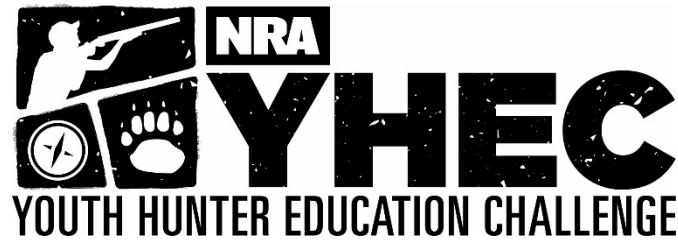


Compass and Orienteering

Coach Study and Resource Guide



This information contained herein is intended to assist YHEC coaches in learning and becoming better educated teachers in the use of a compass and map. All of the information has been compiled from various online sources readily available to anyone with a computer and internet connection. Credit for much of the data and information can be found on the resources section at the back of this guide.

In addition to this guide, I encourage coaches to further their understanding of navigation principles by turning to a number of great print publications available at bookstores and online. Specifically, I would direct you to: Wilderness Navigation, 3rd Ed. by Bob Burns and Mike Burns, and Essential Wilderness Navigation by Craig Caudill and Tracy Trimble. Both of these books have been the basis of inspiration and information in the creation of our field course and mapping test. You should also turn to the great number of instructional YouTube videos available today. Simply search for orienteering, compass, navigation, mapping, etc.

Included here are instructions on how to build a simple circular field course. We have found that this basic course is easy to construct and can be a great tool in teaching youth participants the fundamentals of using a compass and pace to find a given location. Credit for the circular course goes to John Horton.

I also include an example of a pace chart I created and have successfully used for many years now. Inspiration for this spreadsheet came from several sources within YHEC and also from trial and error. In real wilderness navigation, and with proper map training and compass use pace becomes much less important. Nonetheless, due to the compact size of our courses (negating the use of a map on the course) correct pace is a critical element in determining correct distance traveled.

One final note on the actual YHEC course and test: Our courses are precisely laid out by professional land surveyors and are accurate to hundredths of degrees and feet. We are constrained in the area in which we can lay out the course due to safety and size of the event. We require preciseness in navigation to the particular points so as to mimic a much longer distance typically encountered in back country navigation. For instance, if a course participant is off just 2 degrees he will certainly miss his destination. Why is it so precise? Well, If a wilderness hiker needs to return to her car which is parked five miles away and she is off 2 degrees, she will miss the car by almost 1,000 feet!

Navigation is about situational awareness. In every aspect, urban or rural. Inside or outside. Land or water or air. Do you ever look out of the window of a passenger jet and recognize the landscape below? Can you say to yourself with any amount of certainty that “we are flying over Knoxville now, or Wichita, or Santa Fe, or any other urban area? Can you identify large bodies of water? Mountains? Rivers? Again, it has to do with situational awareness and knowing your environment.

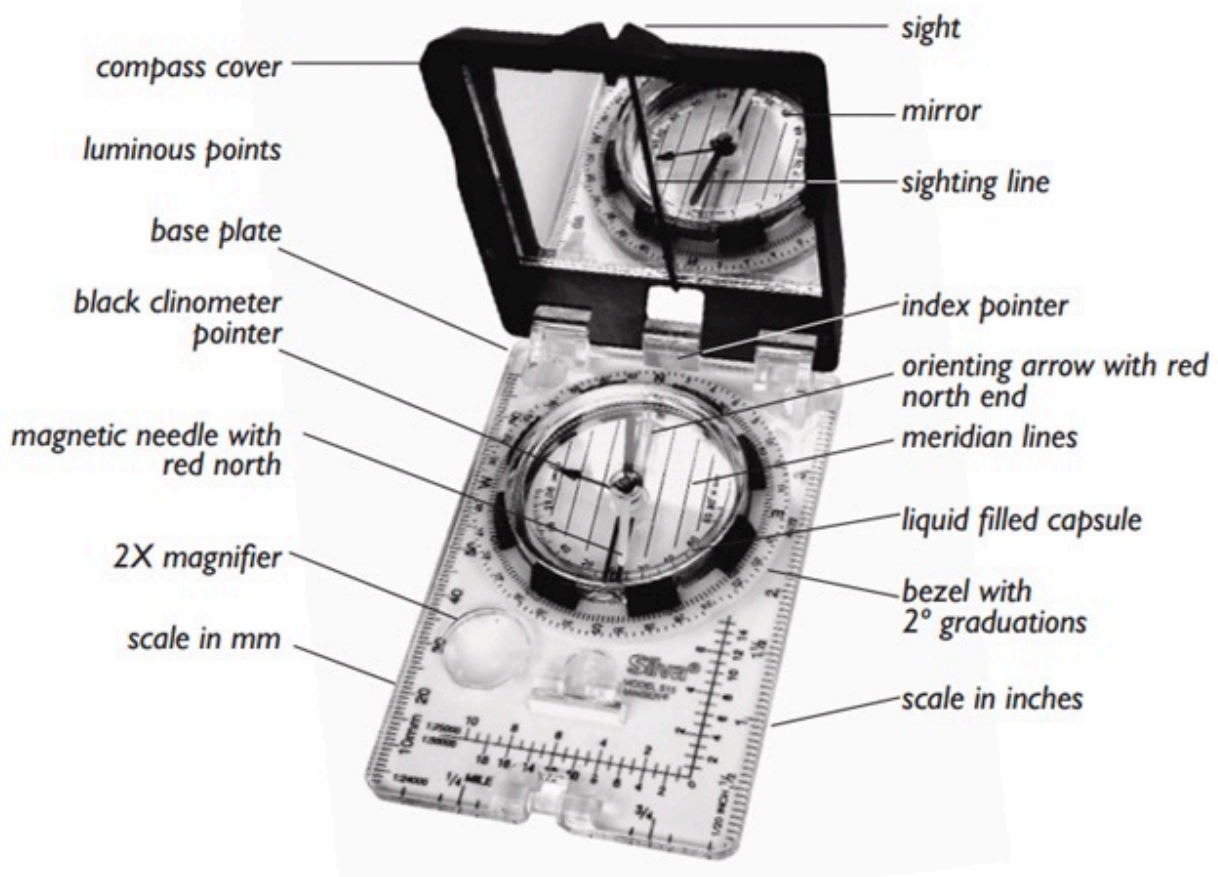
We need to become our own navigators. In the car, on highways, off road, hiking, biking, hunting, etc. We have come to rely too much on electronic devices and maps on the smart phone. These

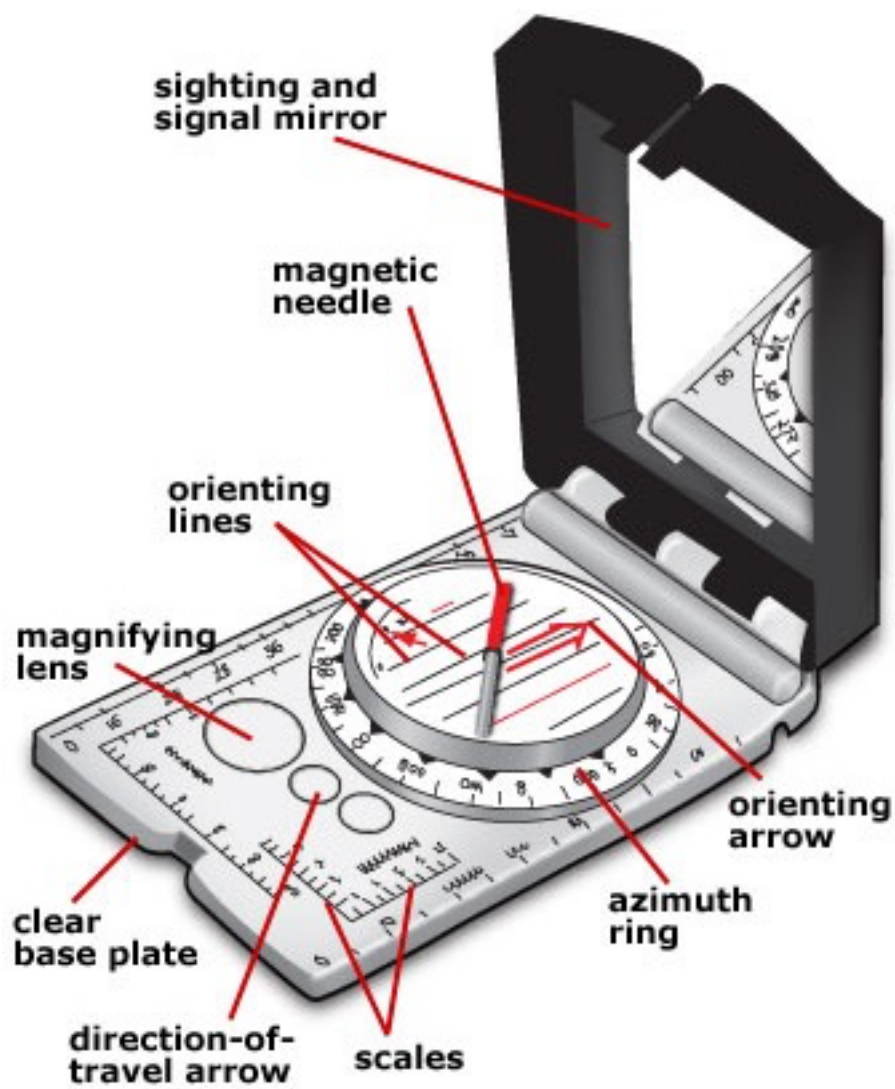
are great tools, but only tools. Learn to familiarize yourself with a geography before you get there by studying maps. Maps give your mind's eye a photo of the area and imprint in you the geography, whether it be a new town, city, state, national park, recreation area, wildlife refuge, river basin, mountain, plateau, or even inside a building.

