I-244

FIELD OBSERVER/DISPLAY PROCESSOR

PRESTUDY

National Park Service
February, 1991

FIELD OBSERVER/DISPLAY PROCESSOR
I-244 Prestudy

The information in this prestudy package are critical to the successful completion of the Field Observer/Display Processor Course. **The trainee should first read the prestudy materials and then take the open-book prestudy exam and bring it to class. A score of 80% or higher is required to enter the classroom portion of this course.** Trainees are expected to seek out instructional assistance from within their work unit if they have difficulty understanding how to use a compass or how to interpret maps.

In addition to passing the prestudy exam, each trainee must successfully complete an orienteering skills test on the first day of class. Key skills to be tested are pacing on flat ground and up and down slopes, backsighting, and navigating and mapping a course established by the instructors.

The prestudy package has been divided into three units. Each unit contains several lessons:

Unit 1-Map Identification and Interpretation
- Lesson 1 - Introduction to Maps
- Lesson 2 - Map Interpretation Information
- Lesson 3 - System of Land Description in the U.S.
- Lesson 4 - Topographic Maps
- Lesson 5 - ICS Map Display Symbols

Unit 2-Map Calculations
- Lesson 1 - Determining Distance, Elevation, and Slope
- Lesson 2 - Determining Area

Unit 3-Observation and Navigation Aids
- Lesson 1 - Equipment for Measuring Elevation, Slope, and Distance in the Field
- Lesson 2 - Pacing
- Lesson 3 - Compass and Protractor

Tools and equipment needed to complete this prestudy and which you must **bring to class** are:

- 12" or 18" clear plastic rule (1/10th inch graduations)
- Suunto clinometer (graduated in degrees and percent)
- Silva Ranger CL-15 type compass (360°)
- 100 foot (preferred) or 30 meter measuring tape
- protractor
- calculator
- Cajon quad included with this prestudy package (please DO NOT WRITE ON THIS MAP or write very lightly in pencil)
- dot grids or acreage overlay transparencies (optional)

UNIT 1
MAP IDENTIFICATION AND INTERPRETATION

LESSON 1 - Introduction to Maps

Objectives:
1. Define and classify maps.
2. Understand the use of planimetric, orthophoto, and topographic maps.
3. Define and understand the use of the quadrangle or "quad" on topographic maps.

A map is designed to permit you to visualize a portion of the earth's surface with pertinent features properly positioned to facilitate planning and organizing operations. Different types of maps are used for different purposes.

Definition of a Map

A map is a line drawing, to some scale, of an area of the earth's surface or of the works of humans. It shows objects and features by conventional signs. A map is a graphic representation of a portion of the earth's surface drawn to scale on a plane. Although drawn to scale, maps are not absolutely accurate because they represent a curved and uneven surface on a flat piece of paper. The accuracy of a map depends on how big an area is represented, and on the type of projection used to make it (some projections are more accurate than others).

Classification of Maps

Generally, maps fall into two categories: 1) public records (such as a subdivision map), and 2) maps used to describe the earth and delineate the works of people.

Public record maps usually show the exact location and description of a piece or many pieces of property, including bearing and exact distance from known points (bench marks) permanently fixed on or in the ground.

Maps used to describe the earth and that delineate the works of people can be divided into three categories:

1. Planimetric Maps
   A planimetric map is a map which does not depict the shape of the land, or only incidentally shows it, but allows the user to travel along roads, paths, utility lines, vegetation or soil divisions, from one known point to another. A road map is a commonly used planimetric map.

2. Orthophoto Maps
   An orthophoto map is a map depicting terrain and other features by color-enhanced photographic images. It is an aerial photograph of the land. Some orthophoto maps are overlain with contour intervals and other features commonly

associated with topographic maps. Orthophoto maps can help the user navigate from one location to another, and to map incident progress. Orthophoto maps without contour intervals can be difficult to use from the ground in densely vegetated areas since points of reference identified aerially can be difficult to distinguish while travelling on the ground. Orthophoto maps, however, are extremely useful when navigating from aircraft.

3. <u>Topographic Maps</u>
A topographic map is a map depicting natural features such as hills, valleys, lakes, and streams. A topographic map may also depict principal human-made features such as structures, roads, trails, powerlines, and wells. The topographic map is the type of map most commonly used by persons travelling off roads to a fire location or to map fire progress. The majority of skills to be developed in this course will require a detailed understanding of how to interpret topographic maps.

Topographic maps are often referred to as **quads or quadrangles**. The United States has been divided into a large number of rectangles known as quadrangles. The term "quad" is an abbreviation of quadrangle. Each quad is a topographic map covering a certain area, and is designated by the name of a town or some natural feature within the area.

LESSON 2 - Map Interpretation Information

Objectives:
1. Determine the geographic area represented by a map.
2. Define and determine map scale, comparison scale, and representative fraction.
3. Determine cardinal directions on a map.
4. Interpret information from a map legend.
5. Locate the revision date on a map.
6. Determine which maps adjoin a known map.

Information needed to interpret a map includes the area represented, the scale, and a legend which explains the symbols used on the map. Other information may be necessary depending upon the intended use of the map. This additional information may include a grid system, adjoining maps, revision dates, legal descriptions, contour lines, natural and human-made features, and various other items.

Geographic Area
Geographic area represented may be determined by a narrative description (Figure 1) such as one would find on a street atlas or county map. Geographic area may be graphically displayed (Figure 2) using a commonly known area or a given grid for reference. Either way, determining the geographic area is the first step in interpreting a map. The geographic area information relates the specific area referred to by a map to a much larger, relatively well-known area.

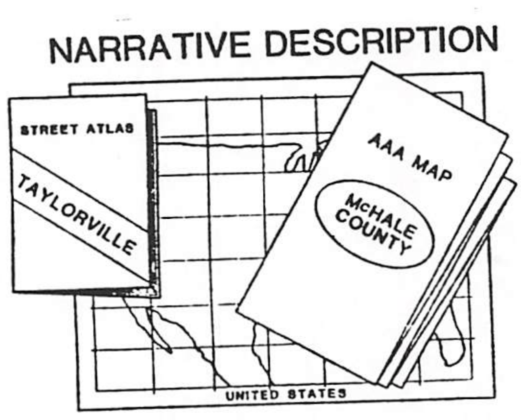


Figure 1: Narrative Description of Geographic Area

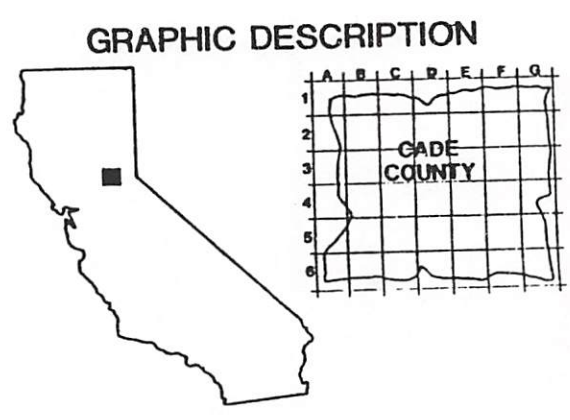


Figure 2: Graphical Representation of Geographic Area

Map Scale

The scale of a map is the ratio of the horizontal distance on the map to the corresponding horizontal distance on the ground. The scale expresses the ratio of the map distance to the ground distance. It is usually written as a fraction or ratio and called the **representative fraction (RF)**.

Example: Representative Fraction = $\dfrac{\text{Map Distance}}{\text{Ground Distance}}$

$$RF = MD/GD \quad \text{or} \quad RF = MD{:}GD$$

A representative fraction is always written with the map distance as 1 (one). A RF of 1/24,000 (1:24,000) means that one UNIT of measurement (inches, millimeters, feet, etc) on the map is equal to 24,000 of the SAME UNITS on the ground (see Figure 3). You cannot mix units in a representative fraction. If it is one INCH on the map, it is 24,000 INCHES on the ground.

A graphic or **comparison scale** is entirely different. It usually compares inches to miles (or like scale figures). Usually comparison scales are printed on the map and show you that so many inches or millimeters equal so many feet, yards, chains, or miles on the ground (see Figure 3). This type of scale is NOT a representative fraction.

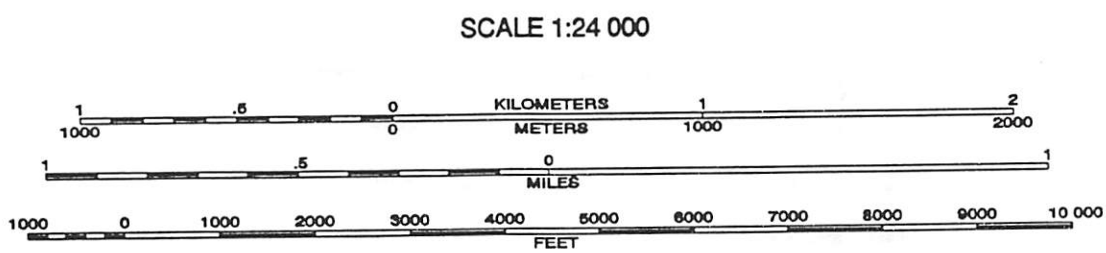


Figure 4: Representative Fraction and Comparison Scale

Cardinal Directions

Most maps are oriented with north at the top of the page. North is usually delineated by an arrow pointing to the north or by a cardinal wheel (Figure 4). If north is the top of the page, east is oriented to the right margin, south is at the bottom, and west is oriented to the left margin.

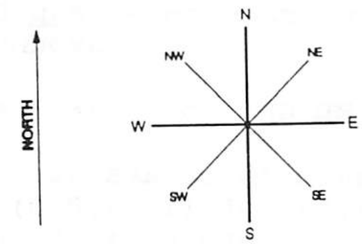


Figure 4: North Arrow

Map Legend

Most maps have a legend to help interpret the map. Legends describe map symbols, such as what color line delineates a road or land ownership boundary, or what figure represents a building, stream, spring, or heliport (see Figure 5).

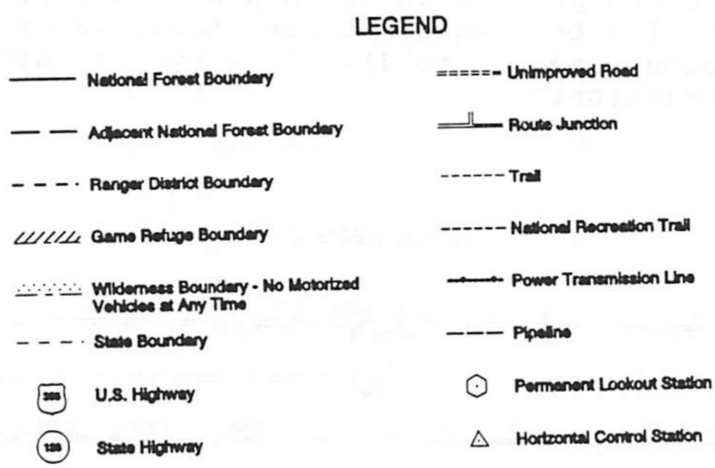


Figure 5: Example of a Map Legend.

Revision Date

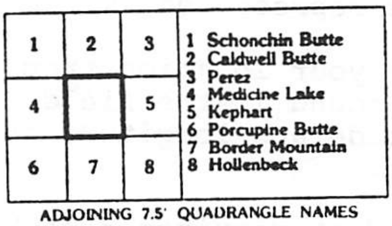
Some maps have a revision date. This is the date the map was last updated to reflect changes in the landscape and human developments (Figure 6). If a map is very old it may not be very accurate.

PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY .... USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1984
FIELD CHECKED..........1985. MAP EDITED 1988

Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
Topography from aerial photographs by photogrammetric methods
Aerial photographs taken 1952. Field check 1956

Figure 6: Examples of Topographic Map Revision Dates.

Adjoining Maps
Some areas are too large to be shown on a single map. Adjoining maps are frequently indicated in the margin of a U.S. Geological Survey (USGS) topographic map or by an adjoining quadrangle legend on the map (Figure 7).



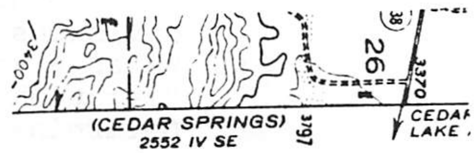


Figure 7: Two Types of Adjoining Map Instructions Located on the Margins of Topographic Maps.

Grid Reference
Some maps are divided into grids to help locate areas. Grids are usually identified alpha-numerically (Figure 8). However, some grids use only letters or only numbers. Many road maps and atlases use a grid reference system to locate streets or other features. An alphabetical index is usually included to help locate an area. For example, in Figure 8. Kington, Wilse, and Laport are located in grid unit 2E.

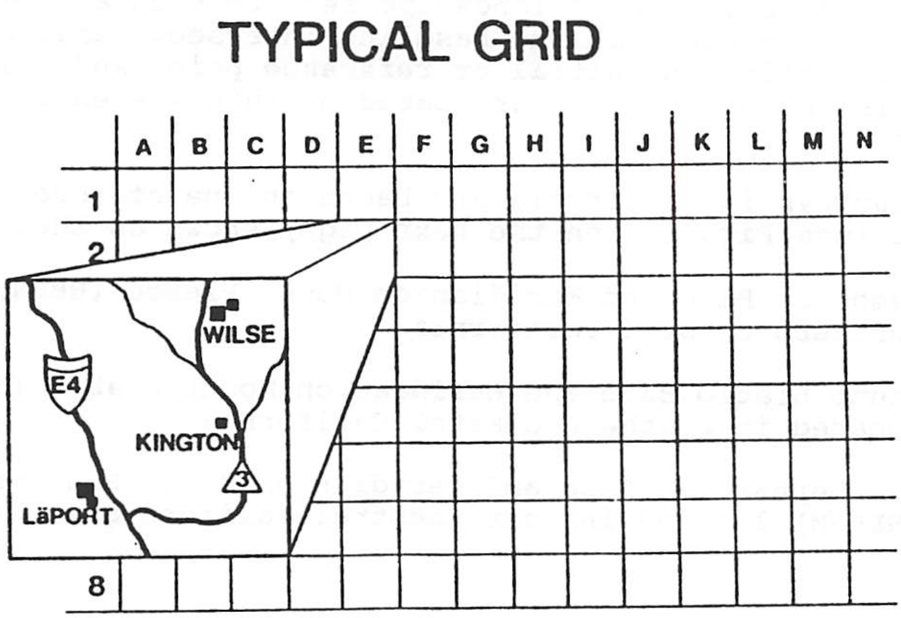


Figure 8: Typical Reference Grid.

LESSON 3 - System of Land Description in the United States

Objectives:
1. Define baseline, principal meridian, and Township, Range and Section used in describing land.
2. Describe the Township numbering system.
3. Give the legal description of a fire location.
4. Divide Townships, Ranges and Sections and give the amount of acres represented by these divisions.
5. Be able to identify your location from "location posters" found in the field.
6. Determine the latitude and longitude of a point or area using a map.

The use of a map for locating an incident requires some knowledge of the system of public land survey. In many areas, land is subdivided into rectangular tracts, and a knowledge of this system enables you to refer to or find blocks of land in the mountains as simply as you find or refer to city blocks by the street names and numbers.

The United States system of surveying public lands (often referred to as the rectangular system) was instituted in 1784 by the Continental Congress and remains in use today. This system divides the land into squares that are defined by north-south and east-west running lines. Before much of the United States was developed, north-south running lines called **meridians or principal meridians**, and east-west running lines called **baselines** divided the country into blocks. Each meridian and baseline originated from a known landscape feature such as a mountain peak. When a meridian and baseline intersect, that spot on the earth is called an **initial or reference point** and all further subdivisions of the land are based on this system of initial points.

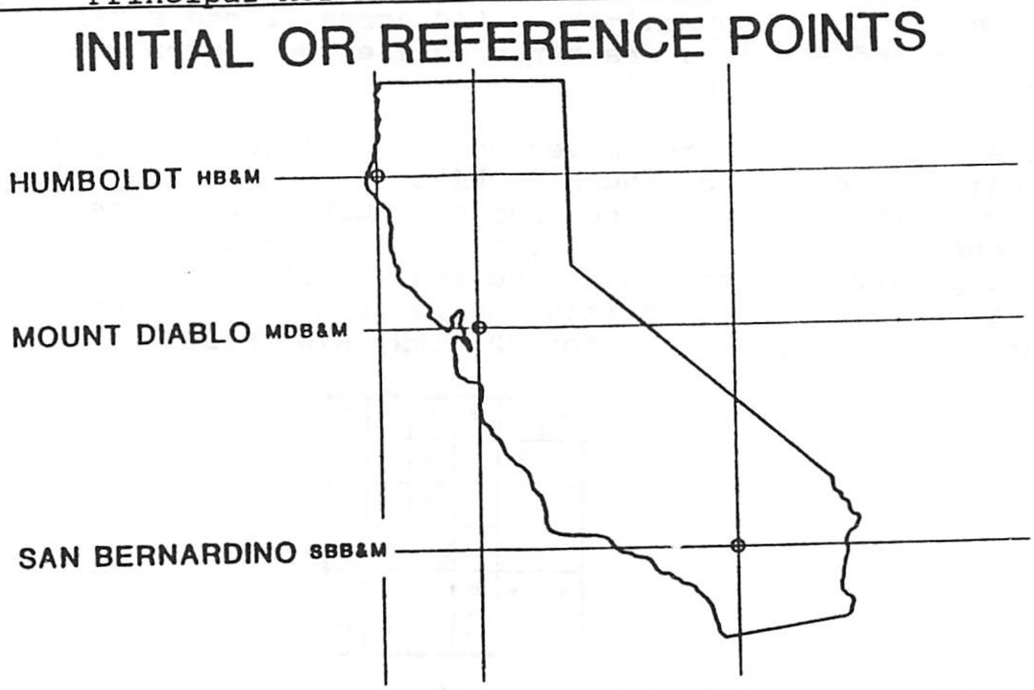
Land surveys in California are based on one of three initial points (see Figure 9 on the next page) known as the:

1. Humboldt Base and Meridian on Mount Pierce (HB&M) located in northern coastal California

2. Mount Diablo Base and Meridian on Mount Diablo (MDB&M) located in southern coastal California

3. San Bernardino Base and Meridian on Mount San Bernardino (SBB&M) located in south central California

Figure 9: Initial or Reference Points in California and Base and Principal Meridians



From these baselines and meridian reference points, land was divided into approximately 6 mile by 6 mile squares known as **Townships.** These Townships are numbered from the initial point, starting with 1 and increasing as the Township falls further north or south from the reference point (Figure 10). A row of Townships running east-west is called a **Range.** Ranges are also numbered from the reference point with Range 1 east (R1E) and Range 1 west (R1W) lying closest to the reference point. Proper descriptions of locations have the Township written first followed by the Range. Often the baseline and meridian are included; for example T45N, R3E (**MDB&M**).

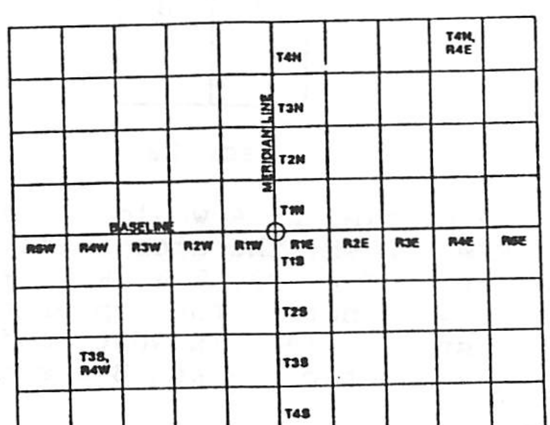


Figure 10: Township-Range Grid

Each Township has been divided into approximately 36 square miles. Each one of the 36 square miles is called a **Section** of land and contains approximately 640 acres or one square mile. Townships and Sections are often smaller or larger where survey corrections have been made.

Each section is numbered based on its position within the Township. The rule of thumb is that Section 1 always lies in the northeast (top right) corner and the numbering of the remaining sections proceeds to the left, then to the right, left, and so on as you progress south (down) the square (Figure 11). A properly written section location (also called the legal description) in Figure 11 would read: Section 22, T5N, R7W, MDB&M).

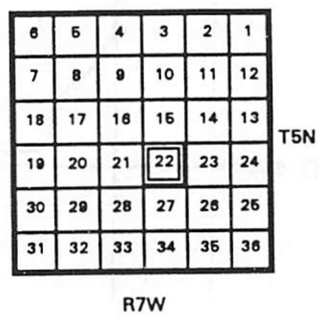
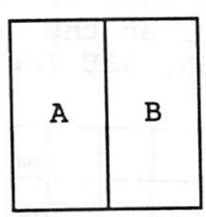


Figure 11: Typical Township

A typical section of 640 acres may be readily divided into smaller areas, each successively smaller piece having a unique location description and from which size can be readily calculated. Let's look at the simplest possible division first - ½ section:

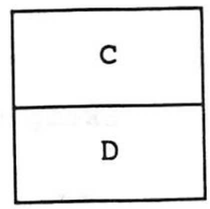
Example 1:



Sec. 22

The area identified by A would be described as **W½** Sec. 22, T5N, R7W, MDB&M; the area identified as B would be described as **E½** Sec. 22, T5N, R7W, MDB&M. (Remember that, unless otherwise noted, the top of the map is north, the right is east, the left is west, and the bottom is south). Half-sections A and B are each 320 acres (640 ÷ 2).

Example 2:



Sec. 22

Area C would be described as N½ Sec 22, T5N, R7W, MDB&M.
Area D would be described as S½ Sec 22, T5N, R7W, MDB&M.
Each half of the section would be equal to 320 acres (640 ÷ 2).

Each section can be further divided into ¼ sections (divisions are not shown on field maps but must be envisioned or drawn by the user) as shown in Figure 12.

