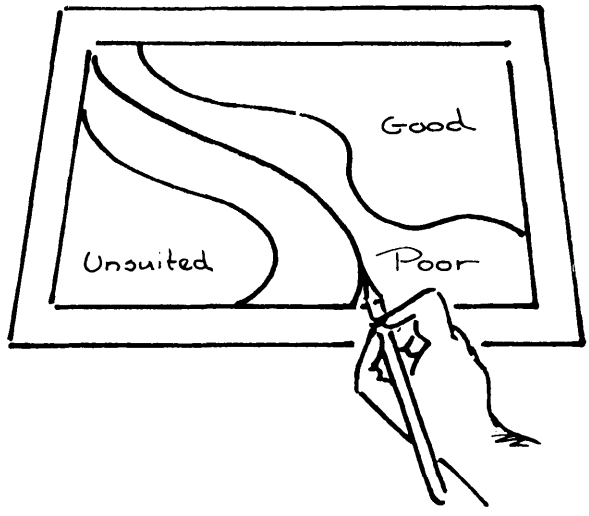
4. Remove the slope overlays and replace them with the soils overlay. Select, outline, and label areas, as you did in step 3, which will prevent movement ("unsuited") or that will allow "poor," "good," or "fair" movement for the vehicle under study. List the areas and reasons for selection in the legend. Consider how the expected weather during the period of use will affect the soil conditions at that time.

5. Vegetation, both natural and cultivated, will tend to slow cross-country movement if it is sufficiently dense. The diameters and spacing of trees are especially important. For example, if it has been established that the vehicles you are concerned about (let's say tanks) cannot knock down a tree more than 20 cm. in diameter and require at least 5 meters clearance between trees, then an area in which trees 20 cm. and more in diameter are closer than 5 meters must be marked as impassable. If all the trees are less than 20 cm. in diameter but they are fairly dense, the area might be crossed with difficulty. Areas of open vegetation, say a desert with less than 50% coverage or a cultivated field, would be marked as "good" for CCM.

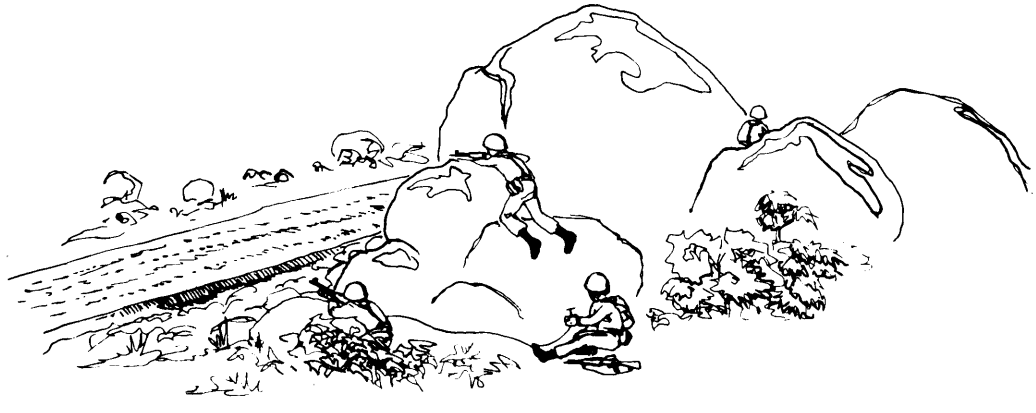
6. Use the same procedure with your drainage overlay. Water courses are obstacles to CCM whenever they are deep enough or turbulent enough or have soft bottoms or steep banks that will affect the crossing ability of vehicles. Consider the time of year and the expected weather; will the water be at a high or low stage? Will it be frozen? In high latitudes, the rivers may be frozen in winter, making them good avenues of movement. On the other hand, they might be impossible to cross during the spring "breakup." Considering all these factors, mark on your CCM map those areas where streams, lakes, or other waterbodies will prevent or slow down cross-country movement.

7. After analyzing the factors of slope, soils, vegetation, and drainage, which are the chief ones affecting CCM, look at your other overlays and see if there are any other terrain factors to be considered. Are there any settlements that will be obstacles to movement? You are not concerned with prepared roads in this analysis, but road cuts or railroad embankments might be obstacles to cross-country movement. What about boulder fields or rock formations that might be obstacles? These will appear on your geology overlay.