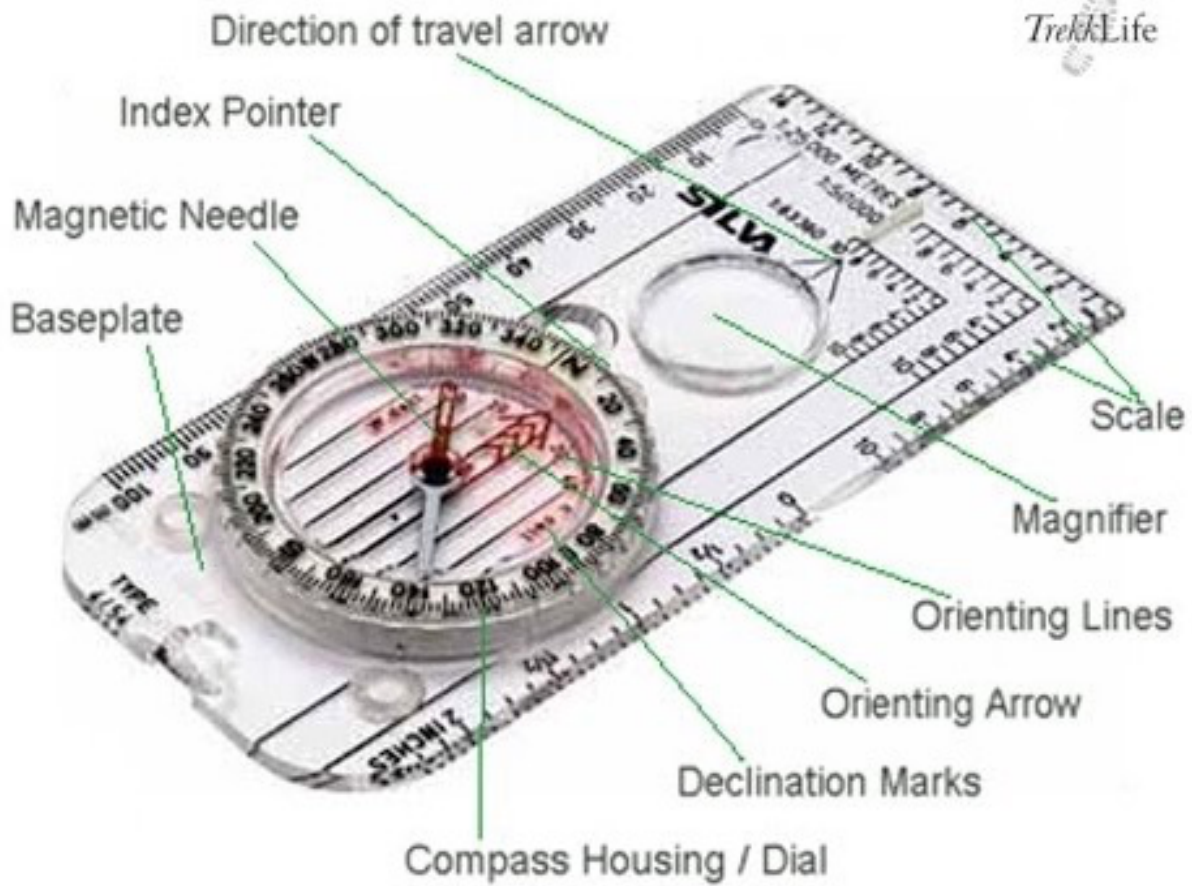
Thank you for attending and it is our hope that you will leave here with a better understanding of navigation and the use of maps and a compass. If we are successful, you should be able to better teach your kids and hopefully instill the desire and enthusiasm to learn about the landscape which you call home, no matter where on earth that is.

Jeff Nicholas, March 2021

Compass Basics





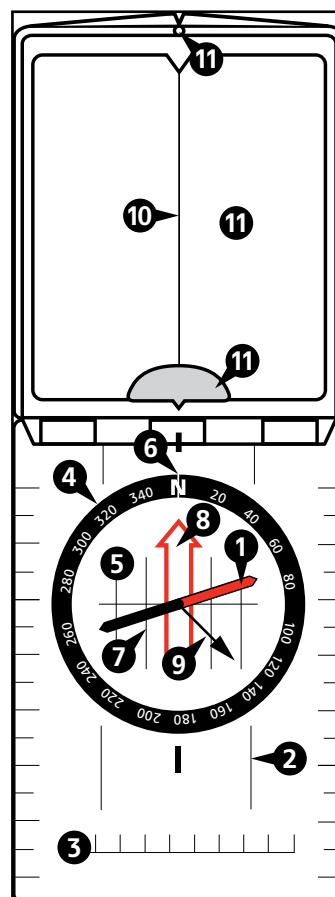


SUUNTO MIRROR COMPASSES

USER GUIDE

1. Compass anatomy

1. Needle with red end that points to magnetic north
2. Direction-of-travel arrow for pointing to target on map and when moving
3. Baseplate with straight edges and scales for working on map
4. Bezel with directional scale for using as a protractor
5. Rotating capsule for setting direction to target
6. Bearing index for reading numerical bearing from bezel
7. Orienting lines used to align capsule with meridian lines on map
8. Orienting arrow for aligning with needle to find direction to target
9. Clinometer (select models only) for measuring vertical angle
10. Center line for aligning target and compass
11. Notch, mirror and hole (select models only) for precise sighting of an object



2. Orienting the map

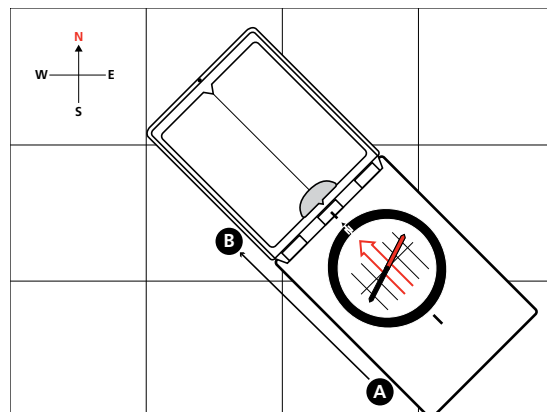
To better understand your surroundings, you should use your compass to first turn your map in the right direction. This ensures the geographic features around you are in the same general direction as you see them on the map.

1. Hold your compass level and look at the red end of the needle to see where north is.
2. Turn the map so that the northern upper edge is pointing north.