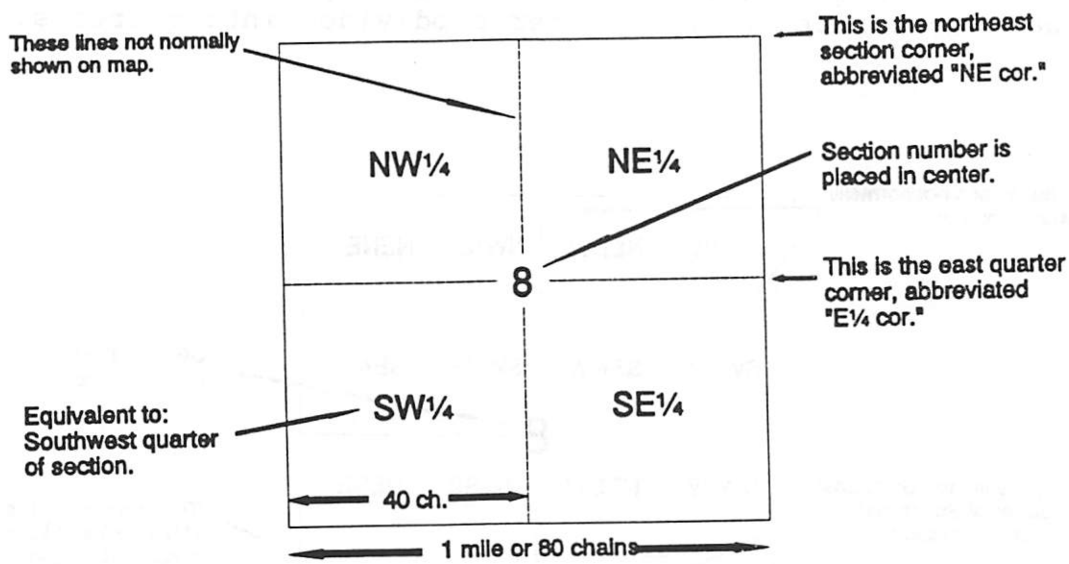
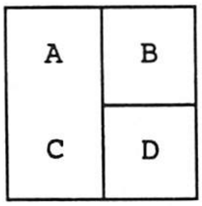


Figure 12: Subdivision of Section into Quarter-sections.

Partial section divisions and combinations of divisions can also be made:

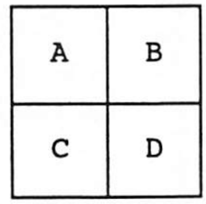
Example 1:



Sec. 22

Descriptions:
- A/C = W½ Sec 22; 320 ac
- B = NE¼ Sec 22; 160 ac
- D = SE¼ Sec 22; 160 ac

Example 2:



Sec. 22

Descriptions:
- A/B = N½ Sec 22; 320 ac
- C = SW¼ Sec 22; 160 ac
- D = SE¼ Sec 22; 160 ac

Quarter-sections can be further divided into halves (80 acres (160 ÷ 2)) or quarters (40 acres (160 ÷ 4)). Figure 13 shows how a Quarter-section can be further subdivided into quarters.

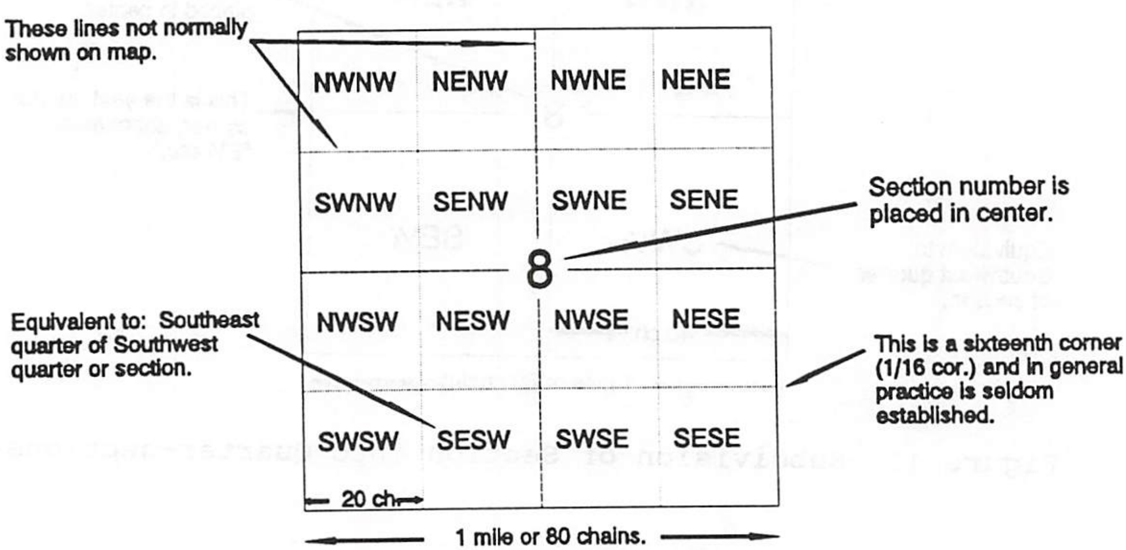
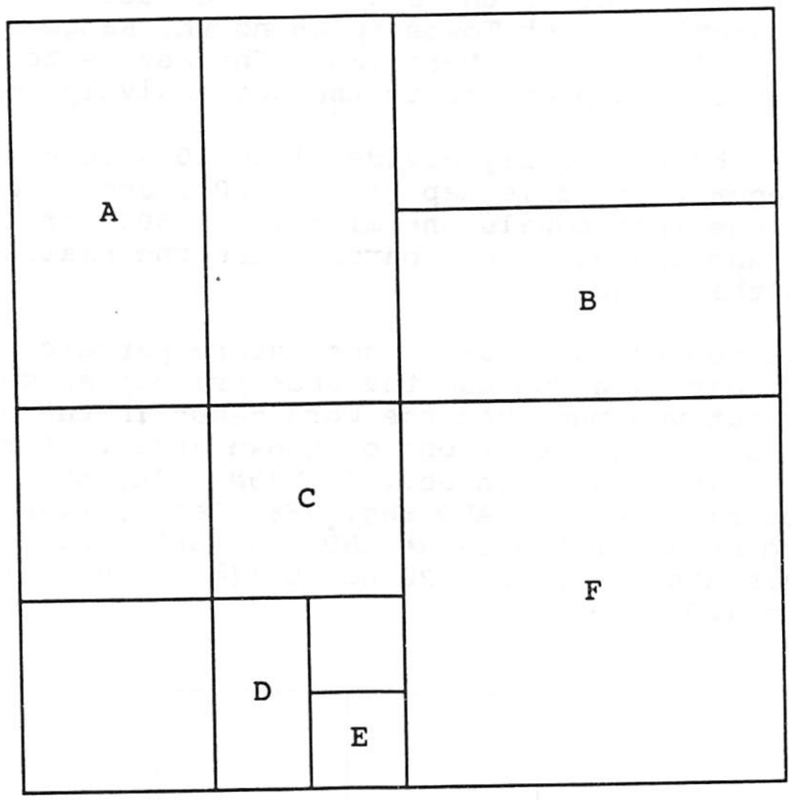


Figure 13: Subdivision of Quarter-sections

In the example that follows a quarter-section of Sec. 8, T45N, R3E, MDB&M has been subdivided. A quarter-section is ¼ of 640 acres, or 160 acres.



NW¼ of Sec. 8 (160 acres)

Each subdivision is part of the NW ¼ of Section 8 and is described below. Acreages are also calculated.

A = W½, NW¼, NW¼, Sec 8, T45N, R3E, MDB&M;
$\frac{1}{2} \times \frac{1}{4} \times \frac{1}{4} \times 640$ acres = 20 acres

B = S½, NE¼, NW¼, Sec 8, T45N, R3E, MDB&M;
$\frac{1}{2} \times \frac{1}{4} \times \frac{1}{4} \times 640$ acres = 20 acres

C = NE¼, SW¼, NW¼, Sec 8, T45N, R3E, MDB&M;
$\frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times 640$ acres = 10 acres

D = W½, SE¼, SW¼, NW¼, Sec 8, T45N, R3E, MDB&M;
$\frac{1}{2} \times \frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times 640$ acres = 5 acres

E = SE¼, SE¼, SW¼, NW¼, Sec 8, T45N, R3E, MDB&M;
$\frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times 640$ acres = 2.5 acres

F = SE¼, NW¼, Sec 8, T45N, R3E, MDB&M;
$\frac{1}{4} \times \frac{1}{4} \times 640$ acres = 40 acres

If you have trouble remembering what order the description is written, replace the commas in your mind for OF THE or OF. For example E above would be described as the southeast quarter of the southeast quarter of the southwest quarter of the northwest quarter of Section eight Township 45 north, Range 3 east, from the Mount Diablo Base and Meridian. The key is to start from the smallest parcel and progress to the successively larger parcel.

Sections can be reasonably divided into 10 acre parcels on a one-half inch equals one mile map (1:126,720), and to 2.5 acre parcels on one inch equals one mile (1:62,500) or larger scale maps. Two and one-half acre parcels are the smallest that will be used in this course.

To describe non-rectangular or non-square parcels and to calculate their size you use the same principles described previously but you must use the word "AND" in the description and you must add together portions of known areas. For example, in Figure 14, A is located in Sec. 3, T45N, R3E, MDB&M, and is legally described as: N½ **AND** SW¼, SE¼, Sec 3, T45N, R3E, MDB&M. It can also be described as W½ **AND** NE¼, SE¼, Sec 3, T45N, R3E, MDB&M. This area would be 120 acres (($\frac{1}{2} \times 160$) + ($\frac{1}{4} \times \frac{1}{4} \times 160$) = (80 + 40) = 120 acres.

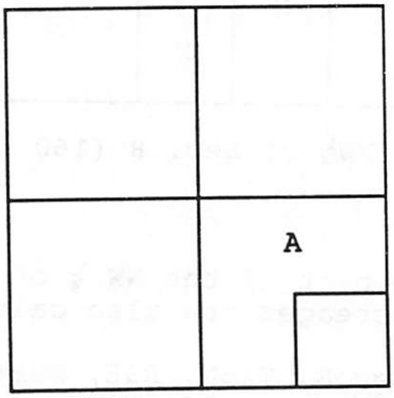


Figure 14

If a Section is delineated on a map, comparison to it of an unknown area such as a fire, makes estimating the size of the fire easier. For example, Map #1 on page 16, has a fire mapped on it; by comparison to a known area (Section 26 which is 640 acres) we can see that the fire occupies about ¼ of a section which is about 160 acres.

On Map #2 (page 17), the fire has burned an area outside of the section lines, but the area of this fire can be estimated by following these steps:

1. Note that a Section of a 7-½ minute topographic map is approximately 2-6/10 inches on a side or 2-6/10 inches = 1 mile.

2. The fire is 3-4/10 inches long (over a 1-¼ mile long).

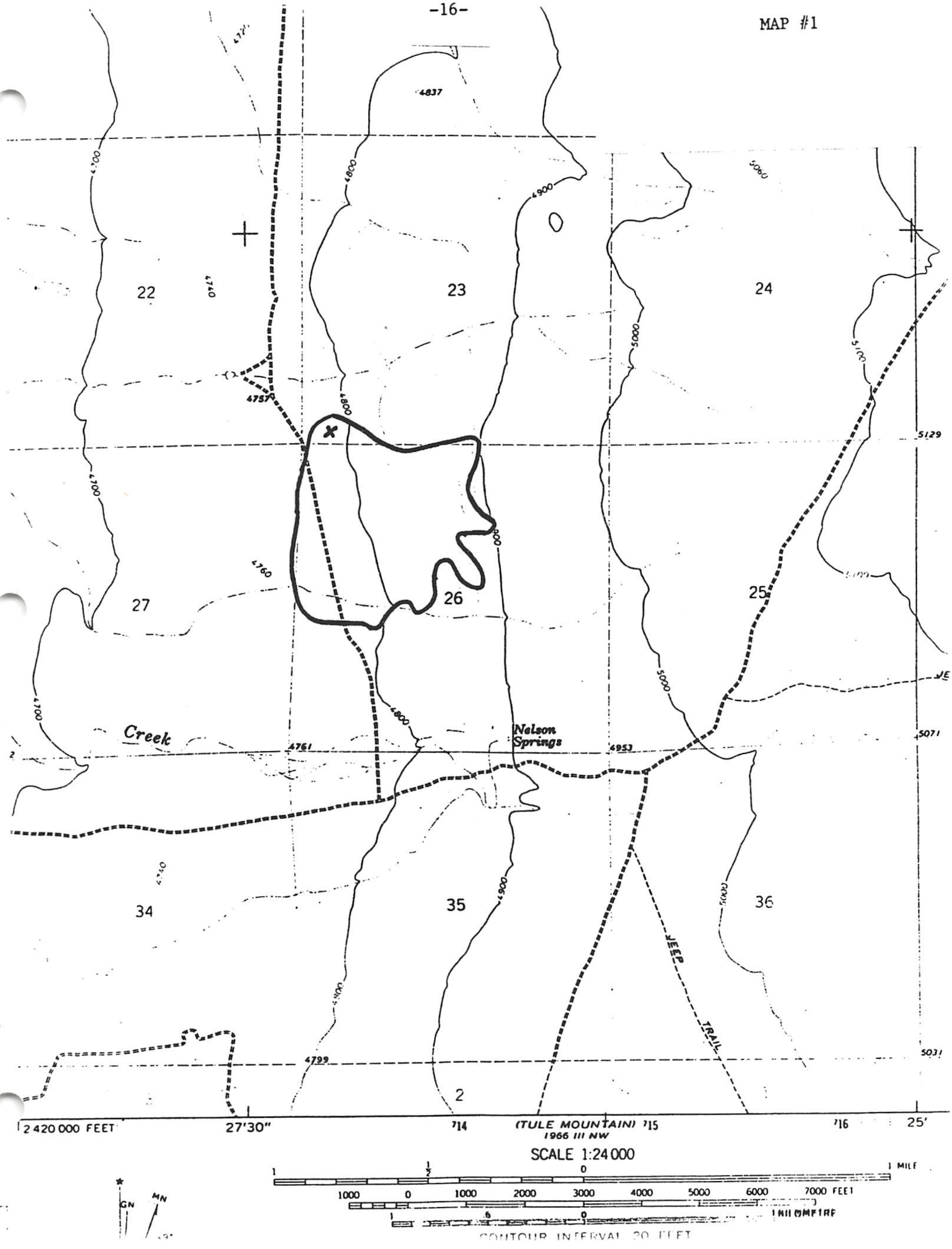
3. The fire is 1-9/10 inches wide (over ½ mile wide (1-3/10 inch = ½ mile).

4. The fire is irregular in shape; this irregularity should be considered.

5. The fire is smaller than a Section (640 acres) which is 2-6/10 inches by 2-6/10 inches.

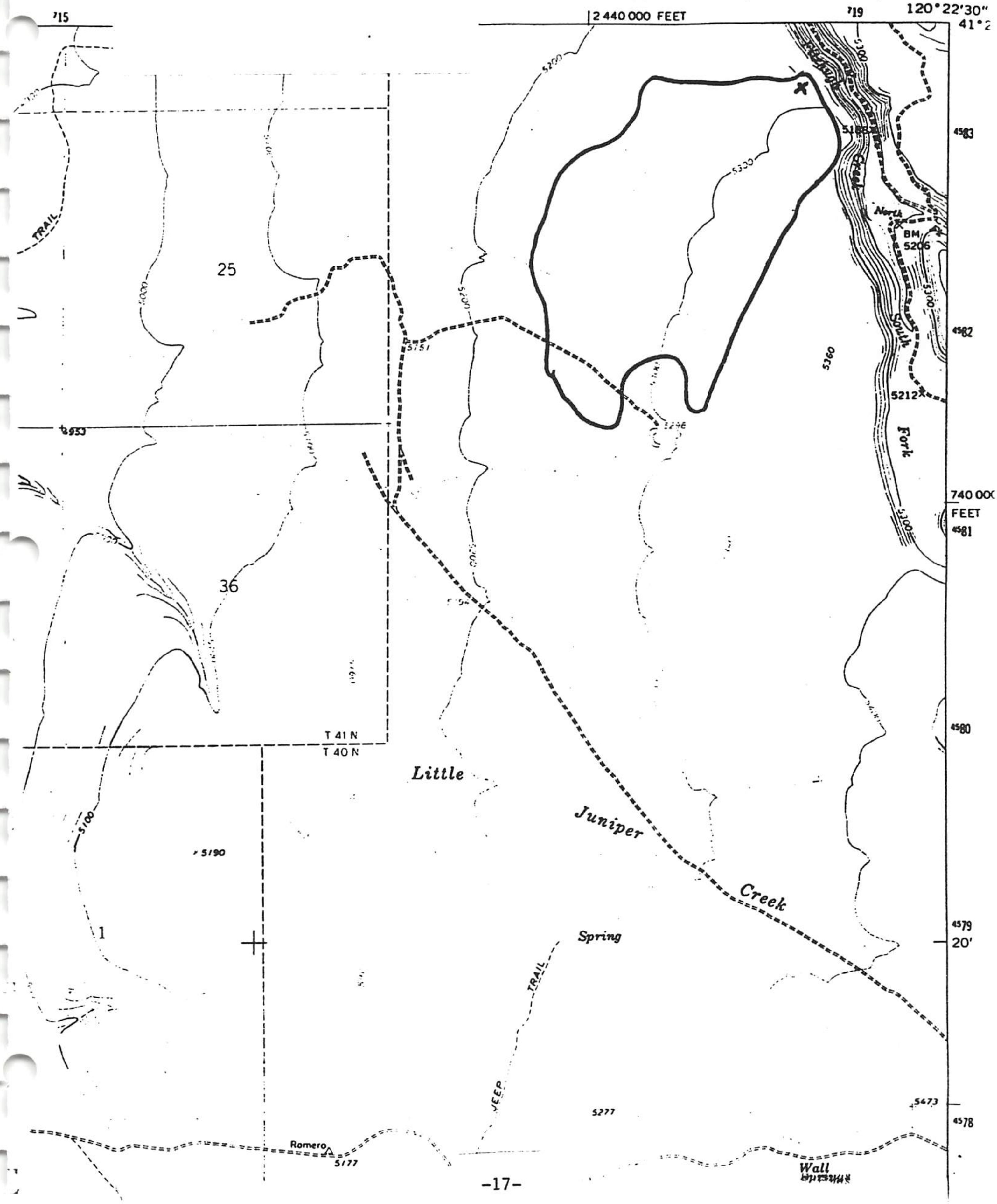
6. It approximates 3/4 of a Section (2-6/10" by 1-8/10") which is 480 acres, but is a little longer (9/10"). This slightly longer length compensates for the irregular shape. Therefore it is safe to say that this fire is approximately 480 acres.

MAP #1


22
23
24
27
26
25
34
35
36
2
4837
4800
4900
5000
5060
5100
4740
4700
4757
4760
5129
Creek
4761
Nelson Springs
4953
5071
JEEP TRAIL
4799
5031
2 420 000 FEET
27'30"
714
(TULE MOUNTAIN) 715
1966 III NW
716
25'
SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
GN
MN
CONTOUR INTERVAL 20 FEET

MAP #2

LITTLE JUNIPER RESERVOIR QUADRANGLE
CALIFORNIA–MODOC CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Location posters

Location posters, sometimes called Section corner markers, Section line markers, "K" tags, or cruiser tags (see Figures 15 and 16) are used by State and Federal agencies, lumber companies, and private landowners to indicate the location of section corners and points where roads or trails cross section lines. These metal posters are 4½ or 5 inches in size with black lines on a yellow background. In recent years, unpainted aluminum tags with the lines and lettering stamped on them have been used. The Township, Range, and Section are marked on the poster. A tack driven at the appropriate place on the poster shows where the poster is located according to the public land survey. Usually, the distance to a section corner is marked on the poster. On the map in Figure 17, points B and C would probably be identified in the field by location posters similar to Figure 15, and point A by a location poster similar to Figure 16.

Figure 15: Location Poster for Indicating Section Corners.

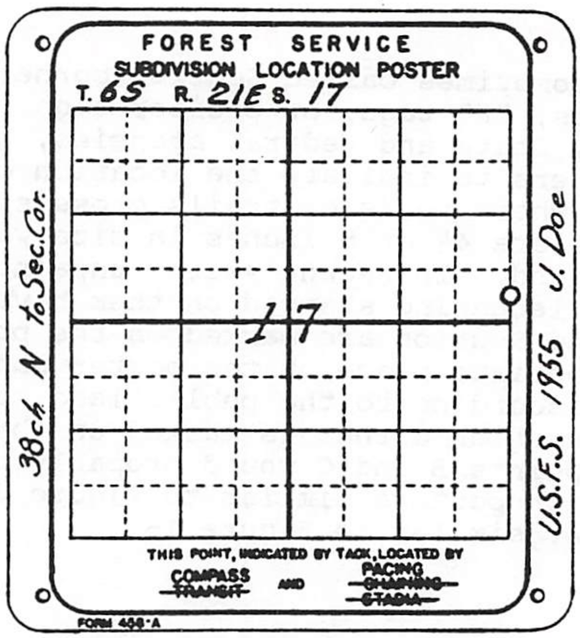
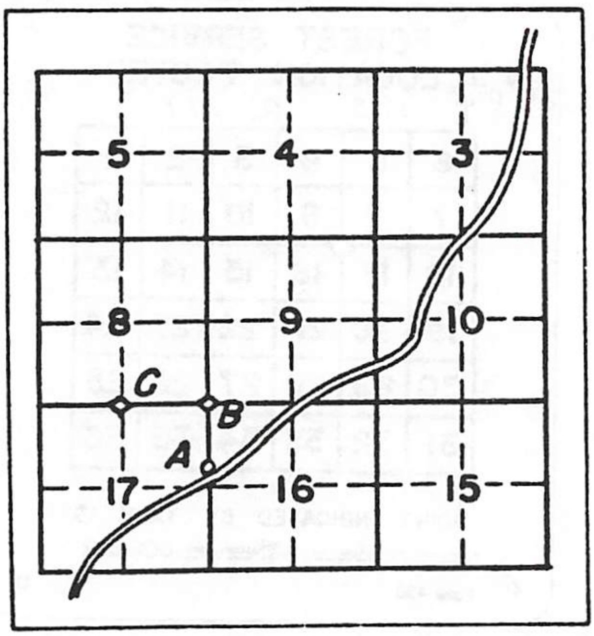


Figure 16: Location Poster for Indicating Section Lines.

Figure 16 is an example of a type of poster used at a road or trail crossing of a section line, or at a quarter-section corner.