8. After analyzing the effects of each terrain factor, your CCM overlay will probably show certain areas that are marked as "unsuitable." Other areas may be shown as "best" for CCM. Then there will probably be a couple of intermediate areas that are passable but rated as "fair" or "poor." See that these are all clearly bounded and labeled.



9. Locate and mark any places where special precautions are needed against a possible enemy ambush. Narrow passes, places where visibility is especially poor, or natural obstacles that will slow down movement should be marked as possible ambush sites.



10. Finally, a table should be made up to go with the CCM map, explaining why these areas are rated as you have shown them. Across the top of the table make a heading for each category on your map. Then down the side list the various aspects of terrain such as cover, concealment, obstacles, and movement. Enter in each box whatever information you can give that will help the commander make his decisions. It might look like this –

Cross-Country Movement Summary

LAGUNA QUADRANGLE, ARIZONA

	1 Best	2 Fair	3 Poor	4 Unsuited
Movement	Gravel plains permit easy movement but repeated passes cause much dust.	Loose sand in washes.	Deeply dissected tertaces. Soil trafficability poor in Laguna reservoir area.	Slopes too steep for any vehicle; difficult for foot soldiers.
Obstacles	None	Flash floods may cause unexpected channels in alluvial fans.	Colorado River requires bridging above Imperial Dam. Fordable below dam.	Mountains generally are prominent obstacles.
Concealment	None	Trees in washes provide some concealment.	Dense vegetation in old Laguna reservoir.	Good in mountains.
Cover	None	Negligible.	Fair in dissected areas.	Good in mountains.

SECTION 2. PREPARE LINES OF COMMUNICATIONS (LOC) MAPS

Lines of communication are all the routes—land, water, and air—which connect an operating military force with a base of operations and along which supplies and reinforcements move.

An LOC map would be needed especially by Transportation Corps and Logistics personnel in planning land, water, and air routes which connect the operating force with base operations. It would also be needed for planning how to interrupt enemy supplies. This map differs from the CCM map in that it shows routes over which supplies rather than deployed forces will move. So it depends more heavily on existing roads, railroads, and airfields, or places where they can be built.

Here is the procedure to follow in making your LOC map:-

1. Get your base topographic map and factor overlays for the same area showing roads and trails, railroads, airfields, landforms and slope, soils, drainage, geology, and vegetation.

2. Place your roads and railroads overlays over the base map and tape a clean sheet over both. Draw the neatline corners and write your title in the top margin. Then transfer the information from the factor overlays to the clean sheet, which will be your LOC map.

3. First draw the primary roads (through routes) and classify them using the conventional symbols from FM 5-36 (which should already be on your factor overlay).

4. Next draw the secondary roads and railroads and annotate them. Begin compiling the legend in the lower margin, and list on the legend whatever you draw on the overlay. If there are no roads or railroads in the area, draw only the trails.

5. Using the airfields factor overlay, add airfields to your LOC map, and add information such as length of runways, type of surface, and landing aids. Do not show unprepared landing areas as these will be on your Zones of Entry (ZOE) map.

6. Check your soils factor overlay to see what the effect of soil conditions will be on unsurfaced routes. Consider the probable weather and whether this might cause surfaces to be muddy, frozen, dry, or dusty. Will the expected condition be favorable or unfavorable to movement along the roads?

7. Put the landforms overlay under your LOC map and see if there are any features where the routes cross steep terrain. If so, consult your slope overlays, but remember that the grade of a road is not the same as the grade shown on your slope overlay unless the road is at right angles to the contours. Prominent surface features should be marked as they may be used as checkpoints.

8. Put the drainage overlay under your LOC map and see if there are any areas where flooding might impede movement; if so, mark them on the map. See if there are any rivers that must be bridged or forded, and what the facilities are for crossing.

9. Check the vegetation overlay and mark any areas where vegetation will conceal the route. Show the percent of canopy closure at the given time of year.