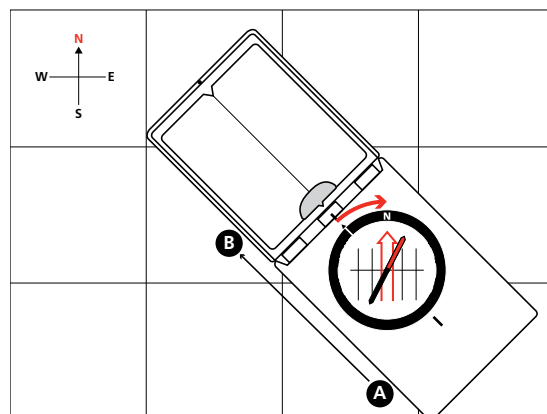
3. Navigate with map and compass

When navigating with a map and compass, you are first determining a direction of travel on the map and then transferring that direction to the real world.

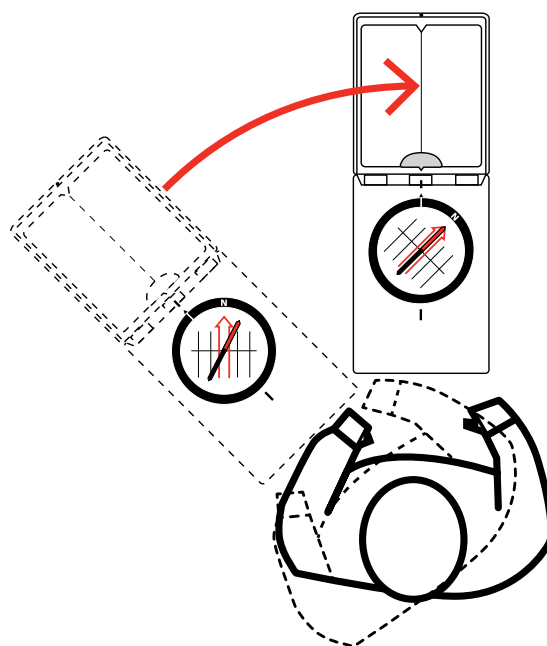
1. Place the compass on the map between your starting point (A) and your target (B).



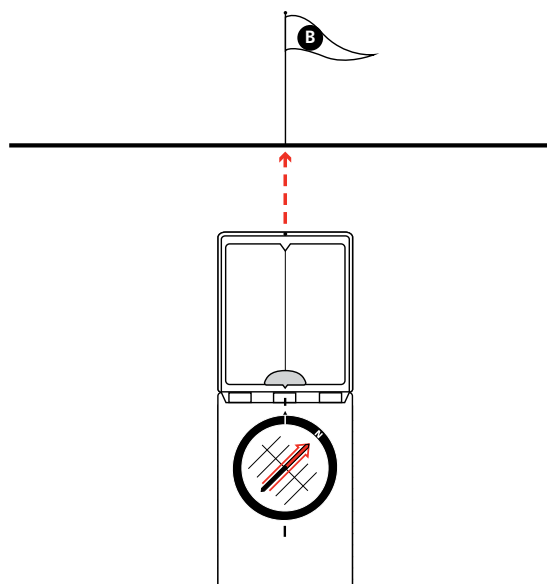
2. Turn the capsule until the orienting lines are parallel to the meridian lines on the map with N pointing north.



3. Hold compass level at waist height and turn yourself until the needle and orienting arrow are aligned.
NOTE: Compensate for declination. See section 5.

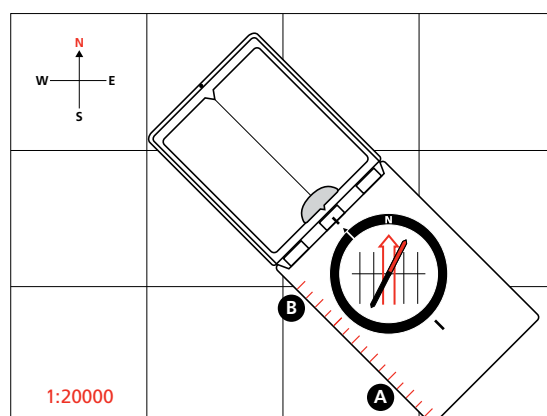


4. Select a visible target in front of you to help you maintain your direction while travelling.
5. Follow your progress by comparing landmarks to the map.



4. Measure distance on map

Your Suunto compass has multiple scales on the baseplate to help you measure distance on a map. Be sure to use the same scale indicated on your map. If the map scale is not on your compass, use a general scale (cm or inch) to calculate distance.



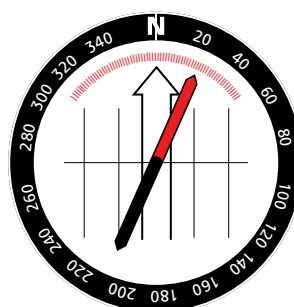
5. Declination correction

The meridian lines on a map indicate the direction toward true north while your compass needle indicates the direction toward magnetic north. The angle between these two directions is called magnetic declination.

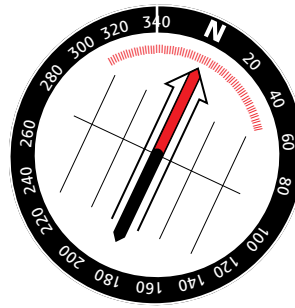
Before navigating you should check your local magnetic declination from a trusted source, such as a recent map or the NOAA website. If the magnetic declination is more than a few degrees, you must compensate for it when navigating.

If your Suunto compass has a fixed declination scale, do the following each time you navigate to a new target.

1. Follow 'Navigate with map and compass' procedure to the end of step 3.
2. Turn left or right until the needle points to the degree of declination on the fixed scale according to your current location.

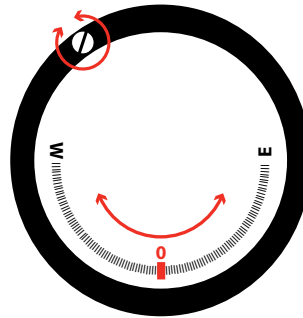


3. Hold the compass steady and turn the capsule to align the orienting arrow with the new needle position.
4. Continue with step 4 of 'Navigate with map and compass' procedure.



If your Suunto compass has adjustable declination, do the following at the start of your navigation.

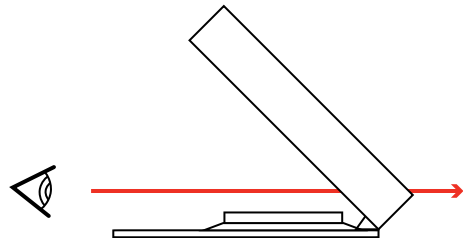
1. Turn the compass over.
2. Insert the metal key into the adjustment screw.
3. Turn the key until the declination indicator is the correct number of degrees east or west of 0°.



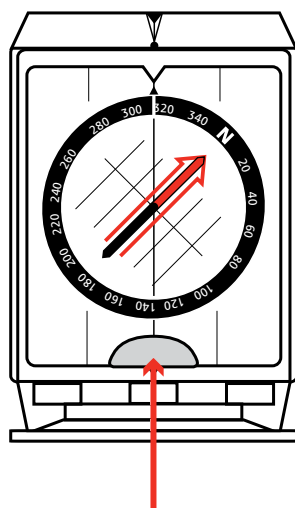
6. Sight a bearing

A bearing is the angle between direction to north and the direction to a target. This can be used for example in communicating directions with others or when finding your location.

1. Open the mirror and hold the compass at eye level so that you can read the capsule from the reflection.



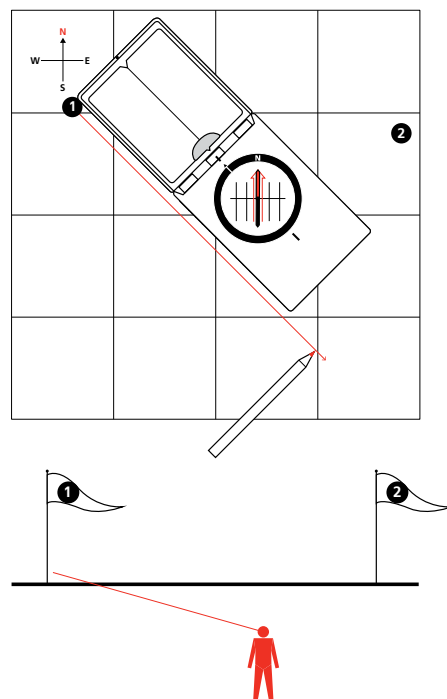
2. Align the target with the sighting notch or hole, keeping the center line on the mirror in line with the center of the capsule.
3. Hold the compass steady and turn the capsule until the orienting arrow and needle are aligned.
NOTE: Compensate for declination. See section 5.
4. If the numerical bearing is needed, read it from the bearing index.