A. Where roads cross section line.
B. At section corners.
C. At quarter section corners.

Figure 17: Portion of a Map Showing Typical Points Where Location Posters are Commonly Placed.

Latitude and Longitude
Many forest maps include rectangular blocks with sides parallel to longitude and latitude lines. These lines with map scales aid in comparing various scale maps.

If a fire or incident occurs, location should be referenced and recorded by latitude and longitude for later use in completing the individual fire report. Enter the latitude and longitude at the point of the fire's origin. Report degrees in whole numbers and minutes to the nearest tenth. In some aircraft, navigation equipment (called a LORAN) that indicate latitude and longitude are standard.

A description of latitude and longitude follows.

Latitude
Is measured in degrees, (0° through 90°), north and south of the equator. Lines of latitude are parallel; therefore, the distance between two lines of latitude remains constant (Figure 18). One degree of latitude = 60 nautical miles (NM); one NM = 6075 feet, or 1.15 statute mile.

Longitude
Is measured in degrees (0° through 180°), east and west of the "prime meridian" which runs between the north and south poles, through Greenwich, England (Figure 18). (When you invent the system of latitude and longitude, as the British did, you get to decide where the lines are.) Lines of longitude are not parallel; the closer to the poles, the smaller the distance between them.

When specifying a position, latitude is normally given first. For instance, Boise, Idaho would be located as: 43° 35' (45 degrees, 35 minutes) north latitude, 116° 15' (116 degrees, 15 minutes) west longitude.

This will locate you within approximately 1 nautical mile (1 minute of latitude is equal to 1 nautical mile). By extending the reading to 0.01 minute, the accuracy is down to approximately 60 feet (0.01 minute of latitude = 60.75 feet).

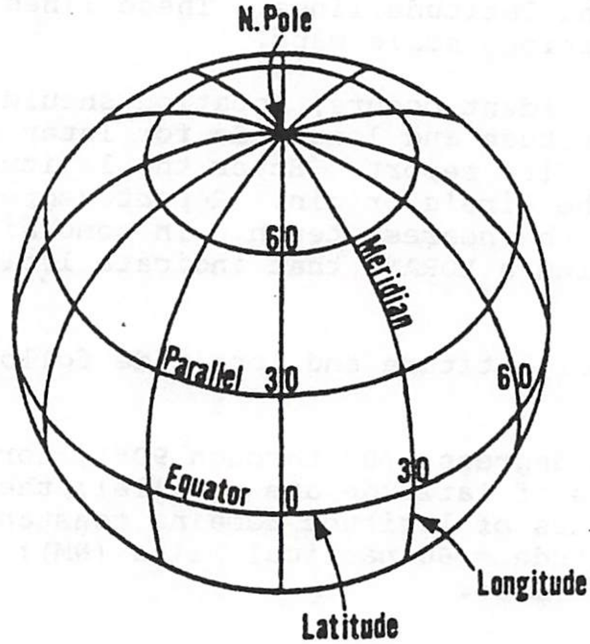


Figure 18: Latitude and Longitude.

Other Location Methods
In some areas the land survey system may not include Township and Section divisions. Some land surveys follow natural geographic features such as ridge tops, stream bottoms, or similar features. This system is called a metes-and-bounds survey.

In many cases, local people may describe a location by naming the drainage, identifying local landmarks, and including the compass direction and distance from a known point to the location being described. For example, fire towers or road junctions are frequently used as checkpoints in directing pilots to specific fires.

Complete the following exercises to test your knowledge of Unit 1 information:

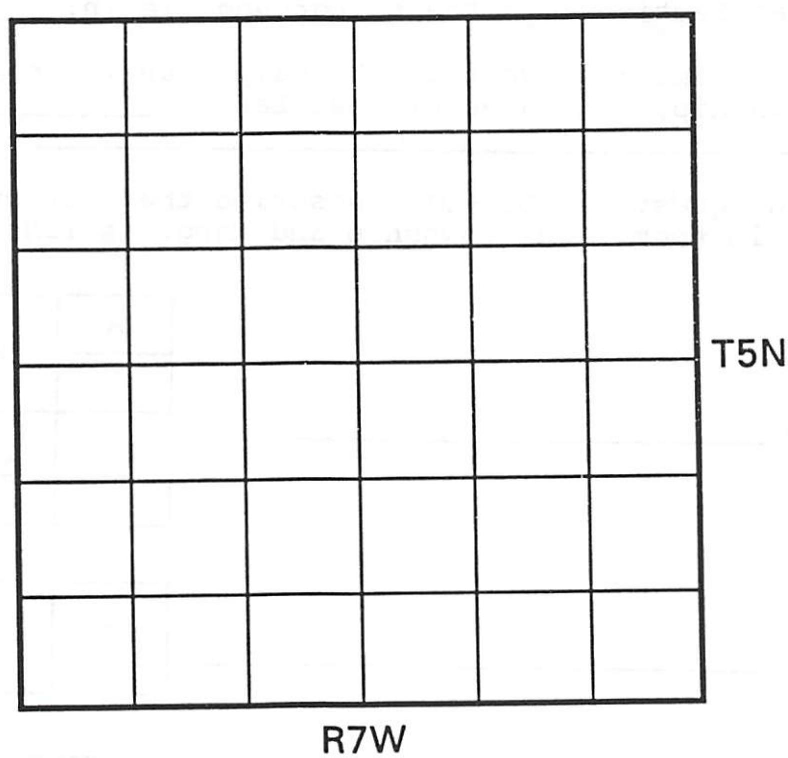
School solutions are available at the end of Unit 1.

Q1: In which direction (East-West or North-South) do Baselines pass through initial points? ______________________.

Q2: Define Principal Meridian: ______________________
____
______________________.

Q3: The lines that parallel the Baseline at 6 mile intervals are called ______________ lines.

Q4: The lines that parallel the Principal Meridian at 6 mile intervals are called ______________ lines.



Q5: The area inside the above large square is ______________ square miles.

Use the large square on the last page to answer questions Q6-Q8.

Q6: This square is called a ________________.

Q7: The small squares are called ________________.

Q8: Each small square contains __________ acres. Number the small squares in accordance with the Rectangular System of Survey.

Use the Cajon quad to answer questions Q9 through Q11.

At the bottom margin of the Cajon quad, Highway 395-66 is shown as a double purple line. Follow this Highway north to the Cajon Campground.

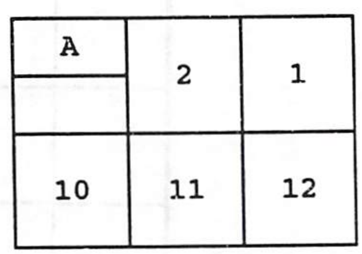
Q9: What Township and Range does the campground lie in? _______ _______.

Q10: What Section does the campground lie in?________________.

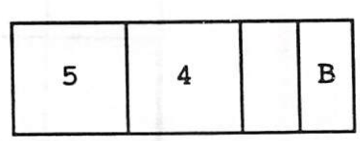
Q11: Lost Lake lies west of the campground. What is the Section, Township, and Range of Lost Lake?________________________ ____.

To answer questions Q12-Q14, describe the section divisions with letters in them. The Township and Range is T5N, R7W, MDB&M

Q12:A = ____________________________

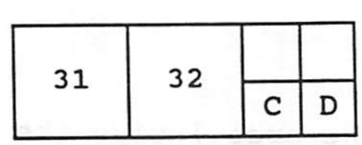


Q13:B = ____________________________



Q14:C = ____________________________

D = ____________________________

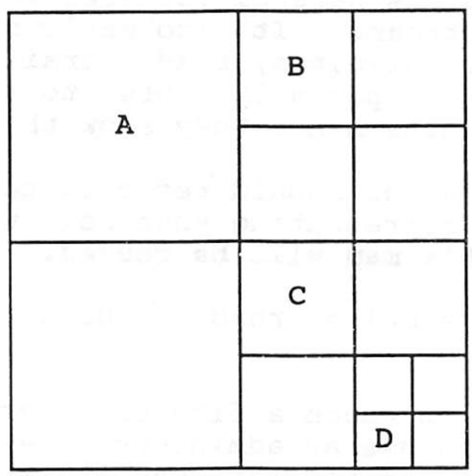


The following three questions refer to the diagram below; assume it represents one Section.

Q15:How many acres in area A?____________

Q16:How many acres in area B plus C?______

Q17:How many acres in area D?____________



LESSON 4 - Topographic Maps

Objectives:

1. Describe the meaning of the five basic map colors.
2. Interpret the purpose or meaning of USGS topographic map symbols.
3. Become familiar with the USGS topographic map index circular.
4. Use contour lines to identify topographic features.
5. Determine magnetic declination.
6. List and interpret information located in the margin of topographic maps.

A topographic map depicts natural features such as mountains, valleys, lakes, and streams. It also depicts principal human-made features such as buildings, roads, trails, powerlines, and wells. These maps are especially useful to field observers and search and rescue parties since they show the shape of the land.

Throughout this lesson you should refer to the Cajon topographic map and to topo maps representing your home unit. **Do not write on the Cajon quad; this map will be reused.**

Before starting this section, read the USGS booklet called "Topographic Maps".

If you were directed to reach a fire or other cross-country destination, you could use an administrative or road map (planimetric maps) to see how far away it is and to calculate how long it should take you to get near your destination. But if there was a 300 foot cliff between you and your destination, the administrative or road map would not show you the cliff and your calculations could be off by hours or days as you would be forced to detour.

Topographic maps are commonly used to navigate because they do show you the shape of the land and allow you to determine the best possible route, which is very often not a straight line. You can also calculate slope, predict the best possible control line locations, determine where your water sources are, and estimate how much elevational gain or loss you will experience.

A topographic map is printed on a flat piece of paper. It is, therefore, necessary to use symbols to represent relief (change in elevation). Hachures, shading, and contours are the most common methods of showing topographic relief.

Colors and Symbols
Symbols are used on maps to indicate objects on the ground. Topographic map symbols are usually printed in colors--each color identifying a class of features. Refer to the Cajon quad as we go through the following color and symbol definitions.

Colors

BLACK: most cultural or human-made features, land use boundaries, unpaved roads, and trails. Buildings are usually represented as black squares.

BLUE: water features such lakes, streams, rivers, or swamps. Permanent bodies of water are represented in solid blue and ephemeral streams, lakes, and ponds are represented in hachured blue (lakes and ponds) or dashed blue lines (streams and creeks).

GREEN: vegetated areas.

BROWN: all relief (vertical change) features, such as contour lines, cuts, and hills; and barren or rocky areas.

RED: main roads, urban areas (red tint), special features such as a campground, and Township, Range, and Section boundaries.

PURPLE: aerial photo generated revisions that have not been field checked.

Symbols

Take the "Topographic Maps" booklet published by the USGS and find symbols on the Cajon quad and on a topographic map for your home base. Be sure you know the symbols for all types of roads, for railroad tracks, a trail, houses, school, church, ranger station, powerlines, mines, marsh or swamp, and all bodies of water.

Complete the following exercises Using the Cajon quad.
School solutions are available at the end of the Unit.

Q1. Due east of Lost Lake, you will see this symbol: ----·----·----·

What does it represent?____.

Q2. In Section 8, T3N, R5W, there is a cistern. Write the legal description to the nearest quarter of the Quarter-section.

__________ ¼ of the __________ ¼ of Section ________ T _______ R _____
________________ Base and Meridian.

Q3. Assuming Section 8 is 640 acres, how many acres are in the parcel of land you just described? ___________________ acres.

Topographic Map Index Circular
The Topographic Map Index Circular contains a map of the state divided into quadrangles (remember that topographic maps are often referred to as quadrangles or quads). If you are working on a large incident, you can use the Index Circular to help you identify and order topographic maps outside the area of the incident, but into which the incident could move.

Using Contour Lines to Identify Terrain Features
Relief is the variation in elevation or height of geographic features such as ridges and valleys. Geographic features can be measured both vertically and horizontally. Vertical measures can be easily obtained from topographic maps, but horizontal distance can only be estimated. On the map, one acre of flat land is equal to one acre of hilly land (Figure 19). In reality, the hilly land contains more surface area.

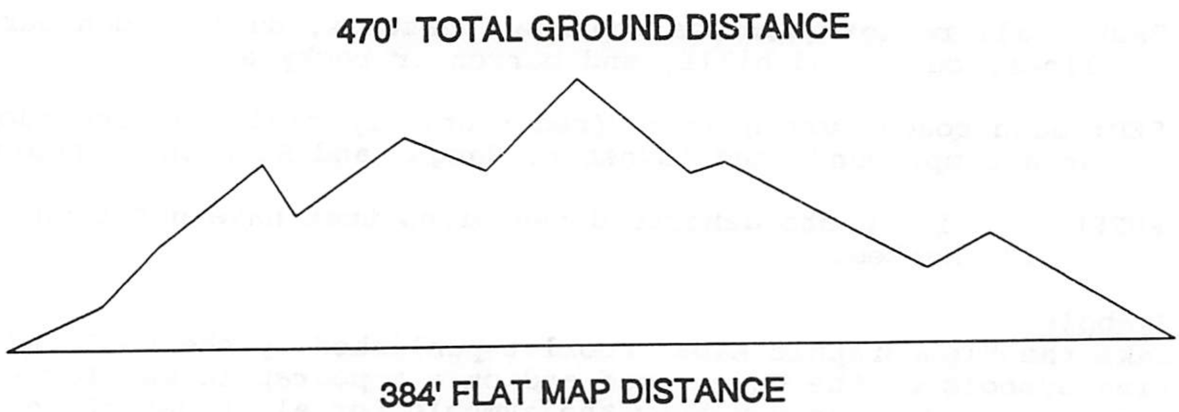


Figure 19: Surface Length Difference on Flat and Rough Land.

A topographic map is very useful to field observers in locating fires and in locating control lines on fires. The topographic map, commonly used for all types of orienteering, shows features such as elevation, grades, and shape or contour of land with its ridges, peaks, and drainages. These features are shown by means of contour lines. Each contour line represents a constant elevation on the ground surface. These lines may appear as more or less parallel or concentric (Figure 20). All points on the same contour are at the same elevation. Other features include survey lines (Section and Township), roads, trails, streams, lakes, and cities.

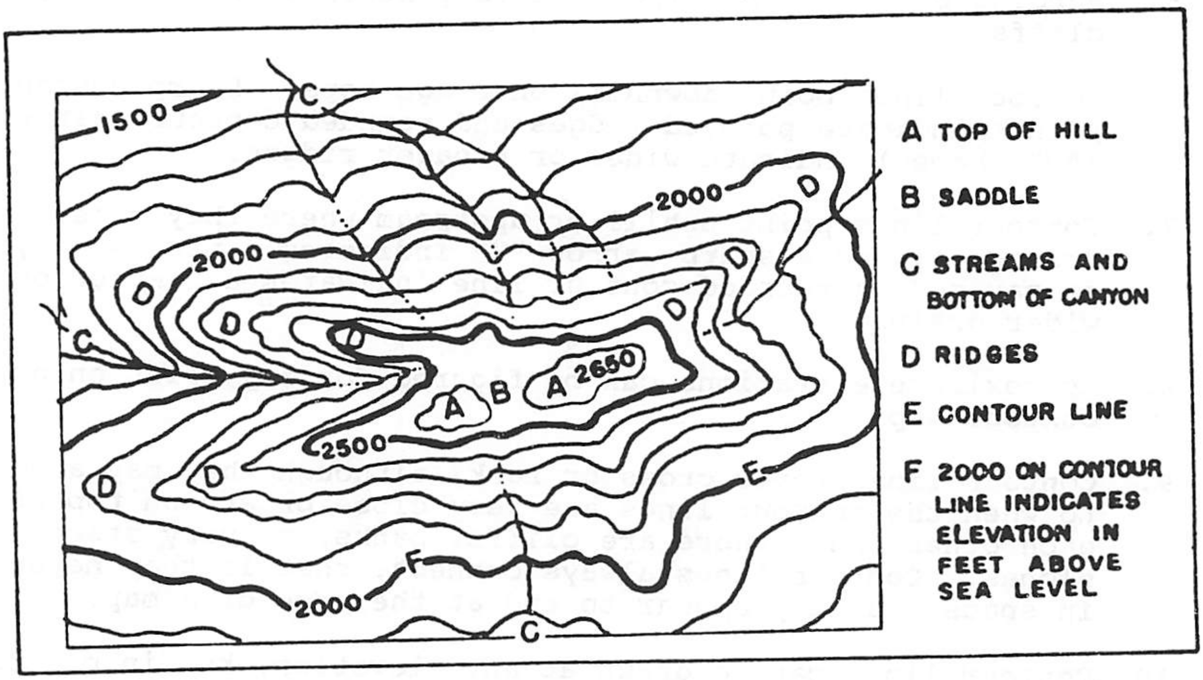


Figure 20: Sample of topographic (contour) map.

The steepness of the topography (relief) is shown by the contour interval, or difference in elevation between the contour lines. The elevation of certain contour lines is marked on all contour maps. Heavier or darker colored contour lines are called **index contours**; the thinner or lighter colored contour lines are called **intermediate contours**.

To use a topographic map you must be familiar with the following terms and features:

1. A contour line is an imaginary line representing a constant elevation on the ground surface.

2. Contour interval is the vertical distance or difference in elevation between contours.

3. Widely separated contour lines indicate gentle slopes.

4. Close contour lines indicate steep slopes.

5. Merging contour lines indicate very steep slopes, banks, or cliffs.

6. Contour lines point downhill on ridge tops. Sharp contour points indicate pointed ridges and rounded contour points ("U" shaped) indicate wider or broader ridges.

7. Contour lines point uphill or upstream where they cross drainages, and a sharp narrow "V" indicates a narrow canyon or ravine. A rounded contour line indicates a flatter or wider drainage.

8. Approximate elevations can be figured for any point on a contour map.

9. Contour lines never cross or fork, although they may appear to when the contour lines are very close or are on top of each other where there are cliffs, banks, or very steep slopes. Contour lines always connect, that is they never end in space, but may appear to end at the edge of a map.

10. Contour lines can be drawn at any elevation, but in practice they are drawn at intervals of 1, 5, 10, 20, 40, and 80 feet. Occasionally you may find a 25 foot contour interval.

11. To make the contour intervals easier to read, every fifth one is printed darker (index contour) and has the elevation marked periodically on the line.

To find the elevation of a point, locate the index contour nearest the point, then count the number of contour lines up or down from the point. Add or subtract the elevational difference represented by the number of contour intervals from the index contour. For example, if your contour interval is 20 feet and your index contour is 3 contour lines below your point (in this case index contour line is at 6,000 feet elevation), your point is at 6,060 feet (6,000 + (3 × 20)).

To calculate the difference in elevation between two points, first find the elevation of each point, then subtract the lower elevation from the higher; i.e. 5,600 ft - 4,800 ft = 800 ft.

To determine which direction is uphill or downhill from your point, look at the nearest index contour in the direction of interest; if the index contour interval is higher than your starting point you will be going uphill, if it is lower you will be going downhill.

Visualizing Landscapes
On the next page you will find a contour lines interpretation sheet (Figure 22). On the lower-right quarter of this sheet is a vertical representation of a land feature using contour lines. Study this diagram and then draw a profile (sideview) of the land from point "a" to point "b" on the diagram below (Figure 21). Draw the profile in the space provided with elevation lines marked in 100 ft increments. Hint: the elevation rises from the 100 ft contour line. After completing this exercise examine the school solution at the end of this unit.

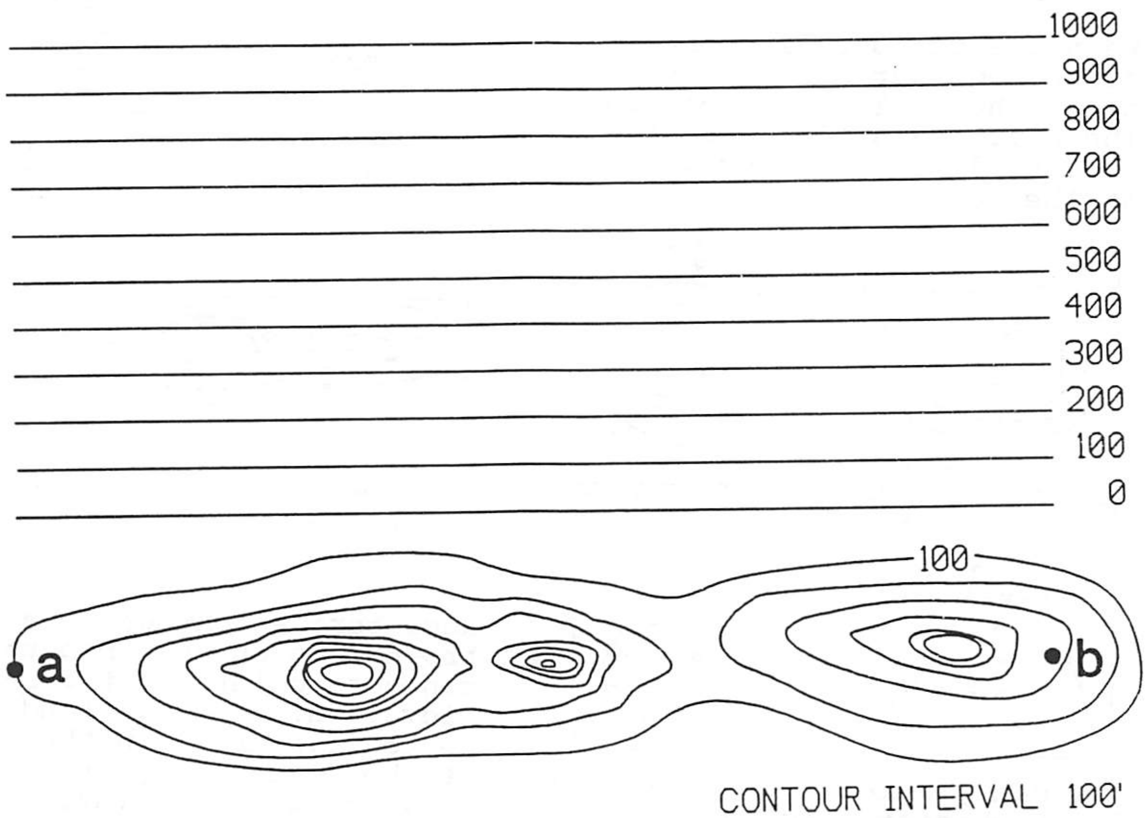
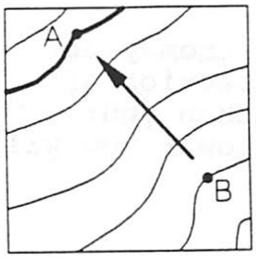


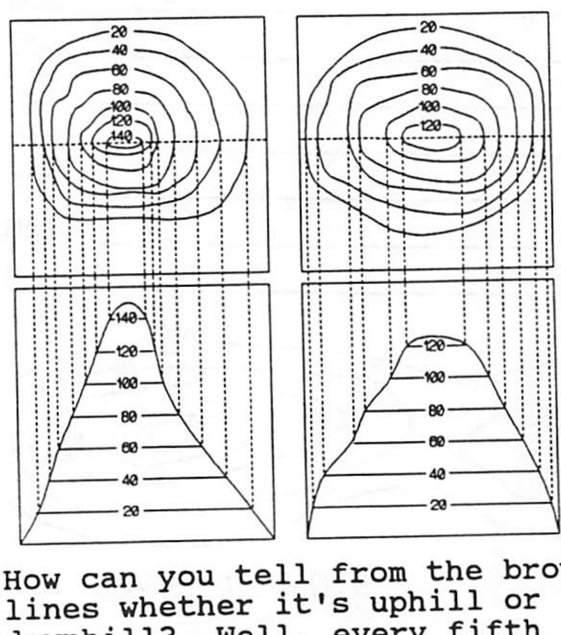
Figure 21: Relation Between Contour Map and Profile (**An Exercise**).