10. The geology overlay will be needed if the commander is interested in maintenance planning along the route. Mark areas where he can obtain gravel or other construction material.

11. Prepare a chart or some other kind of summary explaining the pros and cons of the various routes available. Be sure that everything you mention is shown on the LOC map and explained in the legend.

SECTION 3. PREPARE ZONES OF ENTRY (ZOE) MAPS

Zones of entry are any areas that are used for access to enemy-held territory. They may be helicopter landing zones (HLZ), paratroop drop zones, beaches, or river crossings.

To make a ZOE map, you should follow the same procedure as that outlined for CCM and LOC. You will need factor overlays for surface configuration and slope, soils, beaches, drainage, geology, and vegetation.

Surface configuration is important in several ways. Prominent heights such as hills and ridges will usually be "key terrain" that must be occupied both to control avenues of movement and to prevent their use as enemy observation posts. They also must be noted as possible obstacles to low-flying aircraft. Slopes greater than 7 percent should be marked as possibly hazardous for helicopter landings. Show "exit zones" which the landing force can use to move out from the landing area, whether it is a beach, a drop zone, or an HLZ; if they stay where they are, they will be "sitting ducks," so they must know what avenues can be used to move out quickly.

Your beach factor overlay is essential for studying ZOEs, but it does not tell the whole story. You must add to it information on vegetation, soils, and perhaps manmade features.

Drainage is one of the most important factors in studying ZOEs. This overlay will tell you where rivers or lakes will be an obstacle to the operation, where crossings must be planned, and where in winter frozen lakes can be used as drop zones. As always, the drainage overlay should be studied together with climatic data for the area. This is especially true in places subject to seasonal flooding such as monsoon regions. By marking areas that will be flooded during the time of an operation, you can show the commander where it would be unsafe to drop troops or supplies. Bodies of water can also serve as navigation aids to helicopter pilots.

The geology overlay will show rock outcrops and boulders that might be obstacles either to helicopter landings, paratroop drops, or amphibious operations. Mark and label them on your ZOE map.

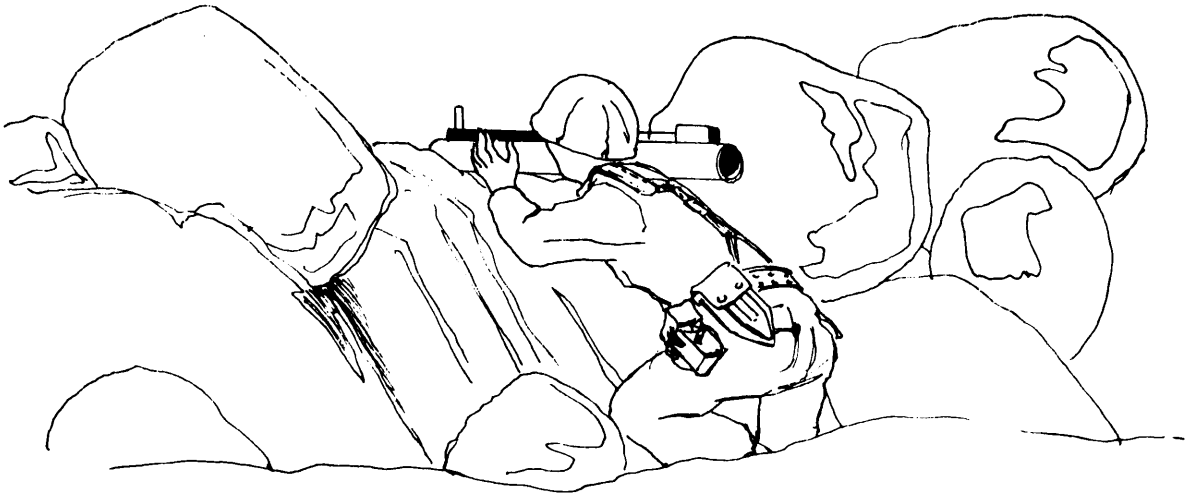
Finally, check your map to see that it is titled, labeled, and annotated. It should have the best ZOEs clearly marked so the user can readily see what areas you have recommended and why.