7. Finding your location

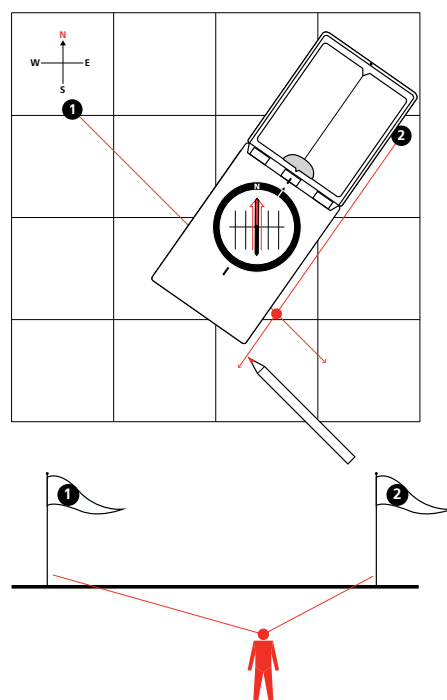
You can sight two or more objects and use triangulation to accurately determine where you are.

1. Find a visible object that is identifiable on your map and follow steps 1-3 of the 'Sight a bearing' procedure.
2. On the map, place the long edge of the compass on the object (1).
3. Turn the compass until the orienting lines and meridian lines are parallel and draw a line from the object.



4. Choose a second object and repeat steps 1-3.

The intersection of the two lines indicates your position, and the closer the angle between the intersecting lines is to 90° , the greater the accuracy.



8. Signal with a mirror

A mirror enables signaling over long distances by flashing sunlight reflected in the mirror.

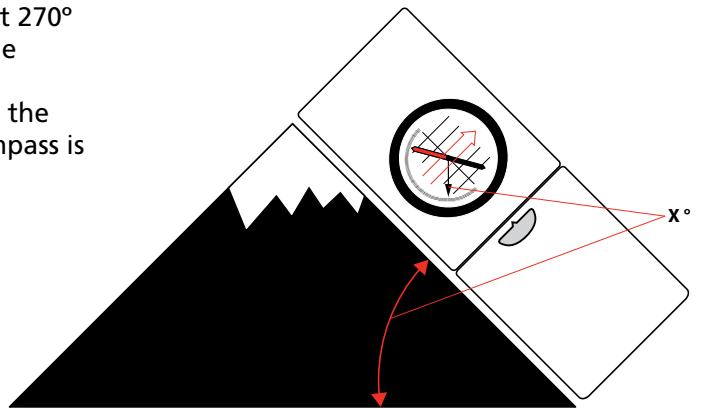
1. Hold two fingers in a V-shape at arm's length so that you see the target between your fingers.
2. Keep the open compass mirror upright close to your eyes and turn the mirror until the reflected sunlight hits your fingers.
3. Rotate the mirror left-to-right to create a flashing signal in the desired direction.

9. Measure slope incline

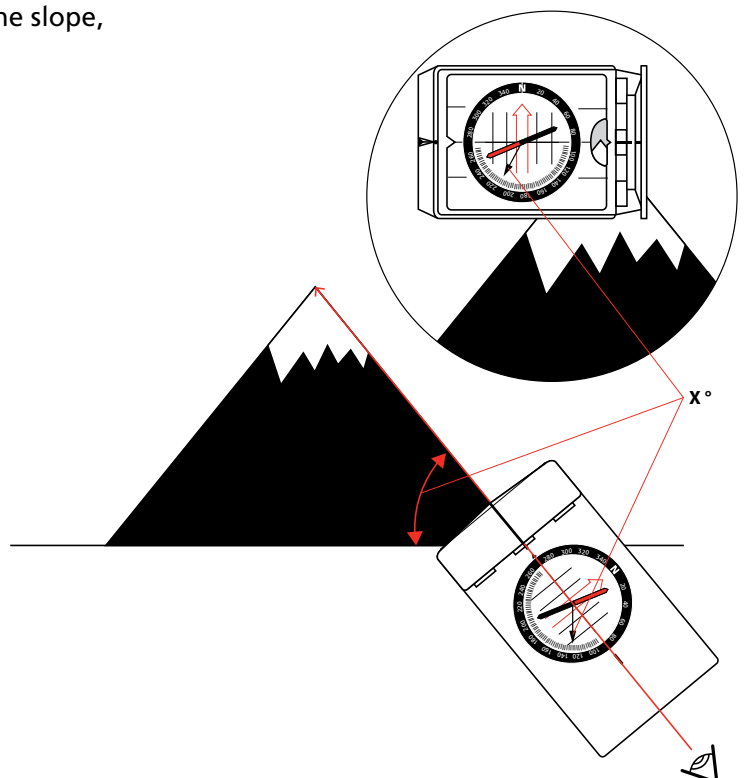
Applies to MC-2 and MC-2 Global only.

The scale for declination correction on the back of the capsule also functions as a scale for the clinometer.

1. Turn the capsule so that the bearing index is at 270° (due West) and tilt compass on its side with the declination scale downwards.
2. If you have a clear view across the slope, align the compass to the slope with the back of the compass is facing you.



3. OR, if you have a clear view up or down the slope, sight the top or the bottom.
4. Read from the clinometer needle to get approximate inclination reading.



10. Care

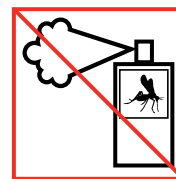
Use only fresh water and mild soap for cleaning. Clean your compass regularly.

Operating/storage temperature:

-30° C - +60° C / -22° F - +140° F



⚠ CAUTION: DO NOT
APPLY SOLVENT OF ANY
KIND.



⚠ CAUTION: DO
NOT APPLY INSECT
REPELLENT.



⚠ CAUTION: DO NOT
KNOCK OR DROP.

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Suunto warrants that during the Warranty Period, as defined below, Suunto or Suunto Authorized Service Center will, at its sole discretion, remedy defects in materials or workmanship free of charge either by a) repairing, or b) replacing with similar product, or c) refunding, subject to the terms and conditions of this International Limited Warranty. This International Limited Warranty does not cover a) wear and tear, b) rough handling, c) modifications, d) exposure to chemicals, or e) misuse. Unless otherwise provided in applicable mandatory legislation, a) this International Limited Warranty is valid and enforceable regardless of the country of purchase, and b) to access the International Limited Warranty service, registration to MySuunto.com and proof of purchase is required. This International Limited Warranty does not affect your legal rights, granted under applicable mandatory legislation on the sale of consumer goods.

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International Limited Lifetime Warranty:

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The International Warranty Period is limited until such reasonable time as the product is no longer reasonably usable due to wear and tear.

International Limited 2-year Warranty:

Applicable to Suunto AIM, Arrow, Orca-Pioneer and KB compasses.

The International Limited Warranty period is two (2) years from the date of original retail purchase.

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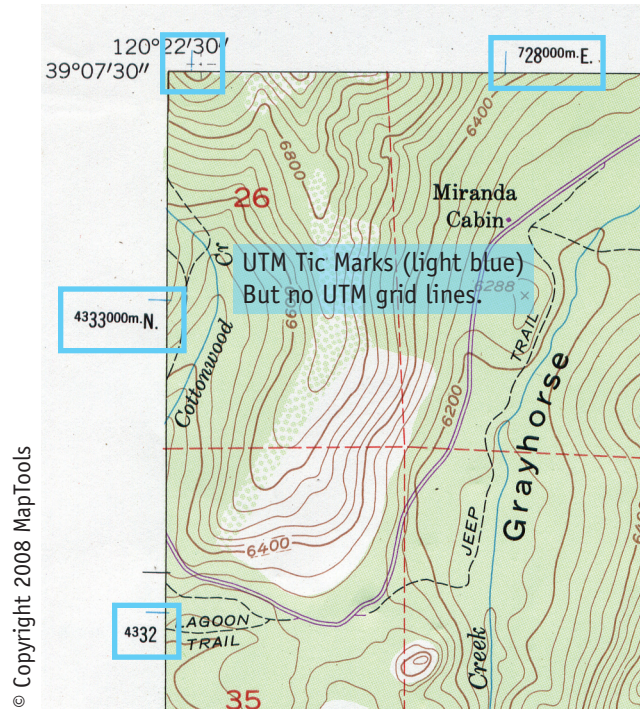
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Maps and Coordinate Systems