Figure 22: Interpreting Contour Lines

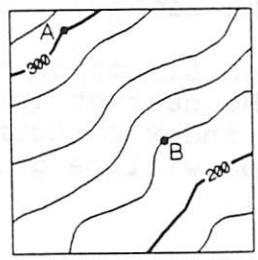


The brown lines on the map are called CONTOUR lines. Each line shows the height above sea level. Contour lines never cross one another. Printed at the bottom of the map is the CONTOUR INTERVAL, which is the difference in height (elevation) between one brown line and the next. On a map with a scale of 1:50,000 contour interval is usually 20 feet. This would make point 'A' 80 feet higher or lower than point 'B'.

When the contour lines are close together at the top of a hill, the hilltop is pointed. The hilltop is flat when the contour lines are widely spaced at the top.

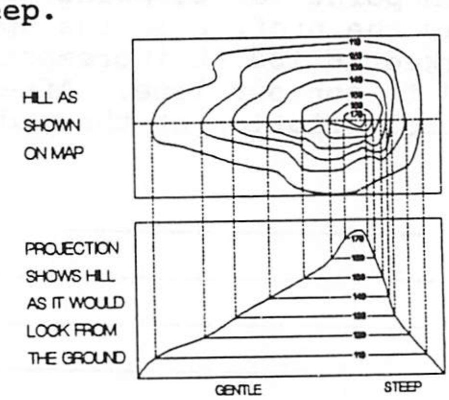


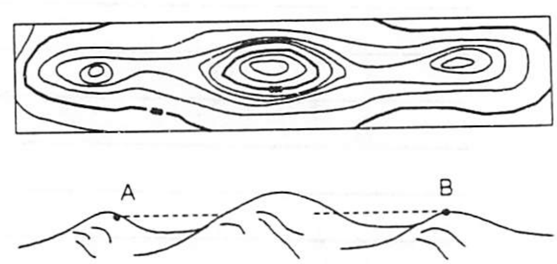
How can you tell from the brown lines whether it's uphill or downhill? Well, every fifth line is heavier than the rest and has a number that gives its elevation. If the contour interval is 20 feet, point 'A'



is 80 feet higher than point 'B'. Also, if you know the ground distance between 'A' and 'B', you could get an idea of how steep the slope was.

Contour lines widely spaced show a gentle slope. When they are close together the slope is steep.





Remember: A contour line is a brown line on your map that connects points of the same elevation. You can find the contour interval in the margin at the bottom of your map. The heavy brown lines (every fifth one) have the elevation printed on them. You can tell from looking at your map what the slopes, hills, and valleys will look like on the ground.

Topographic Map Directions; or How to Find True and Magnetic North

A quick glance at a map will show you the relative direction in which any point lies from any other point. But when you want to find the actual direction between two points as related to north you must know where north is oriented on your map.

In general, north is at the top on a topographic map that is oriented face up with the words right-side-up; south is at the bottom, west is to the left margin, and the right margin is east. To be sure of your topographic map's orientation look at the bottom margin.

Below, you will find a diagram (Figure 23) of an angle with the vertical leg indicated as **true north** and the other leg indicated as **magnetic north.** The angle (in degrees) between these two legs is called the **magnetic declination** (16° in this example). The magnetic declination must be noted and used to adjust your compass for field work (Unit 3).

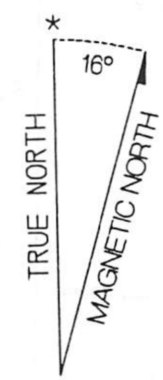


Figure 23: The declination diagram in the bottom margin of the map indicates the angle between the true north and the magnetic north direction of the map area.

Information Located in the Map Margin

Locate the following information in the margin of a topographic map:

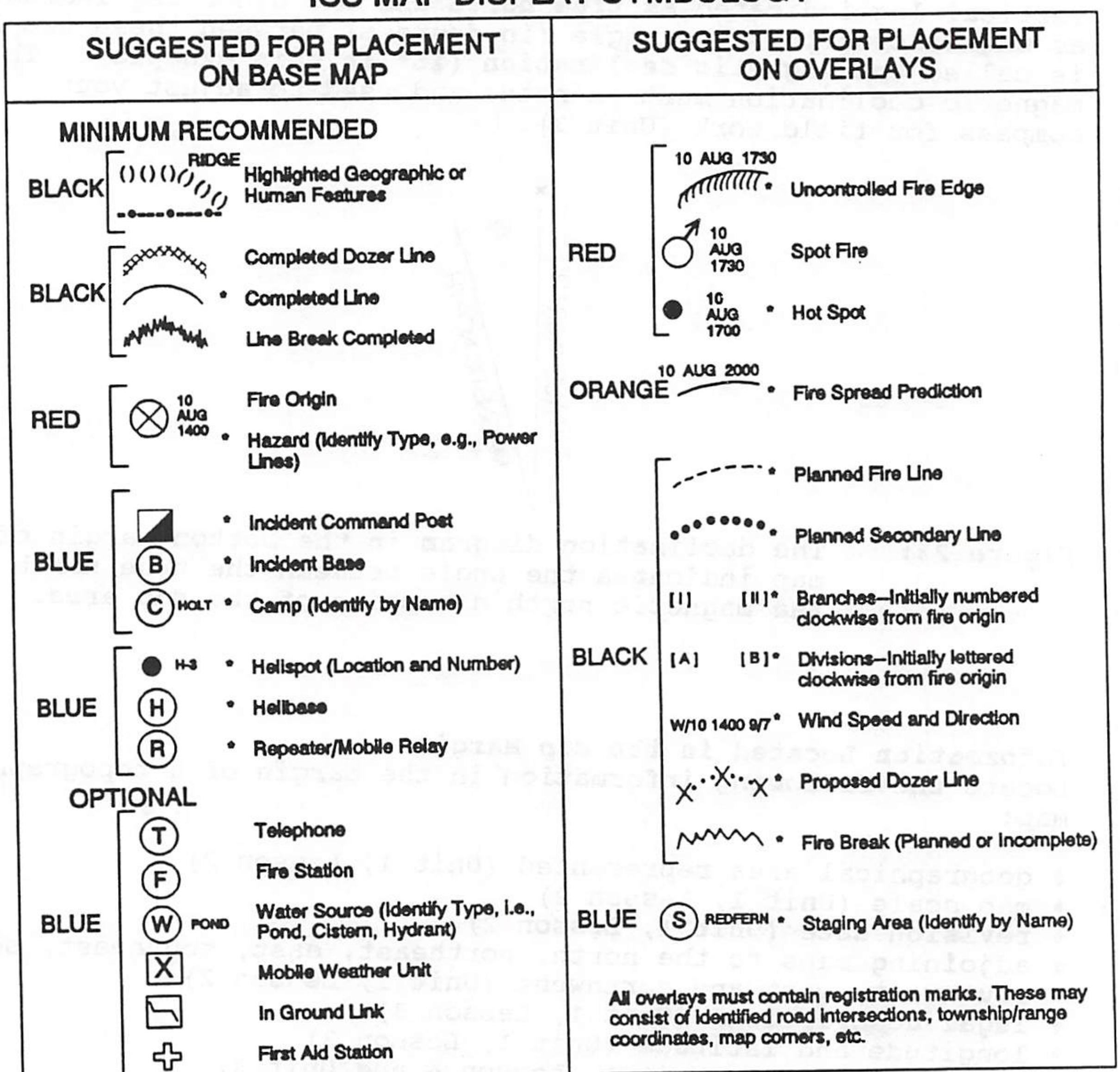
- geographical area represented (Unit 1, Lesson 2)
- map scale (Unit 1, Lesson 2)
- revision date (Unit 1, Lesson 2)
- adjoining maps to the north, northeast, east, southeast, south, southwest, west and northwest (Unit 1, Lesson 2)
- legal descriptions (Unit 1, Lesson 3)
- longitude and latitude (Unit 1, Lesson 3)
- contour interval (Unit 1, Lesson 4 and Unit 3)
- magnetic declination (Unit 1, Lesson 4 and Unit 3)

LESSON 5 - ICS Display Symbols

Objective: 1. Determine the color and pattern of symbols used to display field information using the Incident Command System.

Most commonly used maps and map symbols are approved and adopted by the U.S. Board of Surveys and Maps. However, some maps and mapping information systems, such as the Incident Command System (ICS) use a specific set of symbols, not commonly used by the public, to display information. For this course you must be able to interpret and draft maps with the ICS map display symbology presented below.

ICS MAP DISPLAY SYMBOLOGY



* To be used on Incident Briefing and Action Plan Maps (No Color)

Identify the ICS Display Symbols below:

Q1: ◪ ______________________________

Q2: Ⓑ ______________________________

Q3: ♂ ______________________________ This symbol is displayed with the ______ & ______.

Q4: ⊗ ______________________________ This symbol is displayed with the ______ & ______.

Q5:  ______________________________ This symbol is displayed with the ______ & ______.

Q6: (A) ______________________________

Q7: [IV] ______________________________

Q8: Ⓢ ______________________________

Q9: Ⓦ ______________________________

Solutions to Exercises in Unit 1

System of Land Description in the United States:

Q1: East-West; Q2: A north-south line which passes through an initial point; Q3: Township; Q4: range; Q5: 36 mi^2; Q6: Township; Q7: Sections; Q8: 640 acres and diagram below.

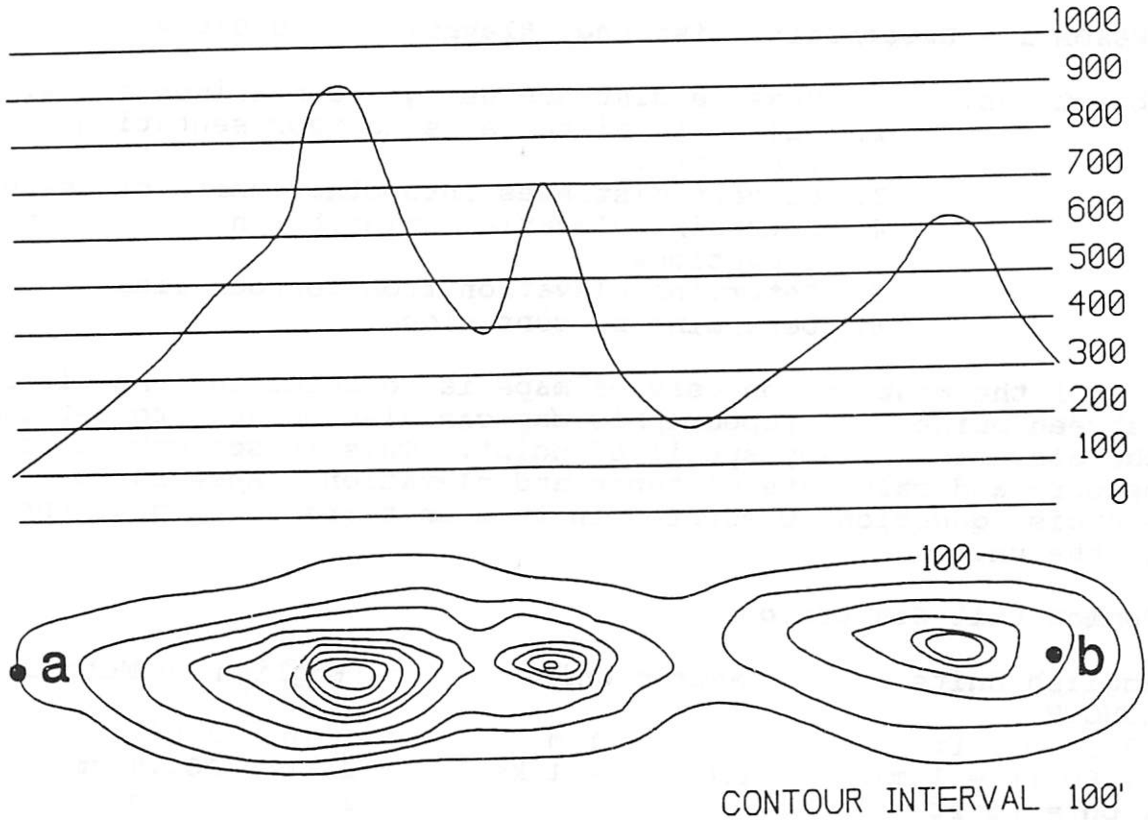
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

T5N

R7W

Q9: T2N, R5W; Q10: 7; Q11: Section 12, T2N, R6W; Q12: A = N½, Sec 3, T5N, R7W, MDB&M; Q13: B = E½, Sec 3, T5N, R7W, MDB&M; Q14: C = SW¼, Sec 33, T5N, R7W, MDB&M; D = SE¼, Sec 33, T5N, R7W, MDB&M; Q15: 160 acres; Q16: 40 acres; Q17: 10 acres

Visualizing Landscapes:



Topographic Map Symbols:

Q1: power transmission line; Q2: SW¼, SE¼, Sec. 8, T3N, R5W, San Bernardino BM; Q3: 40 acres.

ICS Display Symbols:

Q1: ICP; Q2: base; Q3: spot fire, time, date; Q4: origin, time, date; Q5: uncontrolled perimeter, time, date; Q6: division boundary; Q7: branch boundary; Q8: staging area; Q9: water source

UNIT 2
MAP CALCULATIONS

LESSON 1 - Determining Distance, Elevation, and Slope

Objectives:
1. Measure distance using a comparison scale.
2. Calculate distance using representative fractions.
3. Convert distances into other units of measure.
4. Determine elevation using bench mark or spot elevations.
5. Determine elevation from contour lines.
6. Determine percent slope.

One of the most common uses of maps is to determine the distance between points. A topographic map can also be used to determine the elevation of any specified point. This lesson covers how to measure and calculate distance and elevation. Answers to exercise questions presented in this unit are located at the end of the unit.

Common Unit Conversions

English Units	Metric Units	English to Metric
LENGTH		
12 in = 1 ft	10 cm = 1 m	1 in = 2.54 cm
5,280 ft = 1 mi	1,000 m = 1 km	1 ft = 30.48 cm
1 ch = 66 ft		1 ft = 0.305 m
80 ch = 1 mi		1 yd = 0.91 m
AREA		
1 ac = 10 ch^2	1 ha = 10,000 m^2	1 ac = .402 ha
1 ac = 43,560 ft^2		2.49 ac = 1 ha
1 ac = 208 ft × 208 ft		
1 ac = 3.16 ch × 3.16 ch		
1 mi^2 = 640 ac		
1 mi^2 = 1 section		

<u>Abbreviations Legend</u>

in = inch
ft = feet
yd = yard
ch = chain
mi = mile
ac = acre
cm = centimeter
m = meter
km = kilometer
ha = hectare

Measuring Distance Using a Comparison Scale
The comparison scale is a direct representation of distance between a map and the ground. A graphic or **comparison scale** compares inches to miles (or like scale figures). Usually comparison scales are printed on the map and show you that so many inches equals so many feet, yards, chains, or miles on the ground (Figure 24); or so many millimeters equals so many meters or kilometers on the ground.

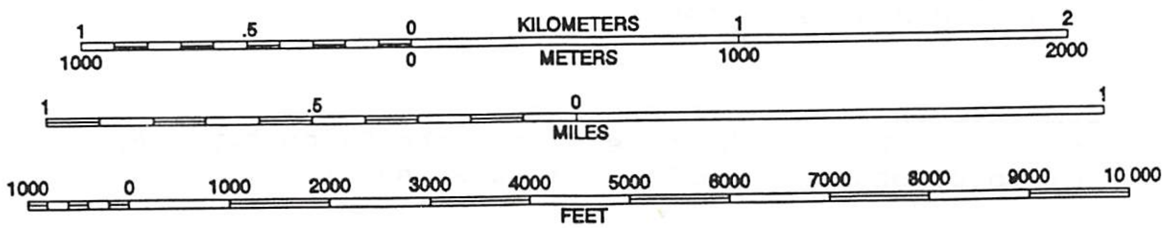


Figure 24: Example Comparison Scale.

Exercises
To complete the following exercises refer to the "Common Unit Conversion" table on the last page and the Cajon topographic map. School solutions are available at the end of this Unit.

Q1: Using the Cajon quad determine the distance in feet between spot elevation 4927 in the SW ¼ of Section 9, T2N, R5W and spot elevation 5461 in NW ¼ of Section 15, T2N, R5W:________.

Q2: How far is it in miles? ____________________________________.

A road passes through spot elevation 4927 and goes to spot elevation 5461. What is the length of the road in feet and miles between these points?

Q3: How many feet?___________. Q4: How many miles?_____________.

Hint: Use a piece of paper and put one corner at 4927. Lay the edge of the paper along the road. Where the road leaves the edge of the paper, place your pencil point on the paper then pivot the paper until the road is lined up again. Keep repeating this process until you reach elevation 5461. Compare the distance from your final mark to the starting corner of the paper with the comparison scale.

Measuring Distance Using a Representative Fraction
A representative fraction (RF) is different from a comparison scale in that the distance is related in LIKE UNITS. For example, the RF on a 7-½ minute topographic map is 1:24,000; 1 map inch equals 24,000 inches on the ground.

The distance on a map can be measured in inches with a ruler and then converted by multiplying the measured value by the RF. This will give you the on-the-ground distance in inches, which if divided by 12 (12 inches equals 1 foot) will give you the horizontal distance in feet.

Exercises
To complete the following exercises refer to the "Common Unit Conversion" table on the page 37 and the Cajon topographic map. School solutions are available at the end of this Unit.

You have measured the distance between two points on the Cajon quad as 4 inches. Using the quad RF, calculate:

Q1: How many on-ground inches are between the two points?________.

Q2: How many feet are between the two points?__________________.

The Cajon quad depicts an area 18-¾ inches wide.

Q3: How many miles does this represent?_________________________.

Determine Elevation from a Topographic Map
Elevation can be determined by using spot elevations and bench marks. Spot elevations can be shown as an "X" with the elevation designated. Bench marks are exact elevations that have been permanently marked on the ground and recorded on the map. Bench marks can be shown on maps as a triangle with a dot in the center, or as an "X" followed by the elevation. The letters "BM" or "VABM" (vertical angle bench mark) usually precede the symbol and elevation.

Elevation can also be determined by reading contour lines. First, the distance between contour intervals must be determined by reading the map legend, or by calculating the difference between index contours (the darker contour lines) and dividing by the number of intervening (intermediate) contour lines. For example, an index contour reads 5,800 and the next index contour reads 6,200. The difference between these index contours is 400 ft (6,200 - 5,800). On most maps, contour intervals come in sets of five with an index contour as number one and four intermediate contour lines before the next index contour. To calculate the elevational difference between contour intervals in this example (no legend available), divide 400 by 5 to get 80 foot contour intervals; this means there is 80 feet of elevational gain or loss between each contour interval.

To determine the elevation of an intermediate contour line or point, simply count the number of intermediate contour lines to an index contour where the elevation is known. Multiply the number of lines by the contour interval previously determined and add or subtract this value from the known elevation, depending upon whether the intermediate contour line or point is above or below the known index contour.

If you wish to determine the elevation between contour lines, interpolate the difference. For example, the contour interval is 40 ft and your point is one-half way between intervals, the half way point would be 20 feet.

Exercises
To complete the following exercises use the Cajon topographic map. School solutions are available at the end of this Unit.

Q1: The contour interval of this map is ______________________.

Q2: The distance between index contours is how many feet? ______.

Q3: What is the elevation of Lost Lake?______________________.

Q4: In the NW ¼ of Section 17, T2N, R5W, what is the elevation of the X labeled "Prospect"?______________________.

Q5: Is the Prospect on a ridge or in a draw?______________________.

Q6: If you are standing at the corner of Sections 8, 9, 16, and 17 of T3N, R5W and walked due south 80 chains, what would the elevation be? ______________________.

Calculating Slope from a Map

Slope is an important input variable for predicting fire behavior. Fire spreads faster upslope than downslope or on level ground, even if wind conditions are constant. In the presence of slope, the flame tilts toward the upslope fuel bed, preheating these fuels which then ignite more rapidly.

Slope can be determined in several ways in the field (discussed in detail in Unit 3). Slope can also be calculated from a topographic map. A number of slope calculation aids are available in the form of tables (that show the relationship between map scale and contour interval (Figure 25)); contour overlays (Figure 26 - 2 pages) and slope indicator overlays or templates (Figure 27). (Copy Figures 26 and 27 onto clear transparencies to create overlays.) Use of slope calculation aids is limited by map scale and contour intervals; you must, also, carry them with you. These aids are designed for USGS 7-½ minute and 15 minute quadrangles.

The most common method of calculating slope (and the method used in this course) is to find the change in elevation and divide it by the change in horizontal distance, then multiply this value by 100 to get percent. The key to remember is the **"rise over the run"** multiplied by 100.