SECTION 4. PREPARE COVER AND CONCEALMENT (C&C) MAPS

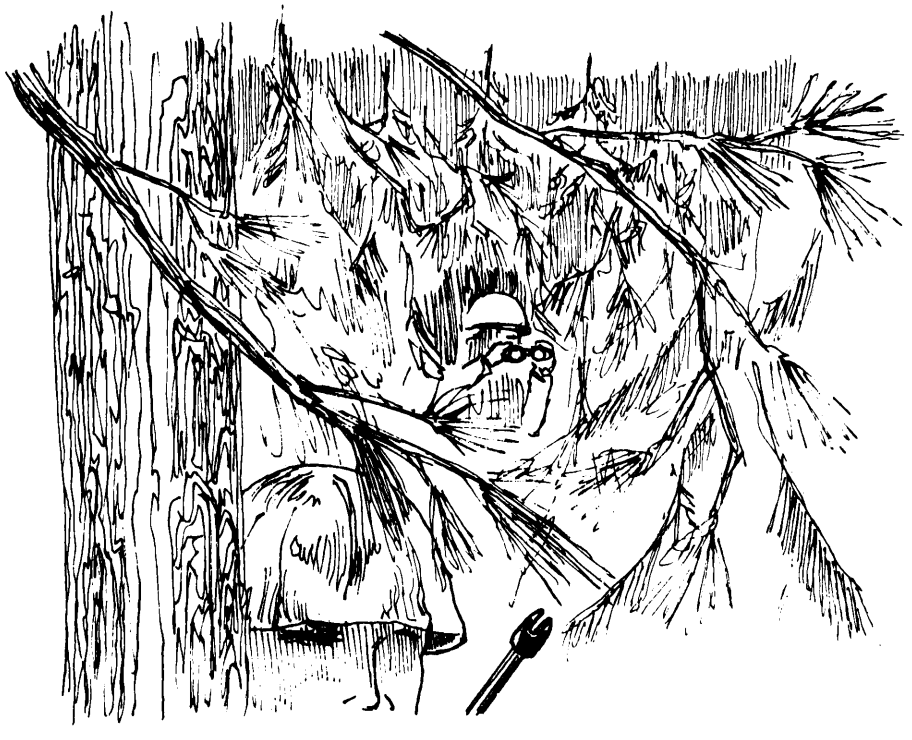
This map is important both for planning protection of friendly forces and for judging where the enemy might be located. It is especially important in areas where guerrilla forces might be operating, because it helps the commander to decide where a guerrilla attack might come from.

The factor overlays to be used in compiling a cover and concealment map are vegetation, surface configuration, geology, and soils. Take them in this order.

1. In most areas vegetation is the most important factor in concealment. Using your crown density or vegetation types overlay, mark off areas on your C&C map where concealment would be good, fair, poor, and none. "Good" concealment would be provided by a broadleaved forest (for example) with a completely closed canopy. No concealment would be afforded in many desert areas or by fallow fields in farmland. Other types of vegetation, such as woodland, tall grass, and brush, would provide partial concealment.



COVER



CONCEALMENT

2. The most important aspect of surface configuration, in most areas, would be the microrelief features. Folds in the ground, minor defiles, and other features that you have marked on your surface configuration maps will provide cover from enemy fire. These should be transferred to the C&C map.

3. Geologic formations such as outcrops and caverns will provide both cover and concealment and should be shown on your C&C map.

4. Soils are important to C&C because of their relation to excavation, field fortifications, and camouflage planning. Show depth of soil and type of material on your C&C map.

Combining the information from these four overlays will produce a map that shows areas of good, fair, and poor cover and concealment. Annotate it to tell why the areas are classified as they are.

SECTION 5. PREPARE OBSERVATION AND FIELDS OF FIRE MAPS

A field of fire is the area which a weapon or group of weapons may cover effectively with fire from a given position. This means that it must be sufficiently clear of vegetation and other obstructions to permit the fire to be effective. So to prepare a special purpose map for fields of fire you will need the same factor overlays that you used for cover and concealment. But this time you are interested in how open the terrain is, not how much concealment it provides.