Locating Coordinate Grid Information on USGS Maps



© Copyright 2008 MapTools

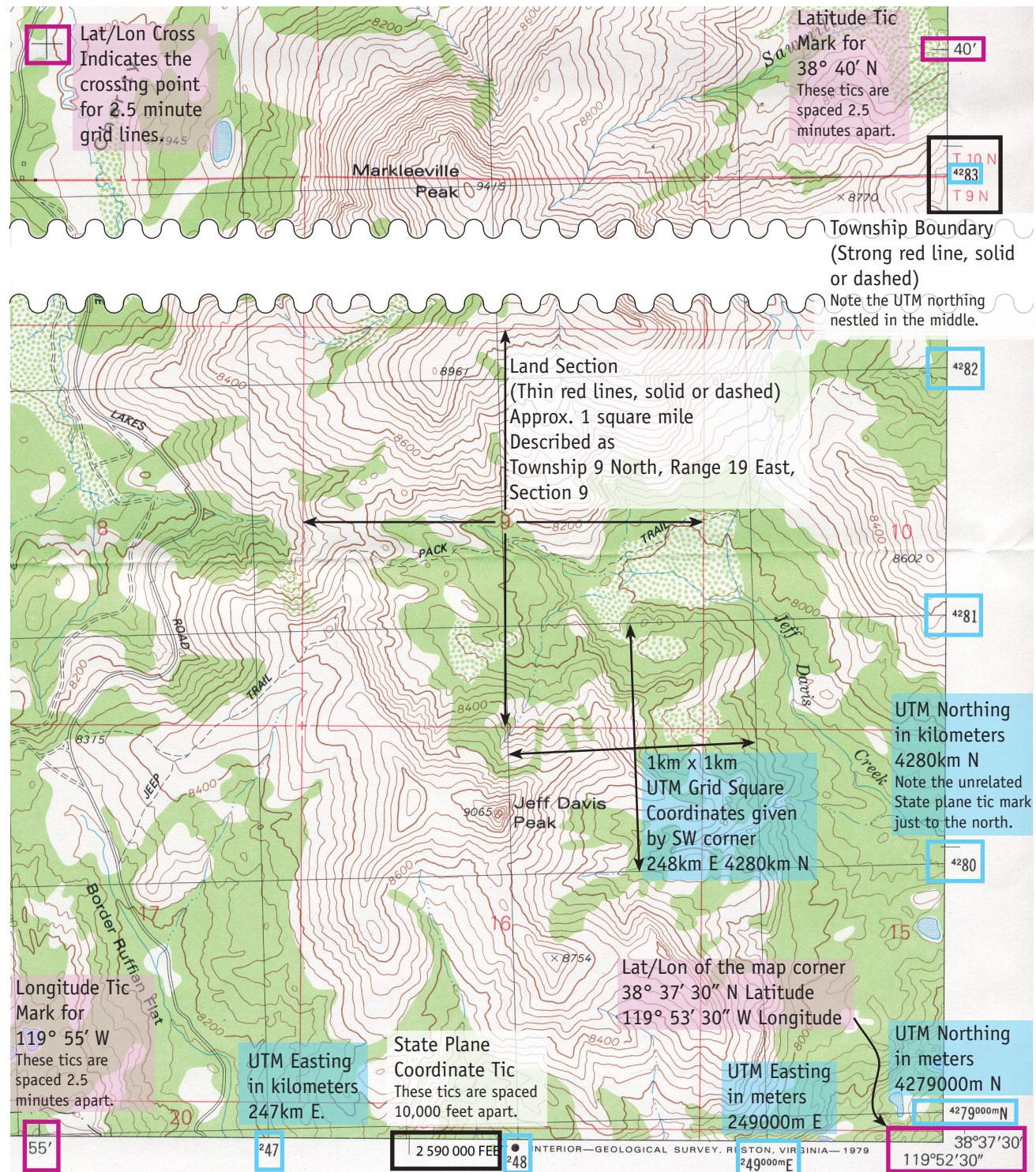
One of the first steps you will need to accomplish, is to locate the coordinate grid you intend to use. The examples shown here are USGS 1:24,000 scale maps, but the notations will be similar on most maps.

UTM 1km Grid Square

Some USGS maps have the 1km UTM grid printed on them using thin black lines spaced 1km apart. See the blue highlighted example to the right. Other USGS maps only have light blue tic marks along the edges of the map, indicating the position of the UTM grid line, but you will need to draw in the grid lines yourself. See the example map above.

Lat/Lon 2.5 Minute Grid Rectangle

If you chose to use lat/lon coordinates you will need to draw in the lat/lon grid lines. You will need to connect the ticks on the edge of the map with the crosses in the interior of the map.



©2008 MapTools

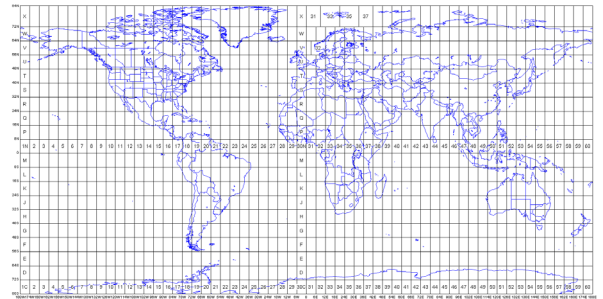
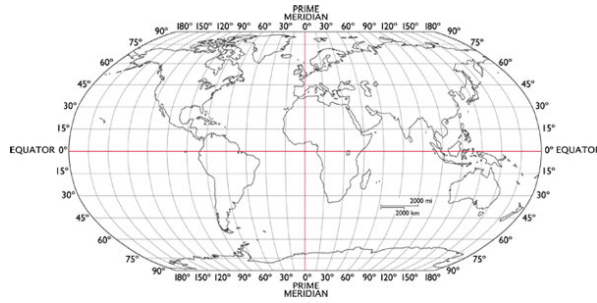


COORDINATES

COORDINATE SYSTEMS

Congratulations on finding your first couple of maps! Now that you have found your map and chose a map scale to print, the next step is learning how to find the coordinates of a locations on that map.

In order to communicate locations we use coordinate systems. The two most common coordinate systems are angular coordinates such as latitude and longitude (below left) and rectangular coordinates such as universal Transverse Mercator (UTM) where we use Northing and Easting (below right).



ANGULAR COORDINATES: LATITUDE AND LONGITUDE

The angular coordinate system uses parallel lines of latitude and meridian lines of longitude to identify points on the globes surface.



Image Source: Encyclopedia Britannica, Inc.

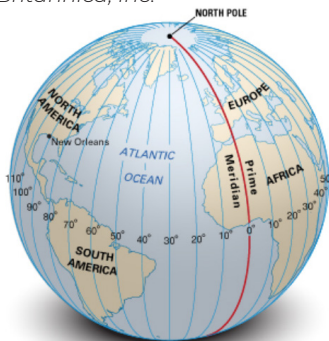


Image Source: Encyclopedia Britannica, Inc.

Latitude – is represented by parallel lines that run east-west and measure distance north-south of the equator. The equator is the 0° line and latitude is measured from 0° to 90° both north and south of the equator.

Putting it into context, you may know that the 49th parallel divides Canada and the USA.

Longitude – is represented by lines that run north and south. These lines measure distance east-west around the globe. The 0° line is known as the Prime Meridian and runs through Greenwich England. The lines are then numbered from 0° to 180° degrees either east or west of the prime meridian.

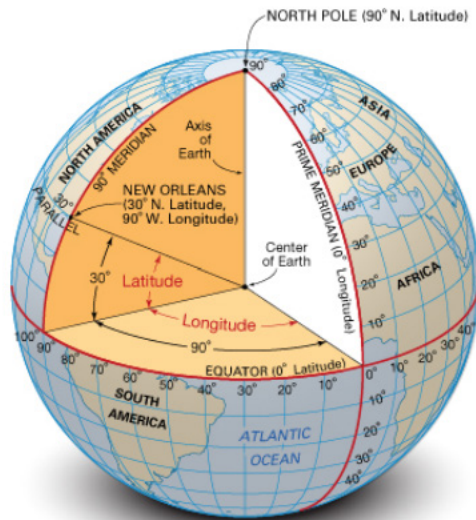


Image Source: Encyclopedia Britannica, Inc.