Formula: Slope percent = $\dfrac{\text{rise in elevation}}{\text{horizontal distance}} \times 100$

Example: Using Map #3, page 46, determine the slope between points A and B.

Step 1: Determine the rise (there are two methods of determining elevational change):

<u>Method 1</u>: Rise = contour interval × # of contours.

In this case count the number of contour lines starting at point A and ending at point B. Point A is zero; point B is 5. There are 5 contour lines. Each contour line represents 20 feet in elevation.

Rise = 20 ft contour intervals × 5 contours = 100 ft

<u>Method 2</u>: Rise = difference in elevation between two points.

Point B lies at 5100 ft and Point A lies at 5000 ft.

Rise = 5100 - 5000 = 100 ft

Step 2: Determine the run (horizontal distance):

Using a ruler measure the distance in inches between points A and B, which in Map #3 (page 46) is 6/10 inches. Since we need to determine a unitless value for slope, we must convert inches to feet so that the units in the formula will cancel. To convert 6/10 inches into feet look at the map scale. In this case 1 inch equals 2000 ft.

Run = 6/10 inches × 2000 feet/inch = 1200 feet

Step 3: Calculate percent slope:

$$\text{percent slope} = \frac{\text{rise}}{\text{run}} \times 100 = \frac{100 \text{ ft}}{1200 \text{ ft}} \times 100 = 8\%$$

SLOPE CONVERSION[1]

MAP SCALE INCH/MILE	CONTOUR INTERVAL 20FT	40FT	80FT	100FT
1	--	0.8%	1.5%	1.9%
2	0.8%	1.5%	3%	3.8%
2.64	1.0%	2.0%	4.0%	5.0%
4	1.5%	3.0%	6.0%	7.6%
8	3.0%	6.0%	12.0%	15.0%

[1] Slope value for one contour per inch on map. To estimate slope percent, count contours over one inch of map, then multiply this value by the slope conversion from the table. For example: there are 15 contours on one inch on a map with a scale 2.64 miles per inch and a contour interval of 20 feet.

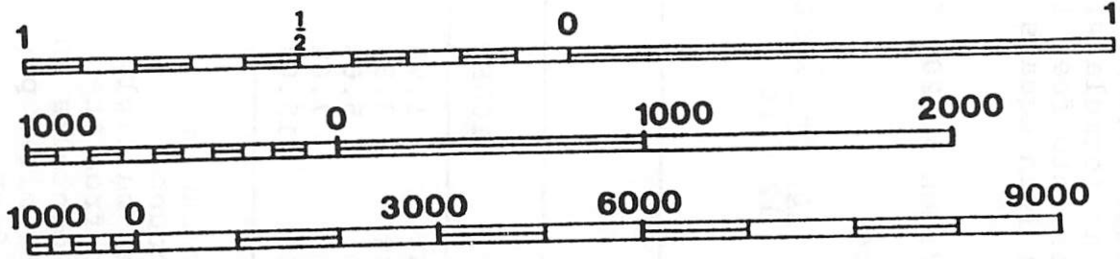
SLOPE = 15 × 1.0% = 15%

Figure 25: Slope Conversion Table.

Figure 26: **CONTOUR OVERLAY (USES 7½ MINUTE QUAD.)**

DISTANCE SCALES

MILES: YARDS: FEET:



SLOPE

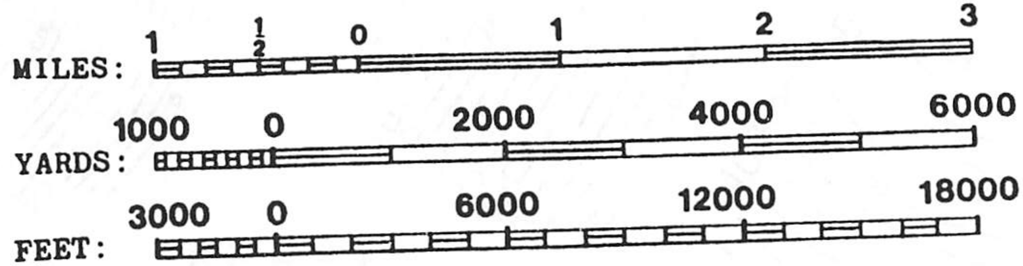
(1000 FT. I.D.)

1. PLACE CIRCLE OVER AREA.
2. COUNT CONTOUR LINES WITHIN CIRCLE (DO NOT COUNT ACROSS RIDGES OR CREEKS).
3. IN TABLE BELOW FIND NUMBER OF CONTOUR LINES COUNTED (NEXT TO PROPER CONTOUR INTERVAL FOR YOUR QUAD) AND READ % SLOPE AT BOTTOM.

		NUMBER OF CONTOUR LINES COUNTED						
CONTOUR INTERVAL	20	12	20	28	30	32	36	40
	40	6	10	14	15	16	18	19
	50	5	8	11	12	13	14	15
	80	3	5	7	8	8	9	10
PERCENT SLOPE		25	40	55	60	65	70	75

Figure 26: CONTOUR OVERLAY (USES 15 MINUTE QUAD.)

DISTANCE SCALES



SLOPE

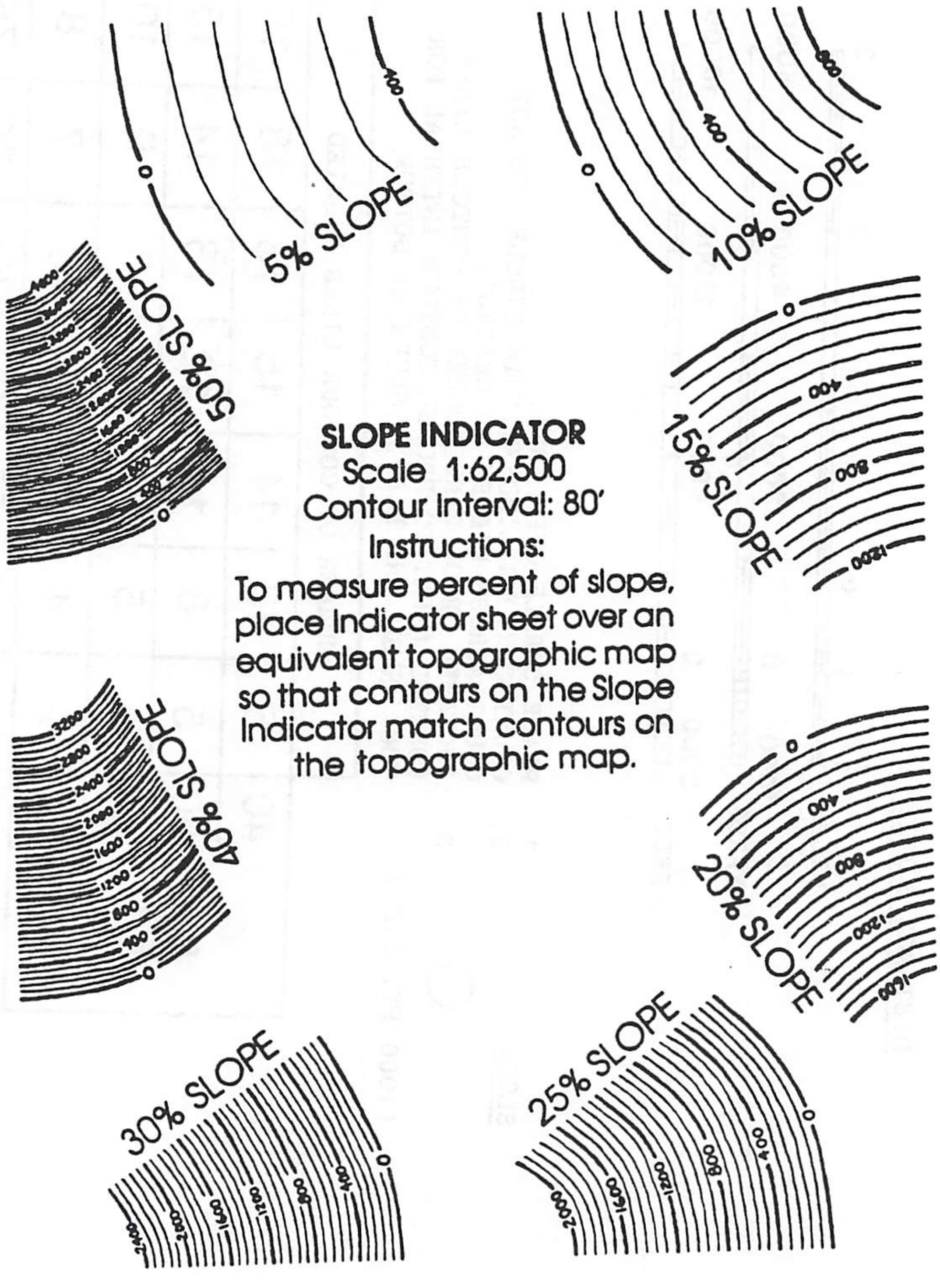
(1000 FT. I.D.)

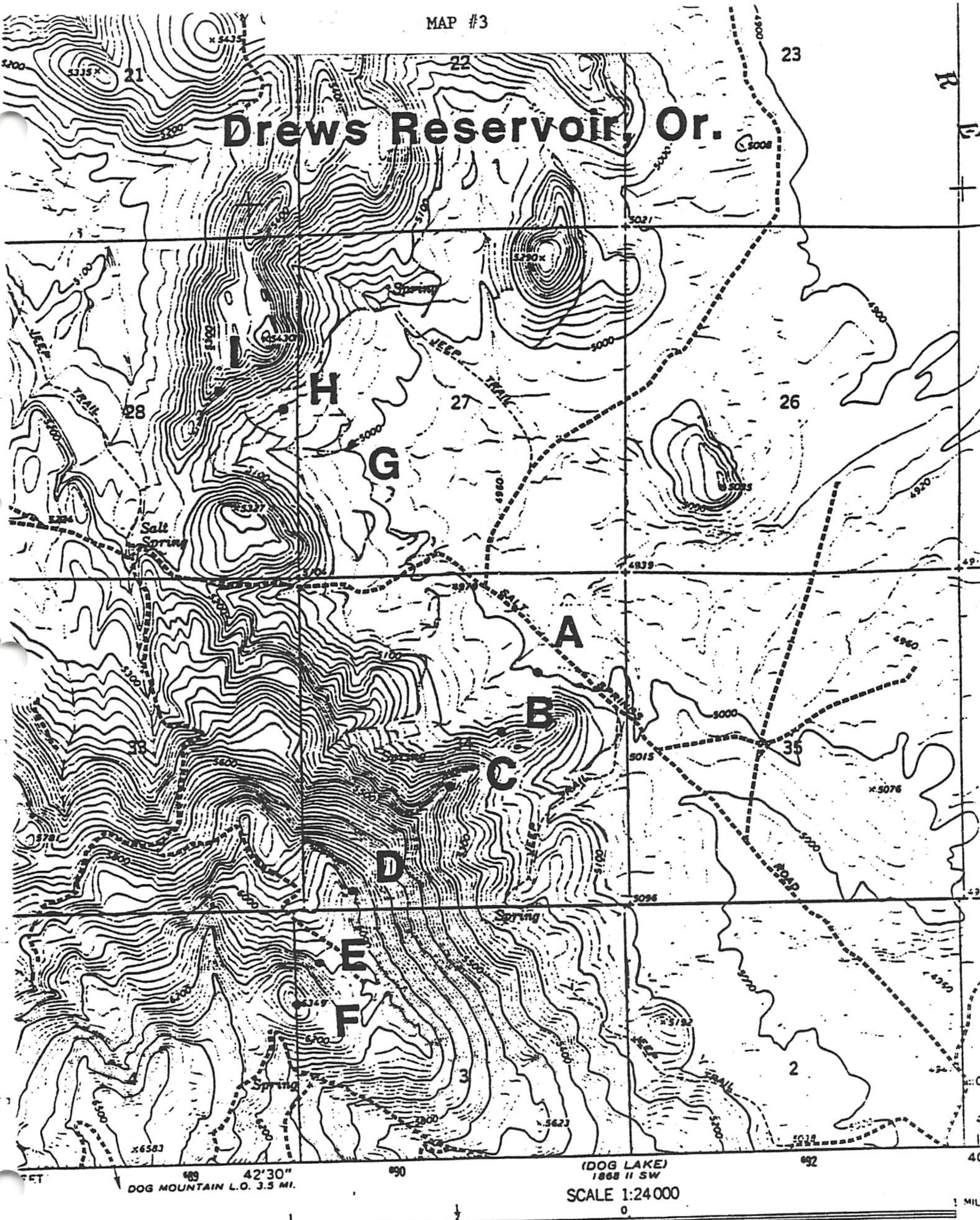
1. PLACE CIRCLE OVER AREA.
2. COUNT CONTOUR LINES WITHIN CIRCLE (DO NOT COUNT ACROSS RIDGES OR CREEKS).
3. IN TABLE BELOW FIND NUMBER OF CONTOUR LINES COUNTED (NEXT TO PROPER CONTOUR INTERVAL FOR YOUR QUAD) AND READ % SLOPE AT BOTTOM.

		NUMBER OF CONTOUR LINES COUNTED						
CONTOUR INTERVAL	40	6	10	14	15	16	18	19
	50	5	8	11	12	13	14	15
	80	3	5	7	8	8	9	10
	100	2	4	5	6	6	7	8
PERCENT SLOPE		25	40	55	60	65	70	75

Figure 27

SLOPE INDICATOR OVERLAY




Drews Reservoir, Or.
A
B
C
D
E
F
G
H
I
Salt Spring
Spring
JEEP TRAIL
SALT SPRINGS ROAD
21
22
23
26
27
28
33
34
35
2
3
(DOG LAKE)
1868 II SW
DOG MOUNTAIN L.O. 3.5 MI.
42'30"
689
690
692
SCALE 1:24000
1 MILE
7000 FEET
1 KILOMETER
GN
MN
1°33'
28 MILS
20°
356 MILS
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Slope Calculations Exercises - Part 1

All questions refer to the map on the next page (Map #4). School Solutions are available at the end of Unit 2.

Q1: The contour interval is __________ feet.

Q2: The Map Scale is: 1" = __________ feet.

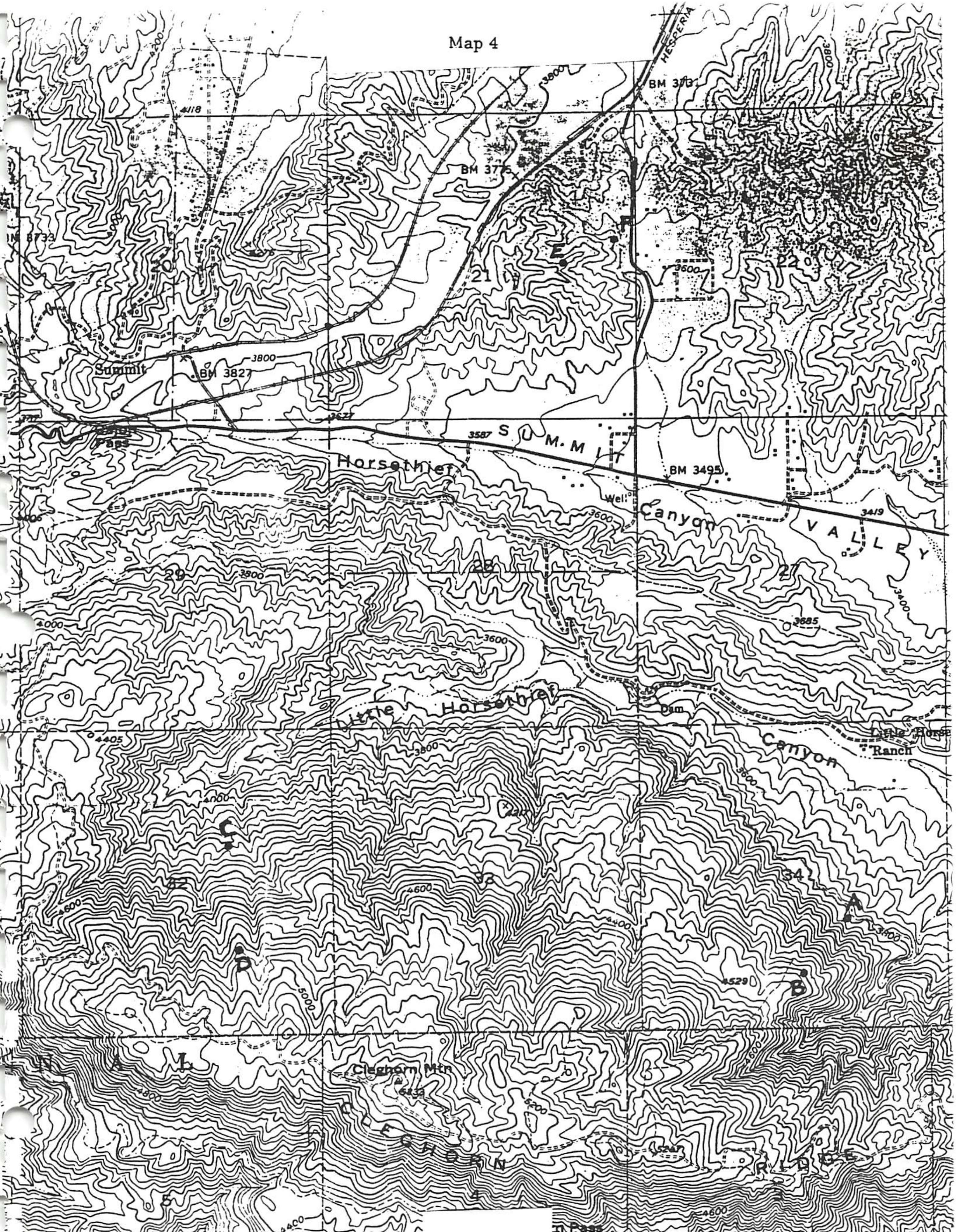
__________ inches = 1 mile

(Hint: G-H is one side of a normal section)

Q3: Compute the percent slope from:

Points	Elevation Change	Distance	% Slope
A to B	________________	__________	__________
C to D	________________	__________	__________
E to F	________________	__________	__________

Map 4


HESPERIA
BM 3776
Summit
BM 3827
Pass
SUMMIT
VALLEY
Horsethief
BM 3495
Well
Canyon
Little Horsethief
Canyon
Dam
Ranch
Cleghorn Mtn
CLEGHORN
RIDGE
A
B
C
D
E
F
20
21
22
27
28
29
32
33
34
5
4
3

Slope Calculations Exercises - Part 2

All questions refer to the map on page 46 (Map #3--Drews Reservoir). School Solutions are available at the end of Unit 2.

Points A, B, C, and D are on contour lines.

Q1: What are the contour intervals on the Drews Reservoir 7.5 minute topographic map?

____

Q2: The map scale is __________ inches equal one mile.

Q3: Give the elevations of the following points:

Point A __________ feet.

Point B __________ feet.

Point C __________ feet.

Point D __________ feet.

Q4: Give the distance between the following points and the percent slope.

A to B = __________ feet __________ % slope

B to C = __________ feet __________ % slope

Slope Calculations Exercises - Part 3

Use the Cajon quad to complete the following exercises. School Solutions are available at the end of Unit 2.

Remember when you calculated the distance between elevations 4927 and 5461?

Q1: Now determine the percent slope between these points _______.

You get into your vehicle and drive north on I-15 from San Bernardino until you reach the section line between Sections 18 and 7 of T2N, R5W. You park your vehicle and follow the section line east on foot.

Q2: What is the steepest percent slope you will encounter within 2,000 meters of I-15?__________________.

LESSON 2 - Determining Area

Objectives:
1. Be able to mathematically calculate area from a map.
2. Determine area using dot and acreage grid overlays.
3. Estimate area using Sections and Townships.

When evaluating the progress of a fire it is important to calculate the fire's size or area. When you arrive at an incident, one of your first duties will probably be to estimate acreage. Practice and a knowledge of acreage estimation techniques will make this important task much easier. In this lesson, we will look at means of calculating or estimating area from a topographic map.

In this course, area will usually be expressed as acres, but area may also be expressed in square miles, square feet, or any other unit of linear measurement, squared.

Mathematically Determining Area
Area is two dimensional, that is it has boundaries within a plane. Area is frequently determined by a length and a width which are both linear measures that when multiplied give you a value squared. One acre represents a space that can be defined as being 208 feet long and 208 feet wide, or 43,560 ft^2; one acre can also be defined as 10 ch^2 (remember "ch" means chain).

To mathematically determine an area, outline the perimeter and then calculate its size by measuring the length and a perpendicular width, and then multiply these two measurements. Most area calculations will require conversion of units, such as from map inches to on-the-ground feet and square feet to acres. On page 37 is a list of common unit conversions that will help you calculate area from a map.

Example

How many acres are there in a rectangular area that is 5 chains × 10 chains?

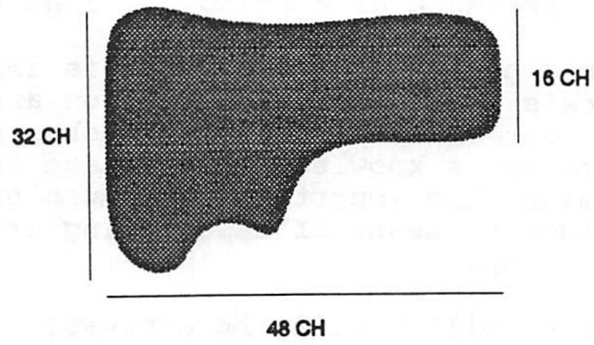
$$10 \text{ ch (length)} \times 5 \text{ ch (width)} = 50 \text{ ch}^2$$

$$50 \text{ ch}^2 \div 1 \text{ acre}/10 \text{ ch}^2 = 5 \text{ acres}$$

(Remember: 1 acre = 10 ch^2).

How to Determine the Area of an Irregular Shape
To compute an irregularly-shaped area, it is often necessary to take two or more measurements across the area to obtain an average length and an average width.

Example 1



How many acres are there in this area?