1. Using the vegetation overlay, you especially want to know about the undergrowth and the spacing of trees. You will mark off on your fields of fire map those areas where horizontal visibility is best, where it is fair (that is, where fields of fire will be good if some clearing is done), and where the vegetation is too dense to allow effective fire at all. If the trees are big enough in diameter to be useful to the enemy as cover whether the trees are standing or down, you should note this fact.

2. Surface configuration might limit fields of fire by giving the enemy cover. Make a note of microrelief features that can be used.

3. Use your soils overlay to determine what opportunities the enemy will have to "dig in" and to use protective excavations.

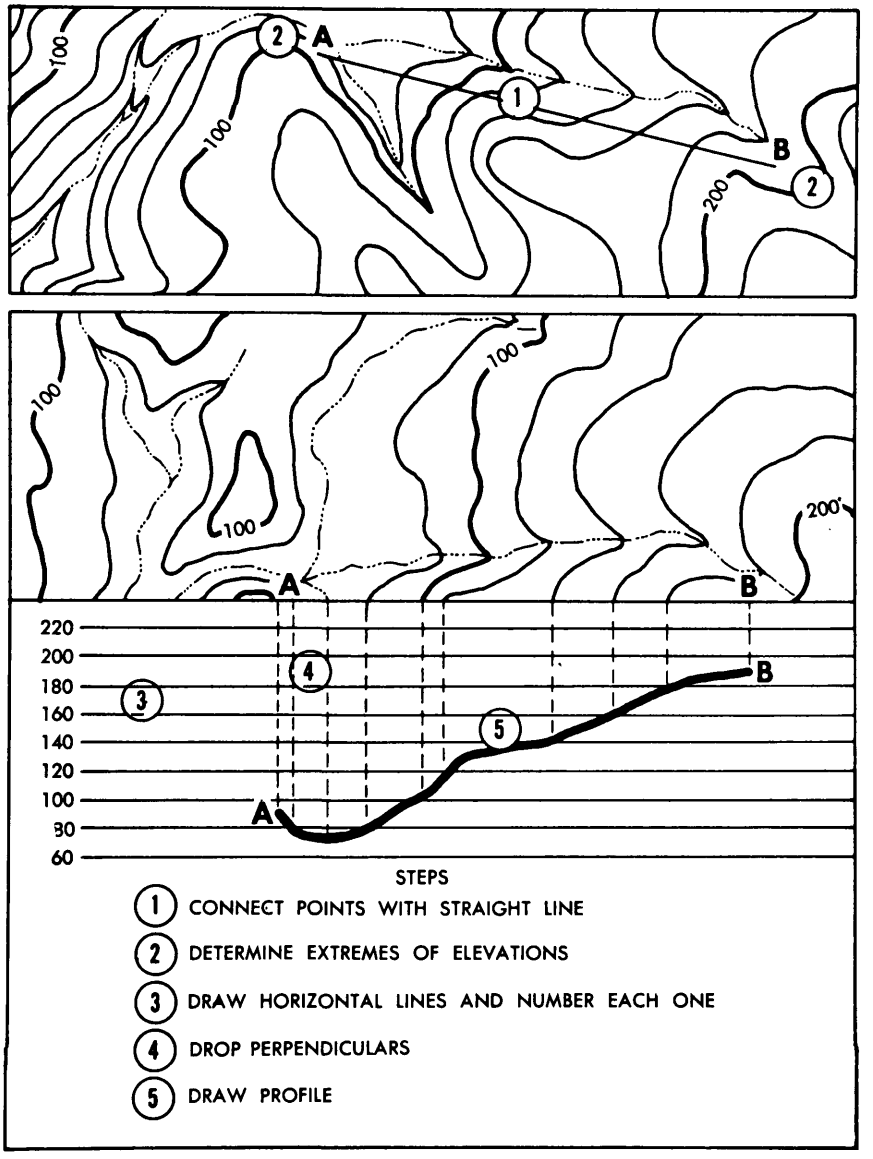
4. Rock outcrops and boulders, which you have located on your geology factor overlay, can interfere with fields of fire and should be labeled on the map.