Together both latitude and longitude can specify a location on the globe. In the image to the left, the location of New Orleans is being shown. Note that if we start at the location where the equator intersects the prime meridian we can navigate west until we hit the meridian line running through New Orleans. Then we can navigate north until we hit the parallel running through New Orleans. As such, the angular coordinates for New Orleans are (30° N, 90°W).

When using angular coordinates, degrees often are too large to convey meaningful measurement to the user. New Orleans for example doesn't actually fall on (30° N, 90°W) but rather (29.957433, -90.062936).

As such, coordinates are generally given in one of two ways. Either Decimal Degrees, DD, (ex 158.2345°) or in Degrees Minutes Seconds, DMS, (ex 158° 14' 4.2"). A degree is broken down into minutes and seconds as follows:

1 degree = 60 minutes

1 minute = 60 seconds

You will notice that Google Maps on your phone or computer gives the coordinates for locations in decimal degrees. But if you are looking at a print map the margins will show degrees, minutes (and sometimes seconds). As such it is helpful to be able to convert between the two.

DD to DMS

1. Take the number before the decimal for Degrees
 $147.8375 = 147^{\circ}$
2. Subtract (1) from starting number, multiply by 60 and keep the number before the decimal as Minutes
 $(147.8375 - 147) = 0.8375 * 60 = 50.25 = 50$
3. Subtract (1) and (2)/60 from starting number, multiply remainder by 3600 for Seconds
 $147.8375 - 147 - (50/60) = 0.004166 * 3600 = 15''$

DMS to DD

The reverse of this is quite simple:

$$147^{\circ} 40' 13'' = 147 + 40/60 + 13/3600 = 147.8375^{\circ}$$



RECTANGULAR COORDINATES: UTM EASTING AND NORTHING

While angular coordinates are great for pilots and seamen traveling long distances, rectangular coordinates will be much easier to use when navigating a comparatively smaller area. Rectangular coordinates were introduced by the military in 1947 for use on large scale mapping projects and has since become the most commonly used form of coordinates for land navigation. This is where you will want to focus your attention as an outdoor enthusiast and here is why:

- Grids are perfectly square
- UTM uses meters as opposed to DMS
- No negative values
- Distances and bearings are very easy to calculate

The UTM system divides the earth into 60 zones each 6 degrees of longitude wide. They are numbered 1 through 60, starting at the international date line, longitude 180°, and proceeding east.

Each zone is then divided into horizontal bands spanning 8° of latitude. These bands are lettered, south to north, beginning at 80° S with the letter C and ending with the letter X at 84° N. The letters I and O are skipped to avoid confusion with the numbers one and zero.

Looking at the map below you can see that the majority of the state of Florida falls in UTM Zone 17F. What zone are you currently living in?

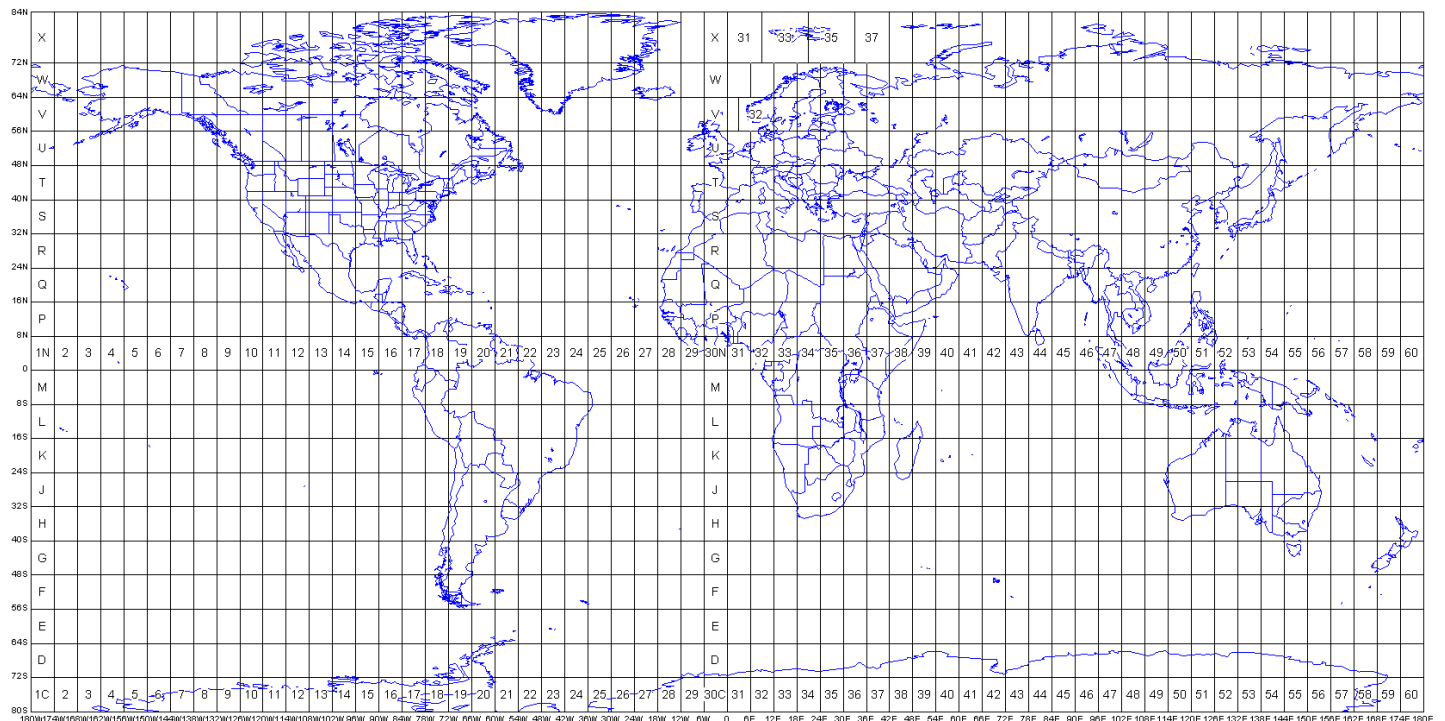
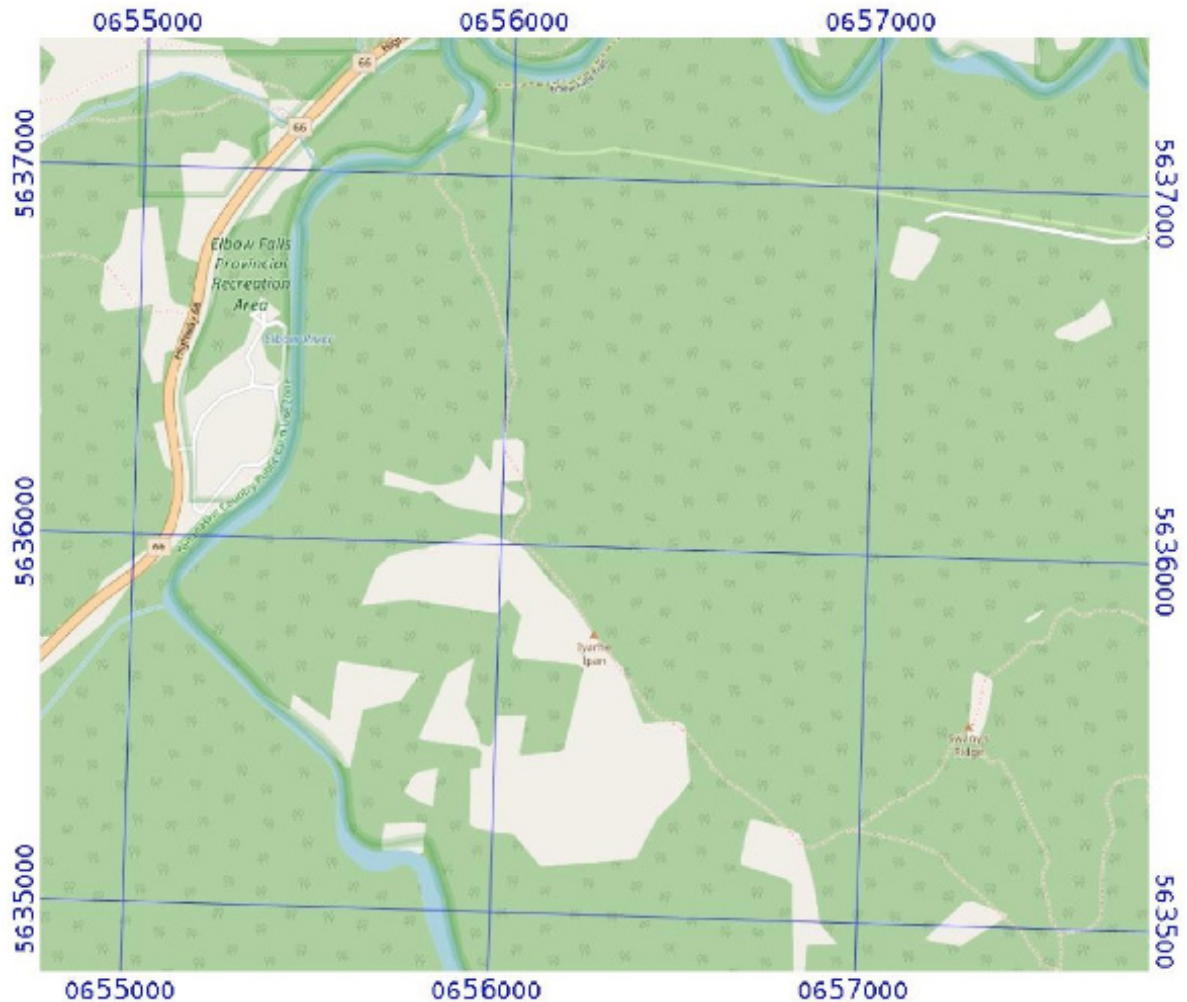