The area outlined above is 32 chains wide at one end and 16 chains wide at the other. The length is 48 chains. In this example the width is not constant, and therefore, an average width must be calculated to determine the area.

$$(32 \text{ ch} + 16 \text{ ch}) \div 2 = 48 \div 2 = 24 \text{ ch (average width)}$$

The area is: $24 \text{ ch (width)} \times 48 \text{ ch (length)} = 1152 \text{ ch}^2$

$$1152 \text{ ch}^2 \div 10 \text{ ch}^2/\text{acre} = 115.2 \text{ acres}$$

Example 2

How many acres would there be in the above area if the length was actually 5,500 ft and the left width was 2,500 feet and right side width was 1,100 feet?

$$(2{,}500 \text{ ft} + 1{,}100 \text{ ft}) \div 2 = 1{,}800 \text{ ft (average width)}$$

The area is: $1{,}800 \text{ ft} \times 5{,}500 \text{ ft} = 9{,}900{,}000 \text{ ft}^2$

$$9{,}900{,}000 \text{ ft}^2 \div 43{,}560 \text{ ft}^2/\text{acre} = 227.3 \text{ acres}$$

Determining Area Using Dot or Acreage Grids
Transparent overlays can be used to rapidly estimate acreage. First check your map scale; the grid overlay must be of the same scale or have a conversion chart or formula written on it. If the overlay and map are compatible, the overlay is laid over the area to be calculated and the user counts the number of dots or grids within the area. In addition to counting all dots that fall within the perimeter, count <u>every other</u> dot or grid (square) that falls on the perimeter. Multiply the number of dots by the conversion factor or formula written on the overlay.

<u>Using Dot Grids on Different Scale Maps</u>
A dot grid can be used on maps of a different scale, but a conversion factor must be determined by the user. To develop a conversion factor (acres per dot), count the number of dots in one section of your map. (Most topographic maps have Sections, Townships, and Ranges delineated.) Divide this number by 640 (there are 640 acres per Section).

For example, you count 400 dots in a section; 640 acres ÷ 400 dots = 1.6 acres/dot. This value is your conversion factor. A problem with this system is that many sections are irregularly shaped or are <u>not</u> 1 mi^2. Always look for the most perfectly square and regular-sized section for this process.

After determining your conversion factor, count the number of dots within the area of unknown size. Multiply the number of dots by the conversion factor to determine acres.

Example

You have counted 347 dots. The conversion factor previously determined is 1.6 acres/dot.

$$347 \text{ dots} \times 1.6 \text{ acres/dot} = 555 \text{ acres}$$

Estimating Area by Comparison
Quick estimations of area can be made by comparisons with an area known to the estimator. For example, a football field is one acre.

This estimation process can be extended to map areas. For example, use your knowledge of section (640 acres) and quarter-section (160 acres) size to estimate an unknown area. If the fire is entirely within a section it must be less then 640 acres. By comparison, and the process of elimination, relatively accurate and fast estimations of area can be made. Unit 1, Lesson 3 contains two maps (Maps #1 & #2) where fire size was estimated by comparison with section area.

Complete the Following Area Determination Exercises
School solutions are available at the end of Unit 2.

Use the Cajon quad for the following exercises.

Q1: This quad is 7.1 miles wide. How many square miles are depicted on this map?____________________________.

Q2: How many total acres?________________________.

Examine the E½ of Section 17, T3N, R5W. A black dashed-line road runs diagonally from the north section line to the south section line. Use chains to calculate the area east of this road bounded by the section lines.

Q3: What is the average width in chains of this area?____________.

Q4: The area is ________________ acres?

Examine the NW¼ of the SW¼ of Section 8, T2N, R5W. Locate spot elevation 4905. Now locate contour interval 4800.

Q5: The area inside this contour interval is ____________________.

Locate Cajon Junction on I-15. Follow Highway 138 northeast 2-½ miles to BM 3515. Turn right on the private road and follow it southwest back to I-15. From here, drive back to Cajon Junction. Use a dot or acreage grid (obtain from someone in your home base) to determine the acreage inside the route you just traveled.

Q6: There are __________________ acres.

About halfway up the Cajon quad on the right-hand margin is a black dash-dot-dash line that designates the National Forest boundary. Estimate the acreage of the area north of this boundary. Use sections, half-sections, and quarter-sections for your estimate.

Q7: The area is roughly ________________ acres.

Solutions to Unit 2 Exercises

Comparison Scale:

Q1: 6,200 feet; Q2: 1.2 miles; Q3: 8,200 feet; Q4: 1.5 miles

Representative Fraction:

Q1: 96,000 inches; Q2: 8,000 feet; Q3: 7.1 miles

Determining Elevation:

Q1: 40'; Q2: 200'; Q3: 2,780'; Q4: 3,500-3,520; Q5: ridge; Q6: 4,120 (you cross contour 4120 twice).

Calculating Percent Slope - Part 1:

Q1: 40'; Q2: 2,000'; Q3: A-B 600', 1,250', 48%; C-D - 640', 1,875', 34%; E-F 260', 1,000', 26%

Calculating Percent Slope - Part 2:

Q1: 20'; Q2: 2.64; Q3: 5,000', 5,100', 5,400', 6,000'; Q4: A-B 1,100 ft, 9% slope; B-C 1,200 ft, 25% slope

Calculating Percent Slope - Part 3:

Q1: 3.4%; Q2: 67%

Area Determination Exercises

Q1: 60.5 mi^2 (between 60.3 and 61.0 mi^2);
Q2: 38,720 $\pm$ ac; Q3: 14.4 ch; Q4: 100-120 ac;
Q5: 10-11 ac; Q6: 650-720 ac;
Q7: 9,600 (between 9,040 and 9,800 ac)

UNIT 3
OBSERVATION AND NAVIGATION AIDS

LESSON 1 - Equipment for Measuring Elevation, Slope, and Distance in the Field

Objectives:
1. Understand how to adjust an aneroid barometer (altimeter)--OPTIONAL.
2. Determine elevation with an aneroid barometer--OPTIONAL.
3. Determine slope using a clinometer.
4. Measure distance using an odometer.

How to Adjust and Use an Altimeter
The aneroid barometer (altimeter) is a convenient instrument for determining elevational change where a relatively low order of accuracy will suffice. It can be a valuable tool for mapping when distances are paced and 50 foot or greater contours intervals are used on the map. It can be especially useful for mapping and navigating at night. Because barometer readings respond to changing weather (atmospheric pressures) they are best used during periods of constant weather when you can tie into points of known elevation every 2 hours or less.

Locate an altimeter. Tap the glass lightly. The needle should move slightly each time as it returns to its original position. Read the instrument at points having known elevations; choose at least two points that are at least 50-100 ft higher or lower in elevation. Several repetitions of this process should establish how accurate the instrument is.

Read the instructions that accompany your altimeter. The following adjustments and recording technique should be applicable to most altimeters.

On the movable foot-scale set the known or assumed elevation of your location. As you travel over hilly terrain, read and record time of reading and successive elevations.

Observe the following precautions: 1) Gently handle the altimeter when the movable foot-scale is set. Record a reading opposite a graduation on the immovable scale (inches of pressure). This will allow you to detect accidental movement of the foot-scale. 2) Tap the glass gently before reading. Wait a few minutes to allow the needle to adjust to the new elevation. 3) Always hold the altimeter in the same position to read. 4) Take every opportunity to check the altimeter's accuracy at points of known elevation.

Determining Slope with a Suunto Clinometer
Obtain a clinometer graduated in degrees and percent. Ask for assistance on how to use it if you get confused by the following instructions.

Read the dial on the left side of the clinometer to determine how it is graduated, or look into the hole and tilt your head back so that the clinometer is 90° from its prior position. The inside scale units should be readable from this position. A degree scale is usually indicated by a "°" symbol and a percent scale is usually indicated by a "%" symbol.

Stand so that you are facing directly uphill or downhill. Keep both eyes open. Use one eye to read the scale inside the hole and the other eye to sight on an object that is about the same height above the ground as your eye level height. For example, if you are 5'5" tall, sight on something (ideally the eyes of another 5'5" tall person) that is 5' tall.

Read the appropriate scale and record your data in the proper units. A common mistake is to read the degree scale and record it as percent slope, or vice versa.

The Silva Ranger CL-15 compass has a built-in clinometer. This scale is only graduated in degrees. 45° = 100% slope; or 1° = (approximately) 2% slope. Read the instructions that accompany this compass on how to use the built-in clinometer.

Measuring Distance Using an Odometer
One of the most useful tools for mapping a large incident near roads is the odometer on a vehicle. The odometer measures miles traveled by the vehicle in one-tenth mile increments. The odometer may be used to estimate width and length for area estimations or it may be used to estimate the distance of a known location (such as base camp) to another location (fire).

LESSON 2 - Pacing

Objectives:

1. Be able to establish a pace distance on flat ground, and up and down steep slopes.

2. Calculate the distance between two points by pacing. The calculation must be within 5% of the measured distance.

One of the easiest methods of estimating distance is pacing. All that is required is that you know your pace over varying terrain.

A **pace** is actually two **steps** at normal stride. Since everyone's "normal stride" is different, everyone's pace is unique to them. A pace is the distance on level ground between the heel of one foot and the heel of the same foot where it next touches the ground while walking normally; that is, two normal steps.

Pacing to Measure Distance
Pacing is the measuring of horizontal distance on the earth's surface by counting steps of a known length. With practice a person can attain accuracy sufficient for most field measurements needed. To determine your pace requires practice.

Determining Your Pace
Because the length of pace varies with the individual, it is necessary for you to learn the length of your normal pace. In order to pace a given distance to an incident, you need to know how many paces you take to move a unit of distance such as 1 chain (66 ft) or 100 feet.

To determine the length of your pace, and how many paces you normally take to walk 1 chain or 100 feet, lay out a pre-measured 100 ft course on flat ground. (You may lay out a longer course (the longer the better) or walk back and forth on the same course).

Walk normally from one end of a 66 ft, 100 ft, or longer course, counting the paces as you go. Record the number of paces per distance traveled. Repeat this process until you can develop an average pace count for the unit distance. Divide this average by 1 chain or 100 ft depending on the distance paced to determine your pace length.

<u>Example</u>

Assume the measured course is three chains, or 198 feet (66 × 3). You walk this distance in 36 normal paces. Therefore, the pace is 36/3 or 12 paces per chain. Each pace is 198/36, or 5½ feet long.

Determining Your Pace on Sloping Ground
Steepness of slope affects pacing in two distinct ways. First, the natural length of step in walking or climbing up or down varies with the steepness of slope, so the number of paces per unit distance must change.

The second effect of slope is that land surveys are based on horizontal distances, not slope distances. In order to measure a given horizontal distance (for example: one chain) a person must travel more than one chain when walking on a slope. This is equally true whether going uphill or downhill. The difference between the horizontal distance and the slope distance (Figure 28) becomes increasingly pronounced as the steepness of the slope increases.

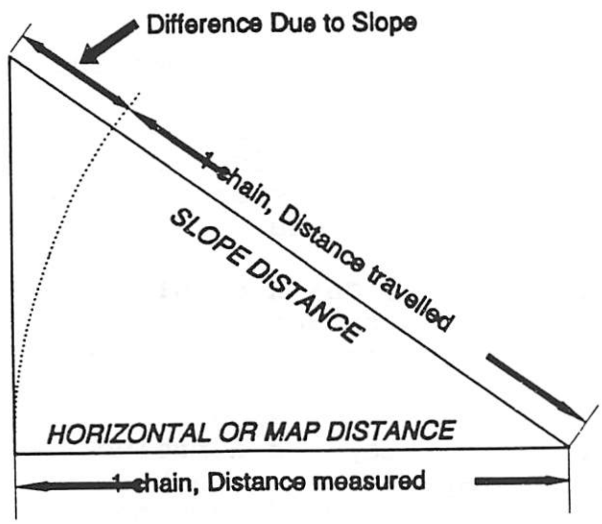


Figure 28: Difference Due to Slope.

When measuring distance to a fire or other location, a person may find several changes in slope. The distance traveled on the surface in measuring one mile is much greater than the horizontal distance. The allowance for slope (Figure 29) or any other factor is usually made as each pace is covered so that a single pace count always indicates the horizontal distance covered. In other words, if a person uses 12 paces to cover one chain on level ground, each pace counted should equal 1/12 chain horizontal distance measured regardless of slope or any other factor.

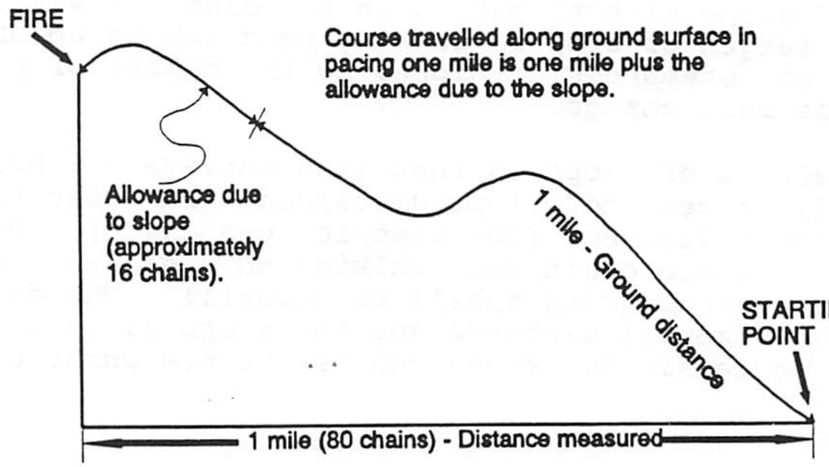


Figure 29: Allowance Needed Due to Slope.

The allowance for slope is applied continually as the pacing progresses. The allowance that is needed will vary with the steepness of slope. The extra steps taken to cover the additional distance traveled due to slope are not counted.

Determining Your Paces per Chain on Sloping Ground
Follow these instructions to determine how much to correct for horizontal distance when pacing on a slope.

Lay off a pre-measured horizontal distance (in this case we'll use chains) with a steel tape on a medium slope. This can be done by holding the tape level on each measurement and using a plumb bob on the downhill end of each measurement (takes two persons to set up the course). Mark both ends of the course. Using normal steps, pace upward on this course the number of paces needed to cover the three chains on the level. Pace the distance remaining to the end of the course. The latter is the amount which must be added to get level distance on a three chain distance traveling uphill. Divide this figure by three to get the amount for one chain. Divide the latter figure by the paces per chain to get the amount to add to each pace.

Example

You walk upslope 36 paces. There are 18 feet left to the end of course.

18 ft ÷ 3 ch = 6 feet per chain (addition per chain to get level distance)

6 ft/ch ÷ 12 paces/ch = ½ foot per pace (addition per pace to get level distance)

Repeat this process on the same course going downhill. Record all figures in a notebook. Use them until such skill in pacing has been acquired as to make frequent reference no longer necessary. On steeper slopes add more slope correction, and on gentler slopes reduce the slope correction allowance.

Adjusting Your Pace to Accurately Measure Distance on Slopes
In the prior discussion we gave you instructions on how to compensate your pace when your objective is to match map distance to distance traveled in steep terrain.

What if you are asked to determine the length of a fire's perimeter so that the overhead can calculate how many chains of fireline need to be cut? This fire has burned an area with many steep slopes. In this case, actual distance over rolling terrain must be determined. One chain on flat ground will have the same relative horizontal distance on a map, but will have a very different horizontal distance if measured on a slope. You must adjust your pace calculations <u>to measure actual distance on slopes</u>. For example, your pace may be 20 for 100 feet of horizontal distance on flat ground. This means that you take 40 steps per 100 feet. On a moderate upslope hike you may have to take 42 steps (21 paces) to travel one hundred feet.

On very steep slopes your pace usually shortens as the body tries to brace itself against the combined force of gravity and body weight. For example, on a very steep slope you may take 46 steps (23 paces) to move 100 feet.

Other Factors Affect Pacing
Human factors must be considered. A person's vitality may decrease during a day's work, after a poor night's sleep, or with illness, and as a result, paces may shorten. A step is shorter when traveling slowly than when moving at a normal rate. Generally, you will lengthen your step in the early morning, when in a hurry, or on gentle slopes after leaving rough country. All of these factors must be considered in pacing.

On loose, rocky, or swampy soils it is more difficult to pace than on firm soil, and allowance must be made for these conditions.

Here are several good rules of thumb to adjust pace calculations:

- your pace lengthens on moderate downgrades and shortens on the upgrade or very steep downgrades.
- walking into strong winds causes the pace to shorten; walking with a tail wind causes it to lengthen.
- soft surfaces such as sand and gravel tend to shorten the pace.
- when its snowing or raining, or you are walking over ice your pace shortens

Visually Estimating Distance
Occasionally, you will encounter a stream too deep to wade or a slope too steep to cross, and the distance must be estimated. In rough country or dense brush, it is more accurate to estimate a short distance to some object than it is to pace the distance. First, practice estimating the units of paces, and then increase the estimate to units of chains or 100 foot increments. Verify each estimate by pacing the distance during practice. Continue practicing until the desired accuracy is reached.

LESSON 3 - Compass and Protractor

Objectives:
1. List the essential parts of the Silva Ranger compass.
2. Locate true north using a compass.
3. Adjust compasses or readings for magnetic declination.
4. Take a field azimuth on an object within 2°.
5. Use a protractor to locate an object by intersection.
6. Orient a map with a Silva Ranger compass.
7. Calculate back azimuths.
8. Find a location on a map by resection.
9. Accurately navigate a three-legged compass course.

The Compass
The compass is an instrument which enables the user to determine direction even in the dark. The most important part of the compass is the magnetic needle that always points to magnetic north and from which **true north** is determined. The north-pointing end of the needle is usually marked by an arrow or painted red with a luminous dot.

A compass also consists of a graduated circle for laying off angles from true or magnetic north; a sighting line for prolonging a line of sight while following a course of direction; and a base plate (Figure 30). Some compasses also have a mirror to assist in sighting.

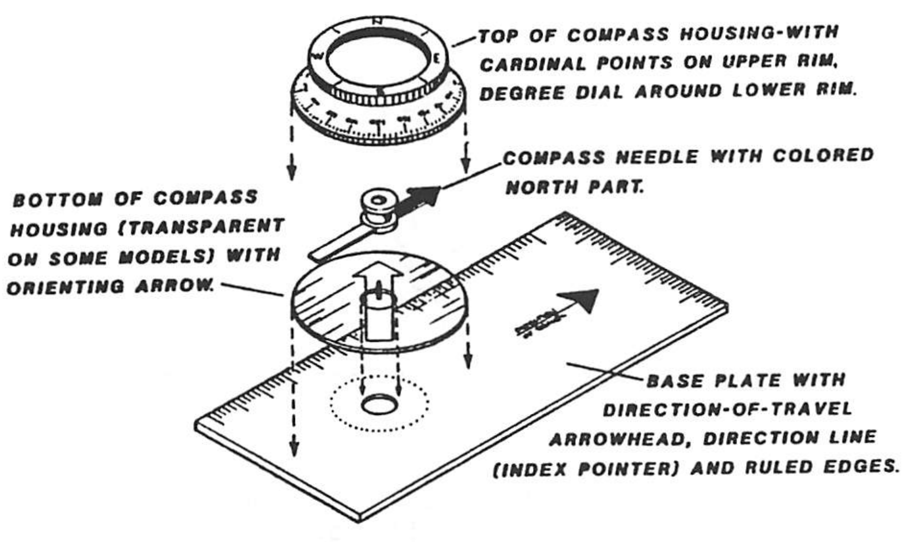


Figure 30: The Parts of a Compass.

Magnetic Declination
Compass directions always refer to true north, but the compass needle always points toward magnetic north. The difference (angle in degrees) between true north and the magnetic north is called **magnetic declination,** or simply the declination (Figure 31).

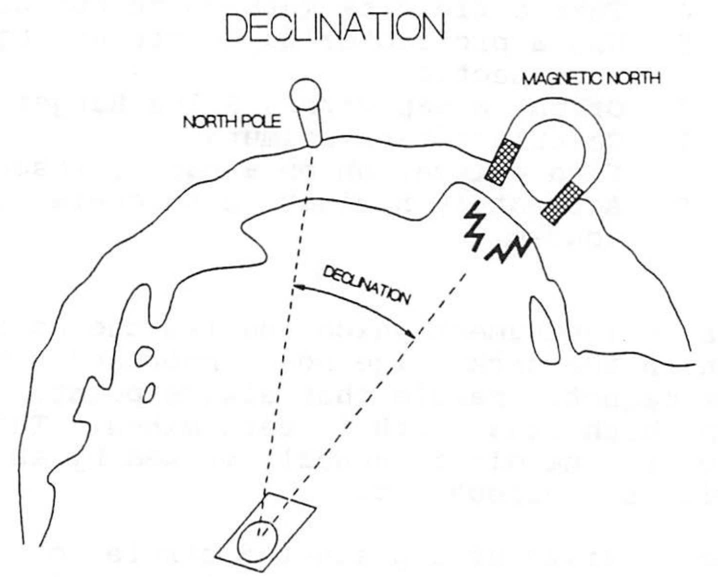


Figure 31: The Effect of Magnetic North on a Compass.

On USGS topographic maps, the declination diagram (degrees of magnetic declination for an area) is located on the bottom margin (Figure 32).

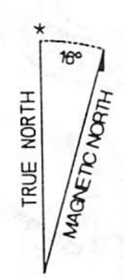


Figure 32: USGS Topographic Map Declination Diagram

Map bearings are true bearings and uncompensated compass bearings are magnetic. This means that all topographic maps are drawn in reference to true north, but the compass does not point to true north unless a magnetic declination adjustment can be made on the compass.

Adjusting for magnetic declination can be very confusing since you must remember a set of rules for when your declination is east of north or west of north, and for when you are looking at terrain from a map azimuth or vice versa.

<u>East Declination</u>
To adjust a compass azimuth for an **east** magnetic declination (**west of the Mississippi River**) follow these steps:

FROM COMPASS BEARING TO MAP BEARING (MAGNETIC TO TRUE)
Suppose you have a compass reading (bearing) and want to plot that bearing on your map.

1. Find your map declination (as an example we will use Seattle, Washington which has a declination of 22° right (east) of true north). Study Figure 33.