SECTION 6. PREPARE TERRAIN MASKING AND NAP OF THE EARTH MAPS

Terrain features that will affect nap of the earth flying—or flight as close to the earth's surface as terrain will allow while following the contours—should be shown on a nap of the earth map. To prepare this map, get out your surface configuration, vegetation, man-made features, and hydrology factor overlays, and use them in this order.

1. The landforms map will show what hills, ridges, and other terrain features will govern the general course of the flight. Outline on your special purpose map the features that stand out, and enter the elevations. It is useful in many cases to plot a profile of the proposed flight course as shown in this illustration from FM 21-26, Map Reading.

2. Vegetation is important to nap of the earth flying because it effectively increases the ground level. Height of the canopy above ground, and the height of any trees that stand out above the canopy level, should be transferred from your vegetation factor overlay to the nap of the earth map.


100
100
2
A
1
B
2
200
100
100
100
200'
A
B
220
200
180
160
140
120
100
80
60
3
4
5
B
A
STEPS
1 CONNECT POINTS WITH STRAIGHT LINE
2 DETERMINE EXTREMES OF ELEVATIONS
3 DRAW HORIZONTAL LINES AND NUMBER EACH ONE
4 DROP PERPENDICULARS
5 DRAW PROFILE

3. Manmade features are important both as navigation aids and as obstacles. Any settlements, power transmission lines, roads, railroads, or other features that can be used as navigation aids should be entered on your special purpose map. In addition, show the elevations of any especially tall objects, such as towers or tall buildings, that might be a hazard to flying.

4. Drainage features (especially rivers) can also serve as aids to navigation in nap of the earth flying. Enter on your map any streams or lakes that will be visible from the air.



SECTION 7. PREPARE OTHER SPECIAL PURPOSE MAPS

You can make any number of other special purpose maps in response to requests that you receive. Most of them require use of several different factor overlays, following a procedure like those we have just described. Here are some of the other special purpose maps that you may be called on to prepare.

1. Construction materials. You will use the vegetation, geology, and soils overlays for this kind of map, perhaps in combination or perhaps singly. For road construction, the soils and geology overlays are most important, although availability of logs will also be a factor if the commander wants to build a "corduroy" road across swampy terrain. For field fortifications, the kind and depth of soil is important as are the number and size of trees.



2. Construction Location. Not only are construction materials dependent on the terrain, but equally so are construction sites. You may need the surface configuration, drainage, and geology overlays for this one.

3. Special Weapons Employment. Whether the commander is planning defense against possible enemy use of special weapons (nuclear, chemical, or biological) or is planning the use of such weapons himself, there are a number of terrain factors that must be considered on a special purpose map. Most important is surface configuration—both micro- and macrorelief features. These influence the extent of blast effects, the direction of movement and dispersal of chemical and biological agents, and the availability of protective cover. Soils, vegetation, rock types, and roads and trails are other factors to be considered.

4. Water Supply. Drainage is the most important factor in preparing a water supply map, but you should also consider geology and soils in connection with the possibility of digging wells. In some places, the vegetation may give important clues to the location of water sources.