Image Source: Alan Morton



Each zone then has a square grid is superimposed on it. The grid uses units of meters to measure distances north-south(Northing) and east-west (Easting). This system makes it incredibly simple to determine the coordinates of points on a map. Lets have a look at a little map:



Map generated with CalTopo, OSM baselayer, UTM Zone 11U WSG84

Here we can see that a square grid has been superimposed over our map. The lines that run vertically are our eastings, like lines of longitude they give us the east-west position of a point. The near horizontal lines give us our northings which measures the north-south position of a point.

The Iyarhe Ipan Campground near the center of the map can be located using the easting line to the left and the northing below its location as follows: 11U 0656250 m E 5635750 m N. This coordinate pair gives us the position of the campground.

LETS PRACTICE

Follow along with the videos to do a few more examples.

The Universal Transverse Mercator (UTM) Grid

Map Projections

The most convenient way to identify points on the curved surface of the Earth is with a system of reference lines called parallels of latitude and meridians of longitude. On some maps, the meridians and parallels appear as straight lines. On most modern maps, however, the meridians and parallels appear as curved lines. These differences are due to the mathematical treatment required to portray a curved surface on a flat surface so that important properties of the map (such as distance and areal accuracy) are shown with minimum distortion. The system used to portray a part of the round Earth on a flat surface is called a map projection.

Grids

To simplify the use of maps and to avoid the inconvenience of pinpointing locations on curved reference lines, cartographers superimpose on the map a rectangular grid consisting of two sets of straight, parallel lines, uniformly spaced, each set perpendicular to the other. This grid is designed so that any point on the map can be designated by its latitude and longitude or by its grid coordinates, and a reference in one system can be converted into a reference in another system. Such grids are usually identified by the name of the particular projection for which they are designed.

The Universal Transverse Mercator Grid

The National Imagery and Mapping Agency (NIMA) (formerly the Defense Mapping Agency) adopted a special grid for military use throughout the world called the Universal Transverse Mercator (UTM) grid. In this grid, the world is divided into 60 north-south zones, each

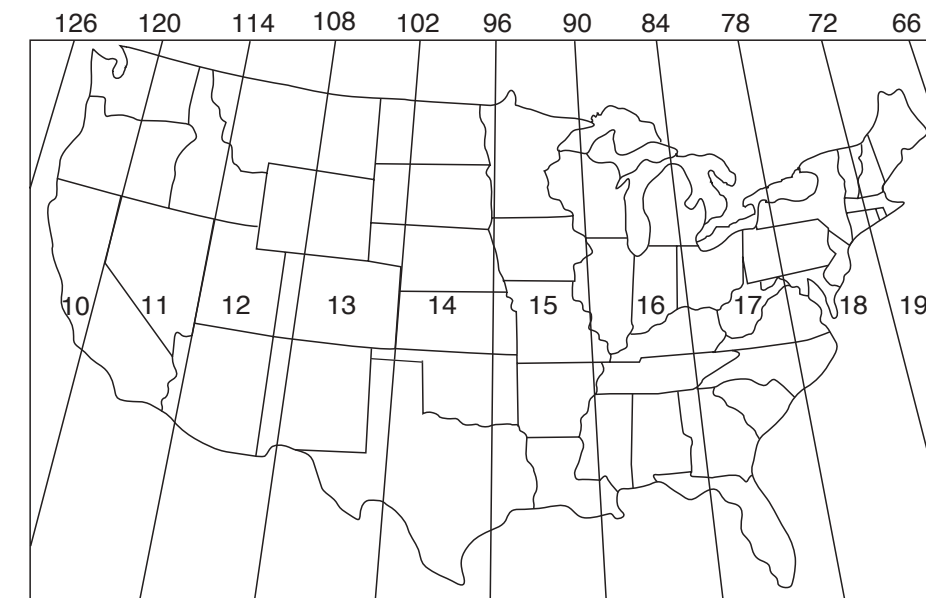


Figure 1. The Universal Transverse Mercator grid that covers the conterminous 48 United States comprises 10 zones—from Zone 10 on the west coast through Zone 19 in New England.

covering a strip 6° wide in longitude. These zones are numbered consecutively beginning with Zone 1, between 180° and 174° west longitude, and progressing eastward to Zone 60, between 174° and 180° east longitude. Thus, the conterminous 48 States are covered by 10 zones, from Zone 10 on the west coast through Zone 19 in New England (fig. 1). In each zone, coordinates are measured north and east in meters. (One meter equals 39.37 inches, or slightly more than 1 yard.) The northing values are measured continuously from zero at the Equator, in a northerly direction. To avoid negative numbers for locations south of the Equator, NIMA's cartographers assigned the Equator an arbitrary false northing value of 10,000,000 meters. A central meridian through the middle of each 6° zone is assigned an easting value of 500,000 meters. Grid values to the west of this central meridian are less than 500,000; to the east, more than 500,000.

Virtually all NIMA-produced topographic maps and many aeronautical charts show the UTM grid lines.

Determining a UTM Grid Value for a Map Point

The UTM grid is shown on all quadrangle maps prepared by the U.S. Geological Survey (USGS). On 7.5-minute quadrangle maps (1:24,000 and 1:25,000 scale) and 15-minute quadrangle maps (1:50,000, 1:62,500, and standard-edition 1:63,360 scales), the UTM grid lines are indicated at intervals of 1,000 meters, either by blue ticks in the margins of the map or with full grid lines. The 1,000-meter value of the ticks is shown for every tick or grid line. In addition, the actual meter value is shown for ticks nearest the southeast and northwest corners of the map. Provisional maps at 1:63,360 scale show full UTM grids at 5,000-meter intervals.

To use the UTM grid, you can place a transparent grid overlay on the map to subdivide the grid, or you can draw lines on the map connecting corresponding ticks on opposite edges. The distances can be measured in meters at the map scale between any map point and the nearest grid lines to the south and west. The northing of the point is the value of the nearest grid line south of it plus its distance north of that line; its easting is the value of the nearest grid line west of it plus its distance east of that line (see fig. 2).

On maps at 1:100,000 and 1:250,000 scale, a full UTM grid is shown at intervals of 10,000 meters and is numbered and used in the same way.