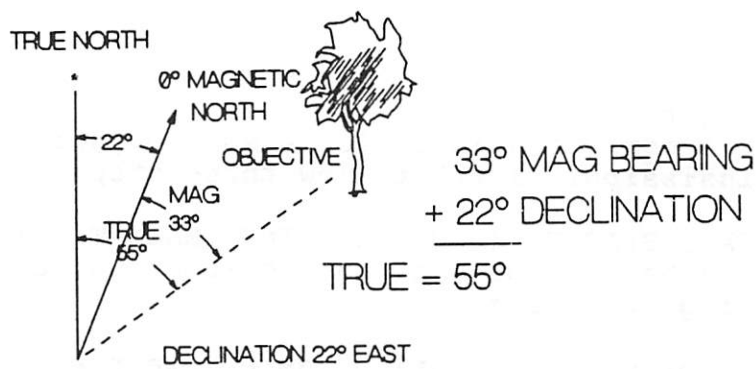


Figure 33: East declination must be **added** to a magnetic bearing to obtain TRUE direction.

2. To change any magnetic bearing to a true bearing, **add** the east declination. For example, your magnetic bearing (compass azimuth) to an object is 33°. To determine the true bearing so that you can plot a course on your map, ADD the declination. In this case the true bearing will be 55°.

   Rule of thumb: Mag to True (compass to map); Add East.

FROM MAP BEARING TO COMPASS (TRUE TO MAGNETIC)
Now you have a course plotted on your map and you want to follow this course using your compass (declination cannot be pre-set on your compass for this exercise). Reverse step 2 taken above.

1. Find your map declination.

2. To put the map bearing back into the magnetic form the compass works with, SUBTRACT the declination.

3. Twist the compass housing so that magnetic needle is pointing to this new value.

Example: Your declination is 17° E. You set your compass for a certain direction on the map and get a reading of 150°. Subtract 17 from 150 and get 133. Now reset your compass to this new number (133°) and you are ready to proceed.

West Declination
To adjust a compass azimuth for a **west** magnetic declination (**east of the Mississippi River**) follow these steps:

FROM COMPASS BEARING TO MAP BEARING (MAGNETIC TO TRUE)
Suppose you have a compass reading (bearing) and want to plot that bearing on your map.

1. Find your map declination (as an example we will use Cap Cod, Massachusetts which has a declination of 15° left (west) of true north). Study Figure 34.

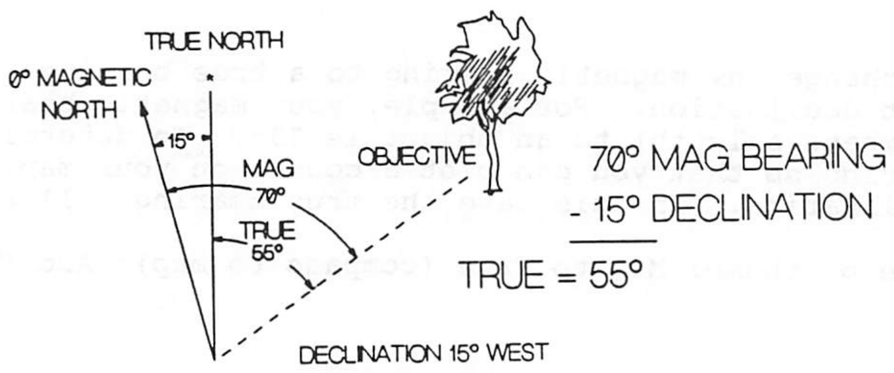


Figure 34: West declination must be **subtracted** from a magnetic bearing to obtain TRUE direction.

2. To change any magnetic bearing to a true bearing, **subtract** the west declination. For example, your magnetic bearing (compass azimuth) to an object is 70°. To determine the true bearing so that you can plot a course on your map, SUBTRACT the declination. In this case the true bearing will be 55° (70 - 15).

   Rule of thumb: Mag to True (compass to map); Subtract West.

FROM MAP BEARING TO COMPASS (TRUE TO MAGNETIC)
Now you have a course plotted on your map and you want to follow this course using your compass (declination cannot be pre-set on your compass for this exercise). Reverse step 2 taken above.

1. Find your map declination.

2. To put the map bearing back into the magnetic form the compass works with, ADD the declination.

3. Twist the compass housing so that the magnetic needle is pointing to this new value.

Example: Your declination is 8° W. You set your compass for a certain direction on the map and get a reading of 253°. Add 8 to 253 and get 261. Now reset your compass to this new number (261°) and you are ready to proceed.

Compass Use
To find a fire or other cross-country destination, the field observer must know the direction and distance to the fire or destination. This direction is usually determined by a compass. Distance which must be covered on foot is generally measured by pacing.

The azimuth compass is best to determine directions. An azimuth compass is graduated with a full circle of 360 degrees (360°) called an azimuth circle (Figure 35). Numbering begins with zero (0°) which is north, and proceeds clockwise. The azimuth graduations are usually etched in to the aluminum or plastic dial that sits on the base plate of the compass.

Ninety degrees is east, 180° is south, 270° is west, and 360°, the same as zero, is north. This circle is used to measure azimuth--the angle measured clockwise between any line and true north (Figure 36).

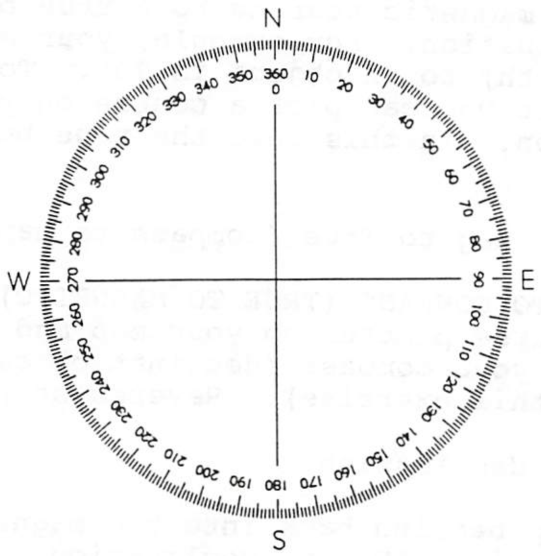


Figure 35: Azimuth Circle.

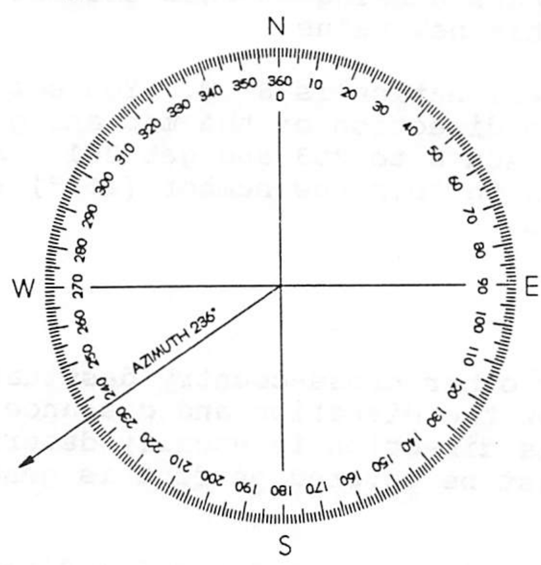


Figure 36: Azimuth (or Azimuth Angle).

Silva Ranger Compass
The Silva Ranger compass is a liquid-filled compass and is probably the most common field compass in use today (see Figure 37). The Silva Ranger azimuth compass will be the standard compass used in this course. Its correct operation will be described below. You must be comfortable using this compass to pass this course.

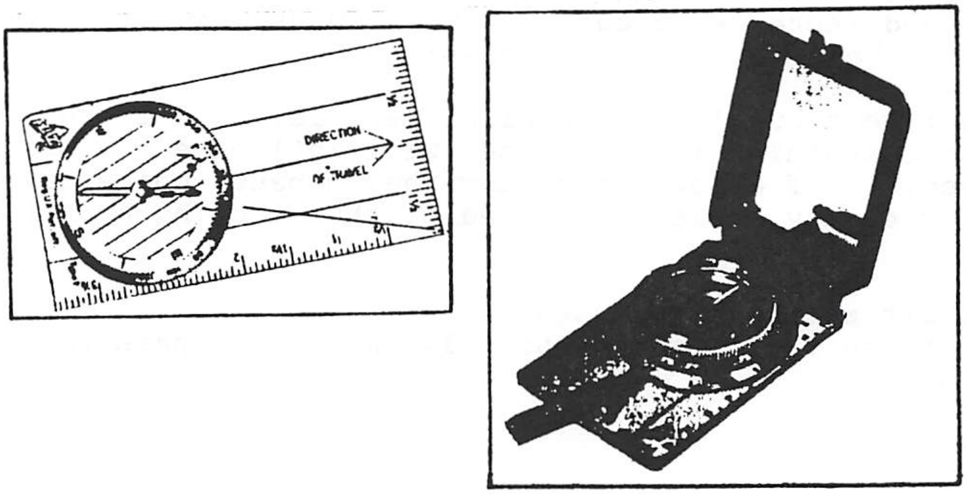


Figure 37: Liquid-Filled Compasses.

How to Use the Silva Ranger Compass
The proper way to stand while using a compass is illustrated in Figures 38 and 39.

Figure 38: Holding the Compass.

Hold the compass in both hands, keep elbows firmly against sides, and distribute weight evenly on both feet.

Figure 39: Prolonging the Line of Sight.

Look along the sighting line then raise eyes to prolong the line of sight ahead. Do not move head; raise eyes.

It is often best to hold this compass at eye level rather than at or below the chest. This makes prolonging the line of sight much easier and increases accuracy. When in use, the compass should always be held as level as possible.

Warning: Belt buckles, mechanical pencils, wire fences, and other objects containing iron or steel will influence the position of the needle. If allowed too near the compass, while taking a sight, they may deflect the needle, thus causing an error.

How to Set a Compass Azimuth
Follow these steps to set the Silva Ranger compass for a desired azimuth.

Step 1

Adjust the compass for Magnetic Declination (i.e.: add east, subtract west) by doing the following:

Determine what the magnetic declination is for the area of work.

<u>Mechanical Adjustment</u>
If your compass has a declination adjustment screw, turn this set screw for the appropriate declination. The set screw key is usually attached to a nylon cord that hangs from the compass. The set screw causes the etched or painted arrow on the base plate (that the floating compass needle sets in) to turn.

Once the proper declination has been set mechanically, it need not be changed while the compass is used in the same area.

<u>Mathematical Adjustment</u>
Some liquid-filled compasses do not have a set screw to adjust for magnetic declination. Magnetic declination can only be adjusted for by calculations from true north or the desired azimuth. Example 1 demonstrates how this is done.

Example 1
The magnetic declination is determined to be 16°E according to your topographic map. Turn the azimuth dial so that the azimuth and floating needle reads 0° (0° is the same as 360°) along the "direction of travel arrow" (see left compass in Figure 37) or "line of sight marks"; the compass is now pointing toward magnetic north. (Usually, the compass casing will be divided down the middle by a thin solid black line, which is called the "direction of travel" line; or by a series of white or yellow marks, which are called the "line of sight" marks

(also indicates the "direction of travel")). To find true north, which is 16°E of magnetic north in this example, orient your body and compass so that the floating needle points 16° to the right (east) of 0°.

Step 2

Set the compass for the desired azimuth by doing the following: Turning the aluminum or plastic dial so that the desired azimuth is aligned with the "line of sight mark" centered at the top of the compass (same as the "direction of travel arrow"). The following examples demonstrates how to set compass azimuths.

Example 2--When Declination Has Been Mechnically Adjusted.

Set the azimuth to 0°, or any other desired azimuth by simply turning the dial so that the azimuth is aligned with the "direction of travel arrow", or the white or yellow "line of sight mark" at the top and center of the compass.

Example 3--When Declination Must be Mathematically Adjusted.

The magnetic declination is determined to be 16°E, and you want to travel on a line due southeast. In this case, southeast is 16° east of 135°, or 151°; your direction of travel would be 151°, so turn your azimuth dial to read 141°.

Step 3

Turn the body (and the compass) until the floating (magnetic) needle is centered over the "etched needle box" on the base plate of the compass. The floating compass needle will be pointing to magnetic north, which is usually not the correct direction unless the declination is 0°. The top of the compass, however, will now by pointed to the desired azimuth.

For example, to orient the body and compass to face true north, set your azimuth to north (0°) as described in Steps 1 and 2. Now turn your body until the floating needle (remember it is usually a red arrow) lies directly over the etched arrow (on the base plate). If magnetic declination has been set, look in the direction of the "line of sight mark" centered at the top of the compass; that direction should be true north.

Step 4

Follow the "line of sight" or direction indicated by the compass.

How to Determine an Unknown Azimuth
Follow these steps to determine the direction of an object (an unknown azimuth).

Step 1

To determine direction where the azimuth is unknown, hold the compass so that an imaginary straight line can be drawn from you to an object (such as a peak).

Step 2

While holding the compass very steady (and level) and keeping your eyes alternately on the object and the compass, turn the plastic or aluminum dial so that the magnetic north (red) arrow is floating directly over the etched arrow on the base plate.

Step 3

Read the azimuth directly opposite the "direction of travel arrow", or opposite the line of sight mark at the top, center of the compass. This is the direction (azimuth) that must be traveled to reach the object if magnetic declination has been mechanically adjusted for. If declination must be adjusted for mathematically, you must reverse the declination rule, i.e., subtract for east and add for west, if west of the Mississippi River to plot this direction on a map.

It is difficult to learn how to set a compass azimuth or to determine an unknown azimuth from reading an instruction set. Find a knowledgeable person to show you these skills and practice them repeatedly on different objectives. You must possess these skills before you enter the classroom portion of the course; and more importantly, before you are on assignment!

How to Use a Liquid-Filled Compass with Reflecting Mirror Cover
Some liquid-filled compasses are equiped with reflecting mirror covers (see Figure 37; page 69); the Silva Ranger CL-15 is one such compass. The reflecting mirror, if used properly, can greatly improve accuracy. Follow these steps when using the reflecting mirror cover type compass. If you have problems following these instructions, have someone show you how to use this type of compass.

Step 1

Set the desired azimuth by turning the aluminum or plastic dial. (Make sure you have adjusted the azimuth or compass for declination). The desired azimuth line should be directly under the "line of sight" mark at the top of the compass (just below the hinge).

Step 2

Hold the compass horizontally on the same level with the sighting eye and adjust the cover (by folding it toward the face of the compass) so that the reflected image of the compass housing fills the mirror (Figures 40 and 41).

Step 3

Move the sighting eye sideways in relation to the compass until the sighting line intersects the reflecting image of the center point (Figure 40).

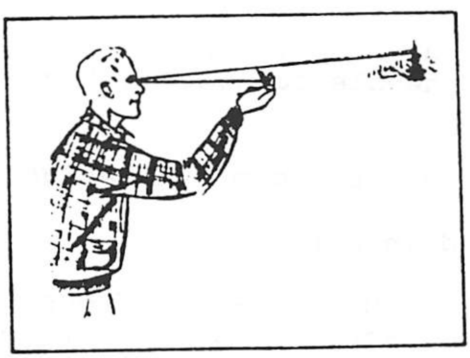


Figure 40: Aligning Sighting Line with Center Point of the Compass.

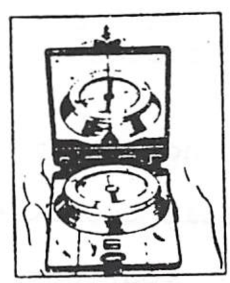


Figure 41: Sighting with the Compass.

Step 4

Without changing the relationship between compass and eye, turn until the head of the floating needle (red end) points to the azimuth line on the compass base, and the floating needle is centered in the etched needle box inside the compass housing.

Step 5

The direction of travel (or objective in the field) will now lie straight beyond the sight on the upper edge of the cover. The line of sight should fall in the "V" notch in the middle of this upper edge of the mirror casing.

When sighting uphill or downhill, lower or raise the sighting eye in relation to the compass. Remember to keep the base plate horizontal so that the compass needle can turn freely.

Precautions to Take When Using a Compass

- Be sure that the correct declination is set on the compass or adjusted for mathematically.
- When running lines always follow the line of sight and not the direction of the needle.
- The compass is a delicate instrument; handle it carefully.
- Always follow the line indicated by the compass rather than relying on judgment as to the direction.
- Remember the tree, rock, or other object sighted on your line of sight. When in doubt, take another compass reading.
- Keep articles containing steel or iron (such as radios) sufficiently far away from the needle to avoid influencing it.
- Do not attempt to repair the compass except in emergencies.

Practical Exercises (will be tested in class)

A. Set your compass to east (90°) as described in Steps 1-4 of "How to Set a Compass Azimuth" (pages 70-71) and travel due east for a few paces. Repeat these procedures to travel south (180°) and west (270°). Remember to compensate for magnetic declination (Step 1--page 70); practice compensating with a compass that has a magnetic declination set screw and one that does not. For example, try adjusting for a magnetic declination of 0°E, 15°E, 20°W, etc.

B. Go outside and find a building, tree, or hill. Locate a point at the top or bottom of this object and determine the azimuth (direction) between you and the object by following Steps 1-3 in "How to Determine an Unknown Azimuth" (page 72).

Protractor

A protractor (Figure 42) is a circle or semi-circle marked in degrees used to determine compass degrees to a point.

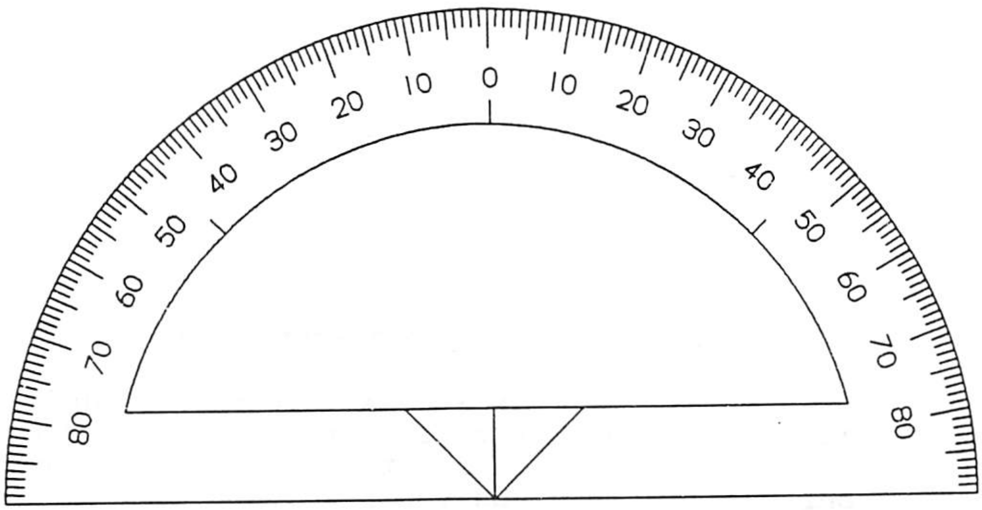


Figure 42: A Protractor.

How to Use a Protractor

1. Draw a line from an initial point to the object (Figure 43).

2. Set the protractor on an east-west axis.

3. Place the center mark of the protractor on the initial point with the 0 on the outer ring at north.

4. The compass degree is read where the line intersects the outer ring. This may be the true compass reading from the initial point to the object, depending upon your protractor's graduations.

5. With a true compass reading and a distance from a given point, a line can be drawn on a map and a location on this line found (Figure 43). This is the principle used by fire lookouts.

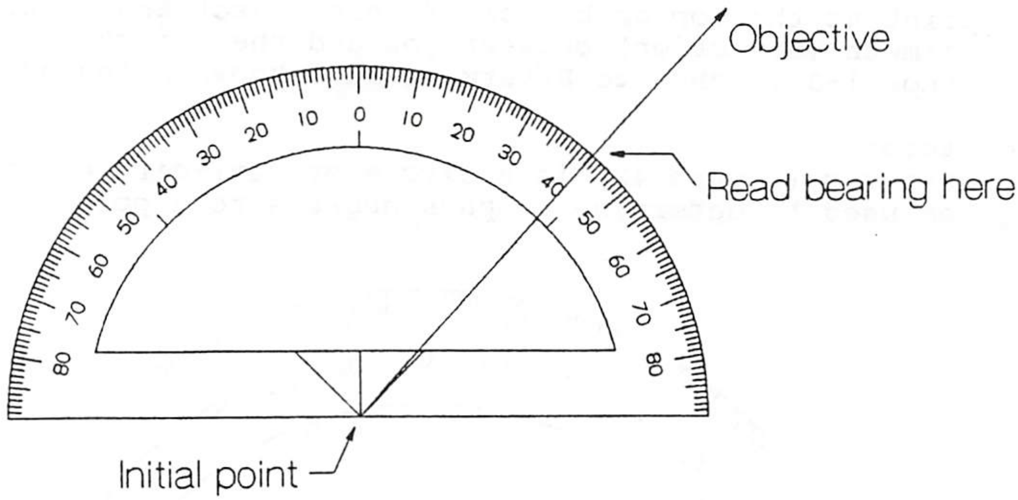
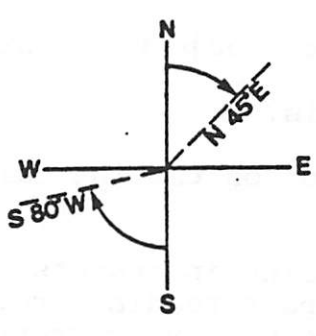
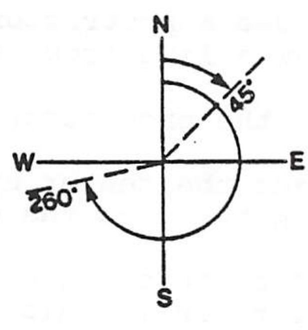


Figure 43: Using the Protractor

A protractor can be a circle or a semi-circle and can be variously graduated. Remember to convert degrees to the proper azimuth (study Figure 44 if you don't know how). For example, in Figure 45, your protractor gives you a reading of 80° in the southwest quarter, but the azimuth is actually 260°.





Bearings: are measured from N & S to the E & W.