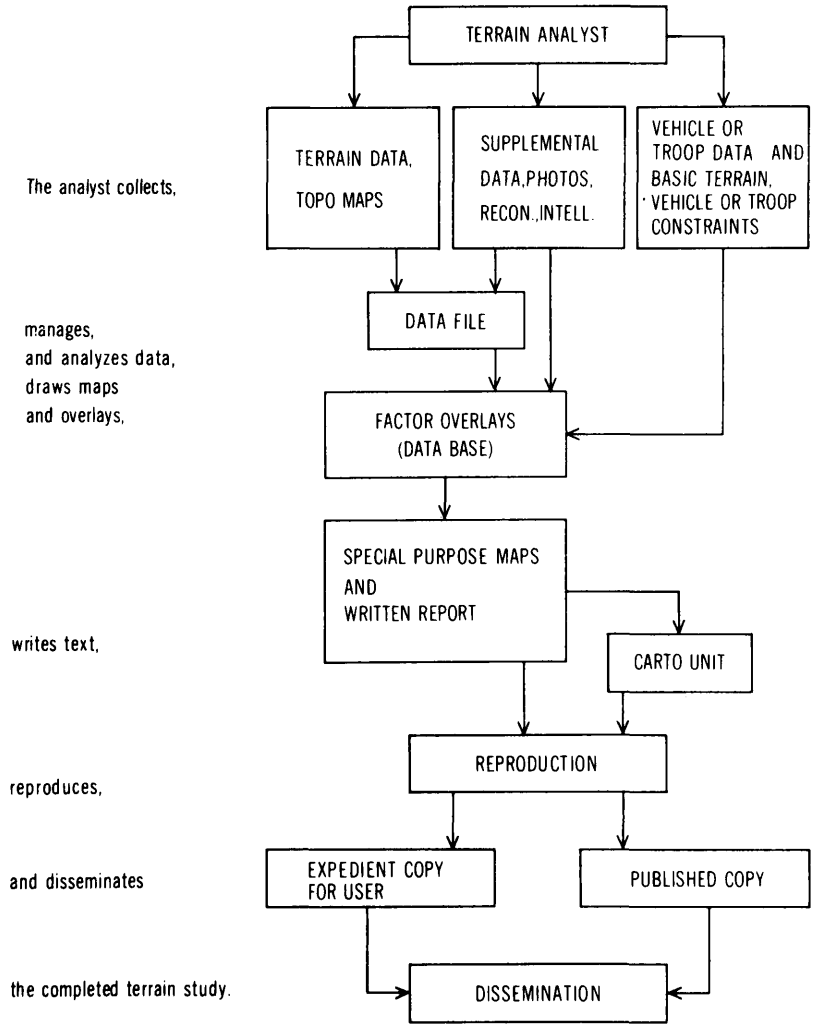
TERMS USED IN DISCUSSING SPECIAL PURPOSE MAPS

Concealment	Protection from observation only.
Cover	Shelter or protection, either natural or artificial.
Cross-country movement	Movement across terrain that is not specifically improved for vehicular traffic.
Field of fire	The area which a weapon or a group of weapons may cover effectively with fire from a given position.
Key terrain	Any locality or area the seizure or retention of which affords a marked advantage to either combatant.
Lines of communication	All the routes, land, water and air, that can be used by military forces in an area of operations.
Nap of the earth flight	Flight as close to the earth's surface as vegetation or obstacles will permit, while generally following the contours of the earth.
Obstacle	Any object that stops, delays, or diverts movement.

CHAPTER 7

PREPARE AND DISTRIBUTE TERRAIN STUDIES

The end product of terrain analysis is a terrain study. Details of the tasks required to complete the study are described in this Manual. These tasks, or steps required, in chart form are:-



The size of a terrain study and the nature of the contents will vary immensely. The study could be as little as one or two annotations on a map or as large as an urban area study of Berlin, Germany, with many special purpose maps and over a hundred pages of written text. Whatever the requirements, large or small, the analyst uses the same techniques. The terrain study will usually contain several special purpose overlays with base maps, a climatic summary, and a written report.

SECTION 1. WRITE TEXT FOR TERRAIN STUDIES

The analyst will usually write a report to accompany special purpose maps, factor overlays, aerial photos, or whatever else is required for the terrain study. Notations are most useful, however, when made directly on the map or photo. Listed below are examples of possible contents of the report. See also FM 30-10, for details of the contents of each section of the report.

EXAMPLE 1

Terrain Study

Contents

Written report section:
- Purpose and Limiting Considerations
- Synopsis
- Orientation Map
- Climatic Conditions
- Topography
- Military Aspects of Terrain, Tactical, Engineering
- Climate and Weather Charts and Graphs

Special map section: Map/Overlays –
- Zones of Entry (ZOE)
- Urban Area
- Trafficability
- Engineer Materials

EXAMPLE 2

Terrain Study

Contents

Written report section: (Same as Example 1)

Special map section: Map/Overlays:-
- Cross-Country Movement
- Lines of Communication (LOC)
- Zones of Entry (ZOE)
- Cover and Concealment
- Observation and Fields of Fire
- Terrain Masking and Nap of the Earth
- Other Special Purpose Overlays
- Helicopter Landing Zones (HLZ)
- Water Resources
- Militarily Significant Cultural Features
- Engineer Materials
- Construction Sites
- Underground Installations
- Industrial Facilities
- Utilities and Power Facilities

The sources of data for the written report can be infinite. Get your information anywhere and everywhere: intelligence reports, reconnaissance notes, photos, sensor imagery, atlases, encyclopedias, travel books, periodicals such as National Geographic, technical papers, etc.