Azimuths: are the clockwise angle measured from N.
Figure 44: Difference Between Bearings and Azimuths

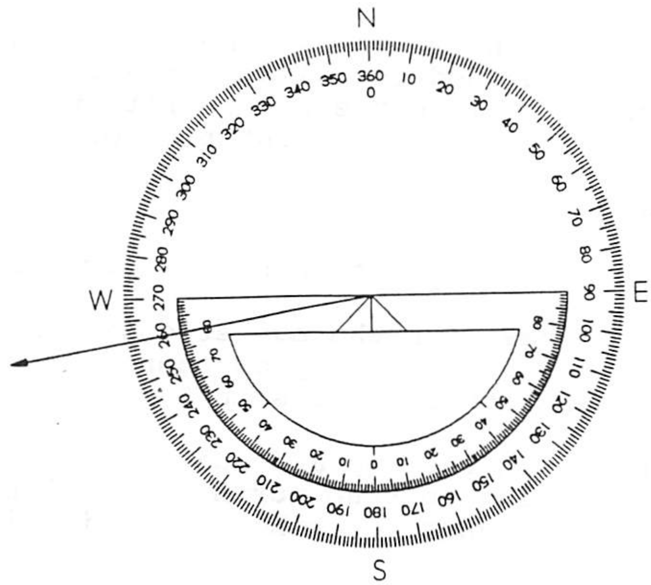


Figure 44: Protractor and Azimuth Circle Overlay

Exercises
Use the Cajon topographic map for the following three exercises. School solutions are located at this end of this Unit.

Locate Cleghorn Mountain in Section 4, T2N, R5W.

Q1: What is the <u>true</u> bearing from Cleghorn Mountain to spot elevation 4217 in Section 33, T3N, R5W? ______________.

Locate Cajon Mountain Lookout, about a mile and a half south of Cleghorn Mountain. The lookout reports a smoke at 229°, 2 miles.

Q2: Describe the area where you think the smoke would be.
____
____
____
__________.

A newly constructed lookout at spot elevation 3240 in Section 12, T2N, R6W gives a cross reading of 166°, just under 2 miles.

Q3: Does this line cross with the line from Cajon Lookout within a tenth of a mile from your answer above? If not, check your readings.

Orienting a Map
Maps can be oriented in two ways. The most accurate method is to use a compass; this method is called compass orientation. The next best method is to move the map to fit known landmarks; this is referred to as topographic orientation or terrain association.

Compass Orientation

1. Lay out your map on a flat, non-metallic surface.

2. Adjust your compass for the magnetic declination specified on the map margin. If your compass cannot be adjusted for magnetic declination skip to step 3.

3. Lay the compass on the map and adjust the compass so that the compass is pointing to true north (if declination has been preadjusted) or magnetic north (if declination cannot be mechanically adjusted).

4. Rotate the map so that the map is physically oriented to the north (parallel to the north/south running line(s) on the compass). If magnetic declination has been preadjusted, the map is now oriented to true north. If not, the map is oriented to magnetic north and you must move on to step 5.

5. Rotate the map the number of degrees west (rotate to the left) or east (rotate to the right) of magnetic north specified as the magnetic declination (i.e. 15° west would be 345°; or 17.5° east would be 17.5°).

Practice orienting a map with a compass. Ask for assistance if you do not understand these instructions.

Topographic Orientation

1. Find your approximate location on the map.

2. Select two prominent landmarks visible to you and shown on the map.

3. Turn the map until the map landmarks are in proper relation to actual landmarks.

4. The map is now oriented generally to true north.

Calculating Back Azimuth or Backsighting
While following a line of sight, or an azimuth, you may sometimes lose the landmark (tree or rock) and find it necessary to recheck your location and its relation to the original line of sight or azimuth. To do this, sight back toward the starting point and then check by compass. This requires sighting a back azimuth which is in the opposite direction from the azimuth. Since there are 360° in the azimuth circle, the opposite direction would be half of 360°, or 180°, difference from the azimuth. A back azimuth is calculated by adding 180° to the azimuth when the azimuth is less than 180°, or by subtracting the 180° from the azimuth if it is more than 180°. Checking your line of sight by using a back azimuth is called backsighting.

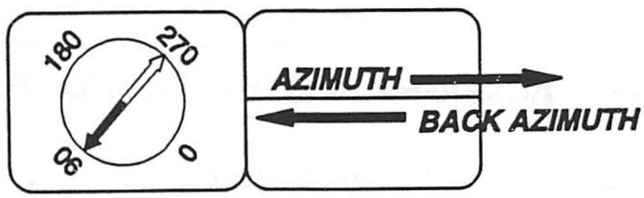


Figure 46: Azimuth and Back Azimuth.

In Figure 46, the north end of the needle indicates the azimuth, which in this case is 90°, or east. The back azimuth is in the opposite direction, or it would be 90° plus 180° which is 270°, or west.

Using a back azimuth to check a line of sight or to sight back on a starting point or lookout point is called backsighting.

Getting on Line
It is not always possible to keep the lookout point or the starting point in view when traveling to a destination. When a point is reached where the lookout, or starting point, can be seen and it is desireable to get on the line between the lookout point and your destination, proceed as follows:

1. Face the general direction of the backsight.

2. Hold the compass as previously described.

3. Set the back azimuth (on the dial).

4. When the needle is centered in the etched needle box, sight along direction of travel line (line of sight).

5. Note on which side and the approximate distance from which the line of sight misses the lookout point.

6. If the lookout point is to the right of line of sight, move to the right. If the lookout point is to the left, move to the left.

7. Estimate the distance that the line of sight misses the lookout point. Move over this distance, either to the right or to the left, as required. Take another backsight on the lookout point. Repeat this procedure until the line of sight passes through the lookout point.

8. This then is the line between the lookout point and the fire. Then turn the compass to the azimuth reading and proceed along the line toward your destination (Figure 47).

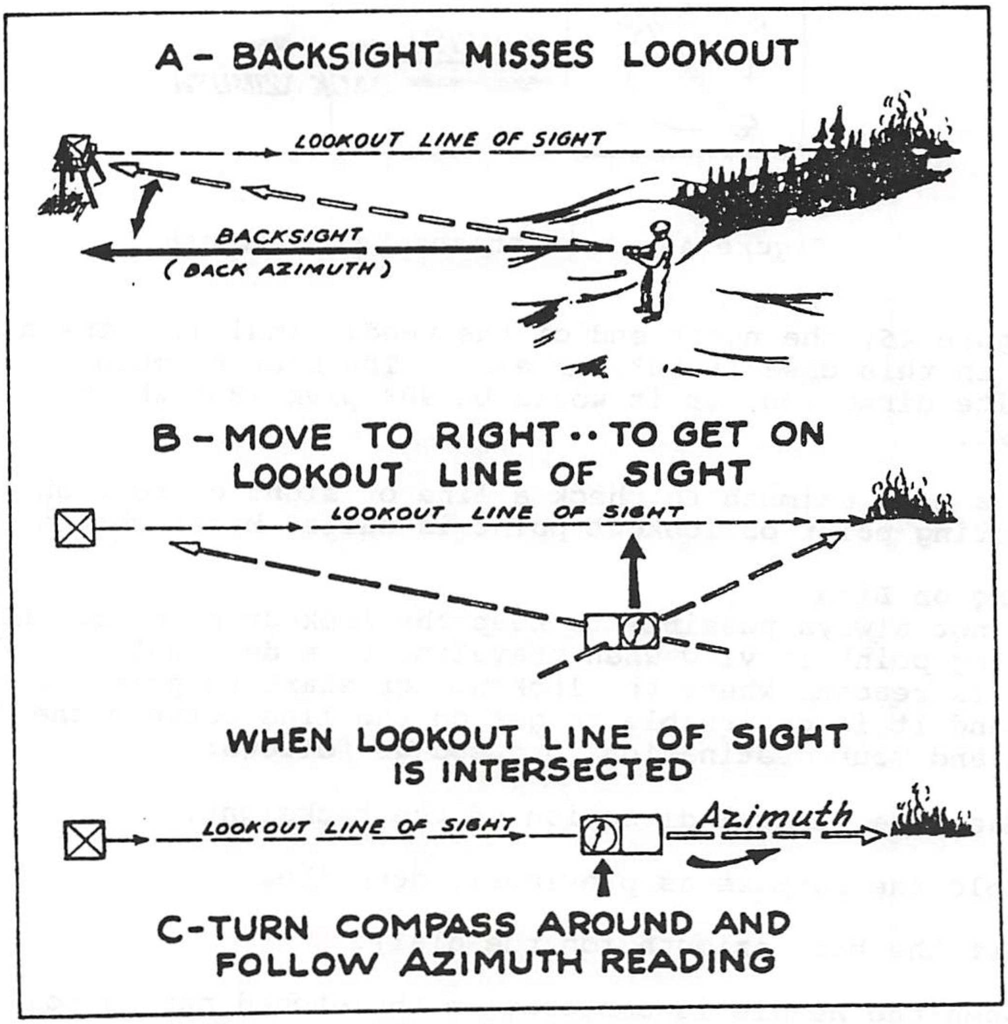


Figure 47: Getting on Lookout's Line of Sight.

Resection
Resection is a technique used to locate yourself or an object on a map when that location is unknown or is uncertain. Resection can best be performed during the day in terrain that has some relief.

To resection follow these steps:

1. Orient your map to true north (page 78).

2. Select two obvious landmarks that you can clearly discern on your map.

3. Take a compass bearing on both landmarks (adjust for declination) and WRITE them down (Figure 48).

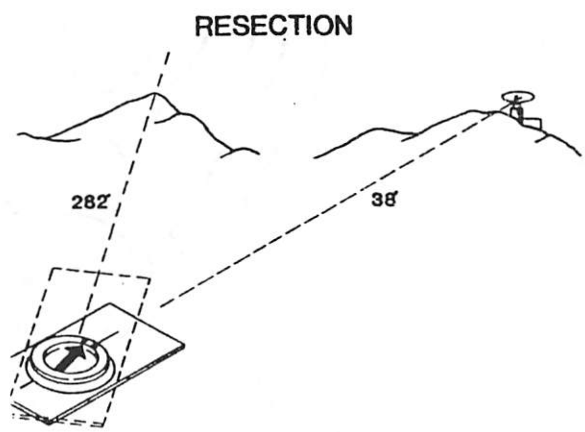


Figure 48: Taking Resection Compass Bearings.

4. Calculate the back azimuth of both bearings.

5. Transfer these bearings onto your map:

   - set the compass for one of the recorded bearings (landmark A) adjust for declination
   - place the compass on the map so that one edge touches landmark A
   - pivot the compass (not the map!) so that the magnetic needle is aligned over the base plate needle, and the edge of the compass is still touching landmark A
   - hold the map and compass very still and draw a line (pencils are usually best in case of error) from landmark A to a point well beyond your suspected location.
   - repeat last step for landmark B

Your location should be the intersection of these two lines; the "X" marks the spot (Figure 49). A protractor, if available, can also be used for resection calculations.

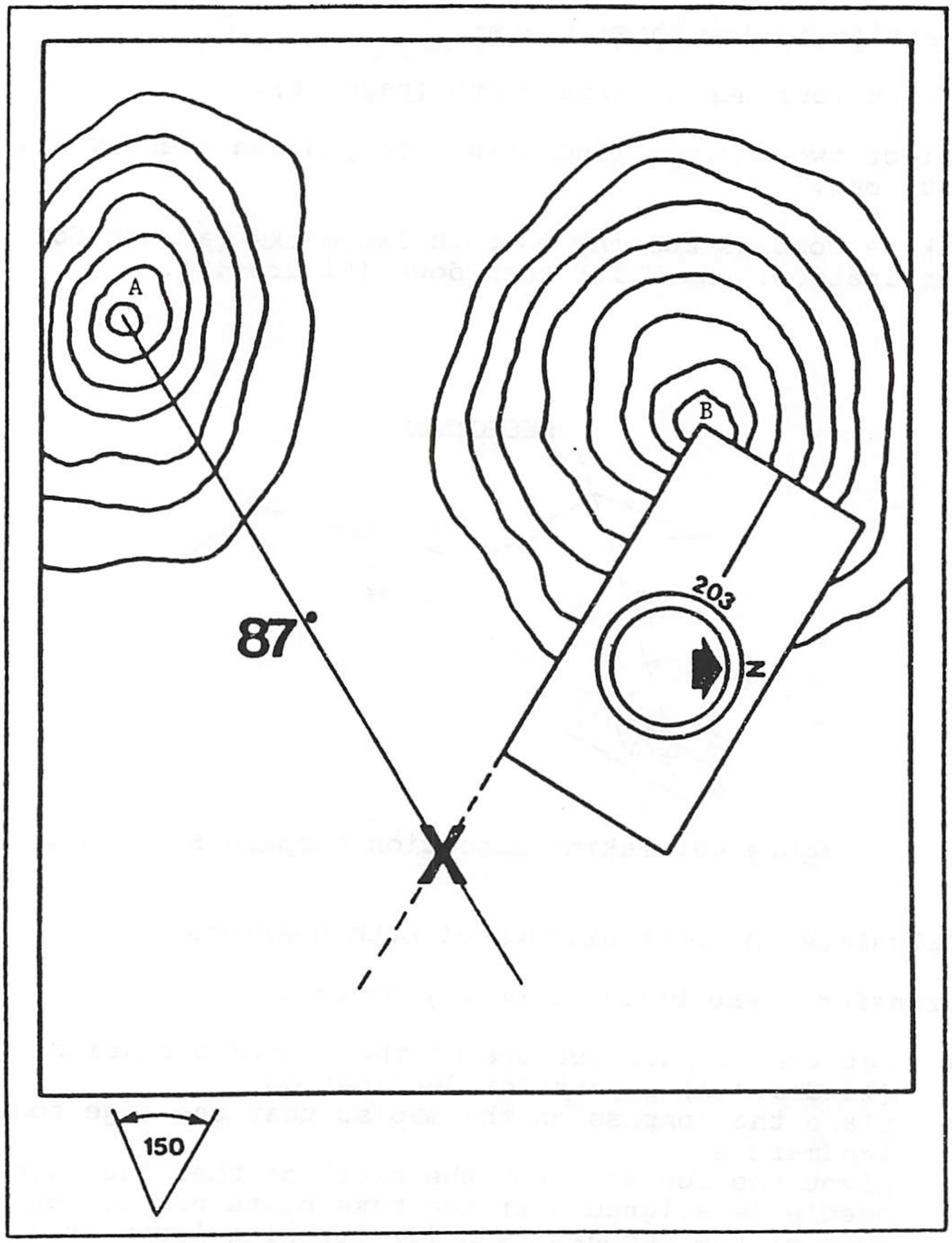


Figure 49: Resection X Marks the Spot

Solutions to Unit 3 Questions

Protractor

Q1: 23°; Q2: At the three structures near the corner of Sections 24, 13, 18, and 19; Q3: Check yourself

UNIT 3 FIELD EXERCISES

Complete the following field exercises to prepare yourself for a timed, in-class skills test on the first day of class. Have a knowledgeable person check your work.

Exercise #1
Lay out a 100 ft course on level ground. Establish a mark one chain (66 ft) from the 0 point. Determine your pace and the number of paces required to walk (normal stride) 1 chain and 100 feet.

Length of pace__________; # paces per 1 chain___________; # paces per 100 feet________________.

Exercise #2
Repeat exercise 2 on a slope of 20% or more. Establish your pace for both upslope and downslope travel.

Uphill:
For a _________% slope, my length of pace__________; # paces per 1 chain___________; # paces per 100 feet________________.

Downhill:
For a _________% slope, my length of pace__________; # paces per 1 chain___________; # paces per 100 feet________________.

Exercise #3
Obtain a topographic map of your home base that includes your place of work. Answer the following questions:

What is the magnetic declination?__________________________.

What is the legal description of your place of work?________________
____.
(Include the Base and Meridian). Bring this quad to class.

Exercise #4
Calculate the distance between two points (i.e. two buildings or two trees) by pacing. Measure this distance. The difference between the distance estimated by pacing and the measured distance must be within 5 percent.

Exercise #5
Walk the following three-legged compass course on relatively flat terrain and return to within 10 feet of the starting point. Go into the field and mark your starting point, then use these distances and azimuths:

<u>Three-legged Course</u>

Go 200 ft at 39.5°; then go 170 ft at 180°; and return to your starting point by going 140 ft at 270°.

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FIELD OBSERVER/DISPLAY PROCESSOR
PRESTUDY EXAMINATION

Date__________ Student's Agency______________________________

Student's Name ____________________________________

	Points
1. Describe a "planimetric map".	1
2. Describe a "topographic map".	1
3. Describe an "orthophoto map".	1
4. Define the term "quad".	1
5. Define "comparison scale".	1
6. Define "representative fraction".	1
7. What is a map legend?	1
8. Where would you usually find the information relating to revision date, adjoining maps, contour interval, and magnetic declination on a topographic map?	1

Points

The next five questions refer to the basic colors used on a topographic map. Briefly explain what features the colors represent.

9. Black 1

10. Blue 1

11. Green 1

12. Brown 1

13. Red 1

14. List two items found in the margin of a topographic map. Do not list those items referred to in Question #8. 2

15. Briefly define the USGS Topographic Map Index Circular. 1

Points

Briefly define the following terms.

16. Baseline 2

17. Principal Meridian 2

18. Township lines 2

19. Range lines 2

20. Township 2

21. Section 2

Draw the ICS display symbol for each of the following items:

22. ICP 2

23. Uncontrolled perimeter 2

24. Origin 2

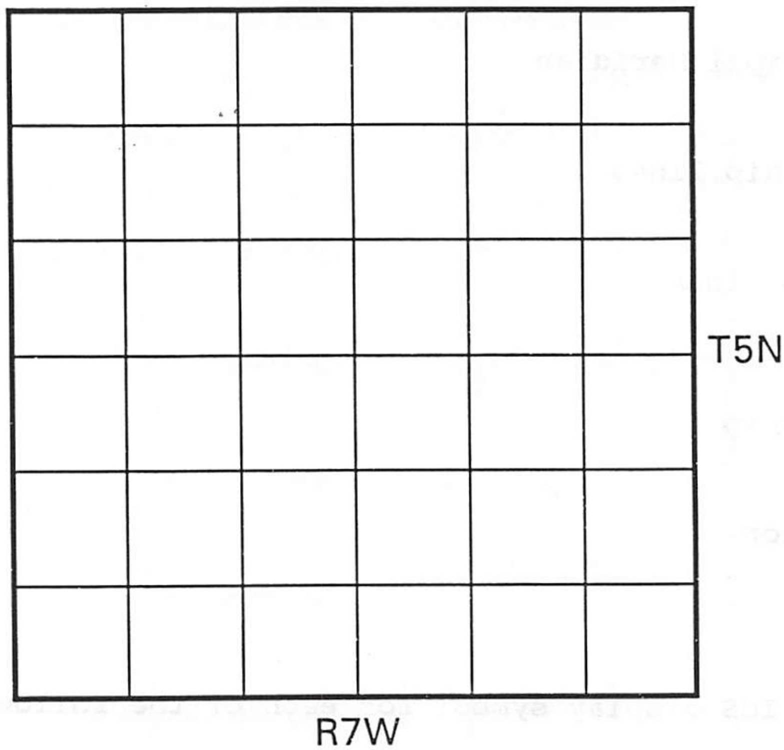
25. Staging Area 2

26. A ridge 2

Points

Questions 27 through 33 require referencing a drawing next to each question.

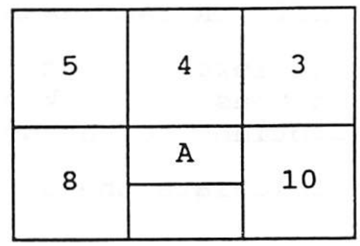
27. Number the Sections in this typical Township 2



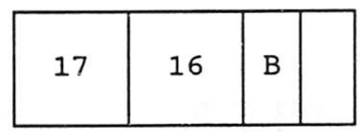
Points

To answer questions 28 through 30, describe the section divisions with letters in them. The Township and Range is T5S, R3W, MDB&M.

28. A = ______________________________ 2

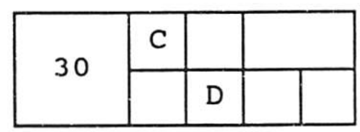


29. B = ______________________________ 2



30. C = ______________________________ 2

D = ______________________________ 2

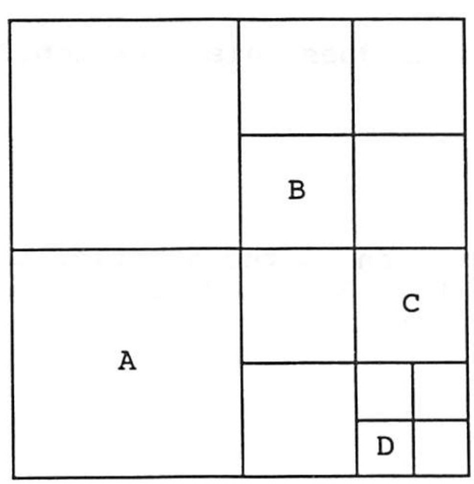


Questions 31 through 33 refer to the diagram below; assume it represents one Section.

31. How many acres in area A?_____________ 2

32. How many acres in area B plus C?______ 2

33. How many acres in area D?_____________ 2



Points

Use the Cajon Topographic Map to answer questions 34 through 39. You may use any mapping aids you wish. DO NOT WRITE ON THE QUAD. ATTACH ALL WORKSHEETS TO RECEIVE FULL CREDIT FOR EACH ANSWER.

34. In the lower left corner of the map there is a road which goes to Stockton Flat Campground to the west and to Scotland to the south.

    A. Calculate the distance of the road, in feet. 6

    B. Using the road and the map margin as boundaries, calculate the acreage of the area inside this road. 6

35. The measured distance from the northwest end of Lost Lake to the Gaging Station near the weighing station is 1-1/2 inches.

    A. How many inches does this represent on the ground? 6

    B. How many chains does this represent? 5

36. What is the elevation at the junction of State Route 138 and Interstate 15? Calculate from directly under the "U" in junction. 5

Points

37. What is the average slope between the highway junction (described in question 36) and Hill 3690, which is due north of this junction. 6

38. What is the average slope between BM 3257 near the Glenn Ranch in Section 15, T2N, R6W and VABM 4306 on Lower Lytle Creek ridge north of the ranch? 6

39. You are trying to determine your location on the map. You use your compass and determine that Cleghorn Mountain bears 70° from your location. Cajon Mountain Lookout bears 145°. Both of these are true azimuths. Describe your location. 6

100 possible points