SECTION 2. REPRODUCE TERRAIN STUDIES

Depending upon the size of the terrain report, reproduction can be extremely simple or very elaborate. You may simply run one overlay through a dry process duplicating machine and copy a few written pages on a copying machine then give it to the user. Other times you may submit multiple overlays to the cartography unit of the topographic battalion for final drafting and printing as map overprints or whatever is most appropriate. Similarly, the written report may be 100 pages or more, with photographs and text printed by the base printing plant. Your commanding officer will tell you what he needs. Generally reproduction should be done by the fastest, cheapest, and easiest method and only in the number of copies required by primary users.

SECTION 3. DISSEMINATE TERRAIN STUDIES

Just as the terrain reports change as requested, so does the distribution change from time to time and organization to organization. The terrain detachment commander provides a distribution list, the length of which depends on the type of study and the user. Usually the distribution is through the topographic battalion to headquarters. Under combat conditions, the report may go only to the divisions involved or the requester. Larger, more detailed studies are disseminated by the staff engineer through engineer channels. If the Corps Headquarters requests the study, they will determine the distribution according to their requirements.

APPENDIX A

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CHAPTER 2 - COLLECT DATA

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FM 30-5 Combat Intelligence
FM 30-16 Technical Intelligence
FM 55-8 Transportation Intelligence
TM 5-248 Foreign Maps
TM 11-401 Elements of Signal Photography
TM 11-401-2 Army Pictorial Techniques, Equipment and Systems; Still Photography
FM 30-10 Military Geographic Intelligence (Terrain)

CHAPTER 3 - MANAGE THE FILE OF DATA

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CHAPTER 4 - USE THE DATA FILE

Section 1 - Analyze Source Maps

FM 21-26	Map Reading
FM 21-30	Military Symbols
FM 21-31	Topographic Symbols
TM 5-232	Elements of Surveying
TM 5-240	Map Compilation and Color Separation of Topographic Maps
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CHAPTER 5 - ANALYZE TERRAIN FACTORS

Section 1 - Prepare Climatic Summaries

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Section 2 - Analyze Drainage Features

FM 30-10	Military Geographic Intelligence (Terrain)
TM 5-545	Geology

Section 3 - Analyze Surface Configuration

Landforms

TM 5-545	Geology
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FM 21-26	Map Reading
FM 21-31	Topographic Symbols

Slope

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Section 5 - Analyze Vegetation

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Section 6 - Analyze Beaches and Other Coastal Features

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FM 31-11	Doctrine for Amphibious Operations

Section 7 - Analyze Manmade Features

Building and Settlement Features

FM 30-10	Military Geographic Intelligence (Terrain)
DIAM 57-3	Guide to the Production of Urban Area Studies
FM 21-31	Topographic Symbols

Transportation Routes

FM 5-36	Route Reconnaissance and Classification
FM 30-10	Military Geographic Intelligence (Terrain)
TM 5-370	Railroad Construction
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CHAPTER 6 - PREPARE SPECIAL PURPOSE MAPS

Section 1 - Prepare Cross-Country Movement (CCM) Maps

FM 30-10	Military Geographic Intelligence (Terrain)

Section 2 - Prepare Lines of Communication (LOC) Maps

FM 5-36	Route Reconnaissance and Classification
FM 30-10	Military Geographic Intelligence (Terrain)
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FM 5-200	Camouflage
FM 21-75	Combat Training of the Individual Soldier and Patrolling
TM 5-200	Camouflage Materials
TC 21-75	Who's Watching You?

Section 5 - Prepare Observation and Fields of Fire Maps

FM 21-75	Combat Training of the Individual Soldier and Patrolling
FM 30-5	Combat Intelligence
FM 30-10	Military Geographic Intelligence (Terrain)

Section 6 - Prepare Terrain Masking and Nap of the Earth Maps

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FM 30-10 Military Geographic Intelligence (Terrain)

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