Information

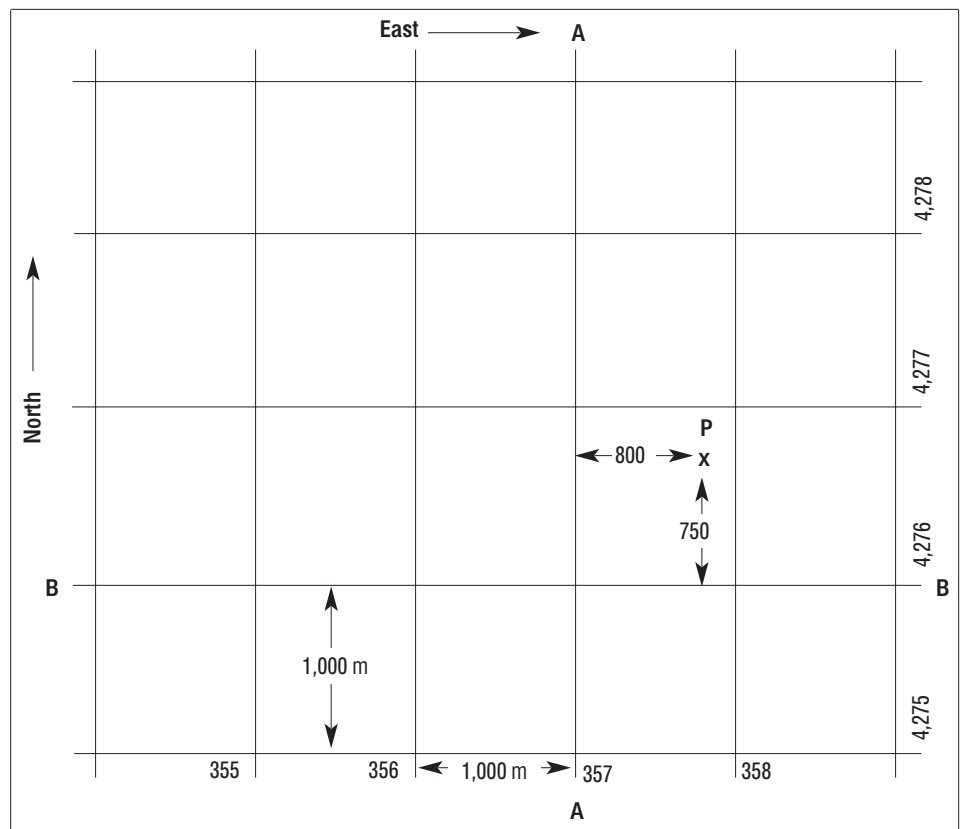


Figure 2. The grid value of line A-A is 357,000 meters east. The grid value of line B-B is 4,276,000 meters north. Point P is 800 meters east and 750 meters north of the grid lines; therefore, the grid coordinates of point P are north 4,276,750 and east 357,800.

For information on these and other USGS products and services, call 1-888-ASK-USGS, use the Ask.USGS fax service, which is available 24 hours a day at 703-648-4888, or visit the general interest publications Web site on mapping, geography, and related topics at mac.usgs.gov/mac/isb/pubs/pubslists/.

For additional information, visit the ask.usgs.gov Web site or the USGS home page at www.usgs.gov.

How to Read US National Grid (USNG) Coordinates

FGDC-STD-011-2001

From www.fgdc.gov/usng

Background. The Federal Geographic Data Committee's (FGDC) consensus based USNG standard provides a nationally consistent *language of location* -- optimized for local applications -- for maps, Global Positioning System (GPS) receivers, and mapping web portals. It is an alpha-numeric point reference system overlaid on the Universal Transverse Mercator (UTM) numerical grid. Truncated USNG coordinates (geoaddresses) range in precision from 1,000 to 1-meter and provide universal map index values for streets and other features. USNG and Military Grid Reference (MGRS) values are identical when referenced to WGS 84 or NAD 83 datum -- USNG only uses a single 100,000-m Square Identification scheme regardless of datum. This example locates the Jefferson Pier at USNG: 18S UJ 23371 06519.

Grid Zone Designation (GZD):

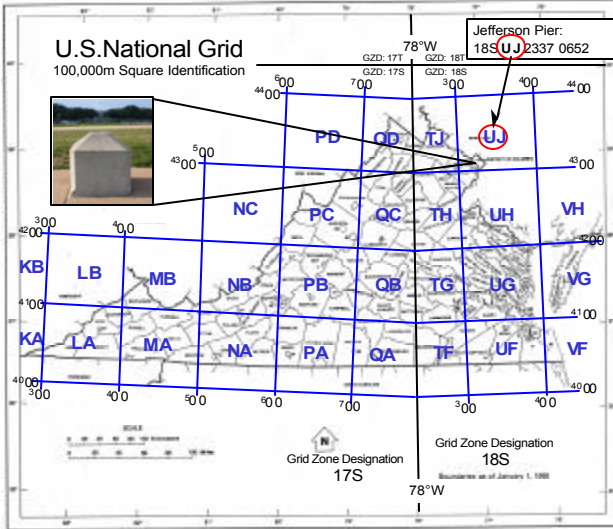
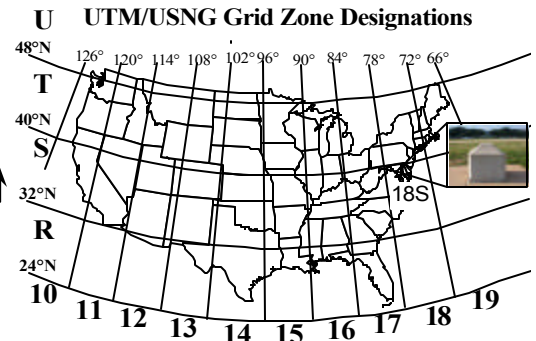
6° x 8° longitude zone / latitude band.

100,000-m Square Identification:

18S UJ 2337 0651

Grid Coordinates:

Read **right**, then **up**.



Users determine the required precision. These values represent a point position (southwest corner) for an area of refinement.

Four digits: 23 06 Locating a point within a 1,000-m square.

Six digits: 233 065 Locating a point within a 100-m square.

Eight digits: 2337 0651 Locating a point within a 10-m square.

Ten digits: 23371 06519 Locating a point within a 1-m square.

Only an 8-digit grid is typically required to locate a modest size home out of a local area.

Full USNG: 18S UJ 2337 0651 - World wide unique.

Without Grid Zone Designation (GZD): UJ 2337 0651 - Regional areas.

Without GZD and 100,000-m Square ID: 2337 0651 - Local areas.

Reading USNG Grid Coordinates.

Principal Digits → 07

- The UTM 10,000 and 1,000 digit values are known as Principal Digits.

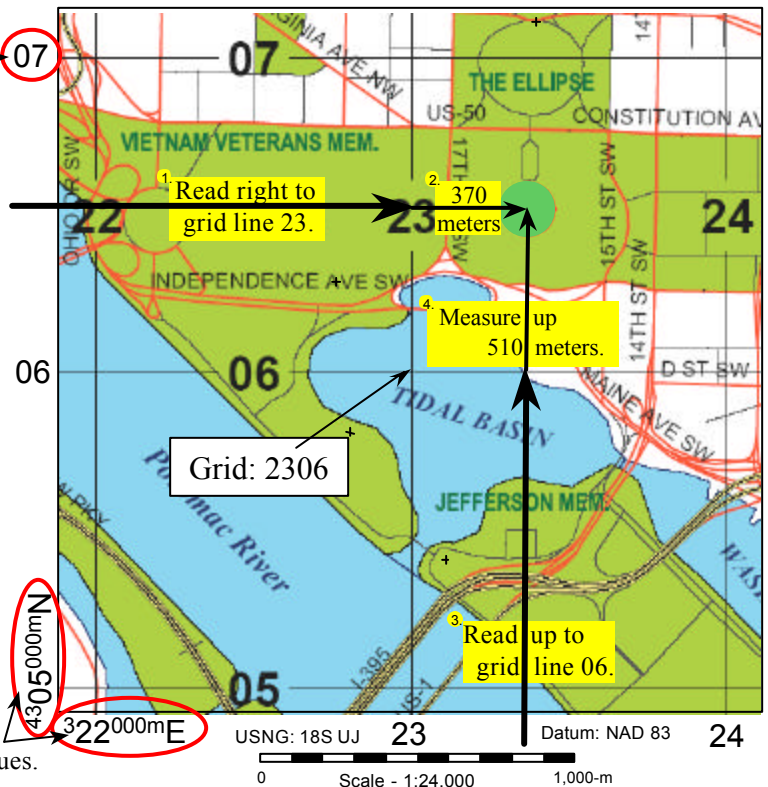
- Coordinates are always given as an even number of digits (i.e. 23370651).

- Divide coordinates in half (2337 0651).

1. Read right to grid line 23. 2. Then measure right another 370 meters. (Think 23.37)

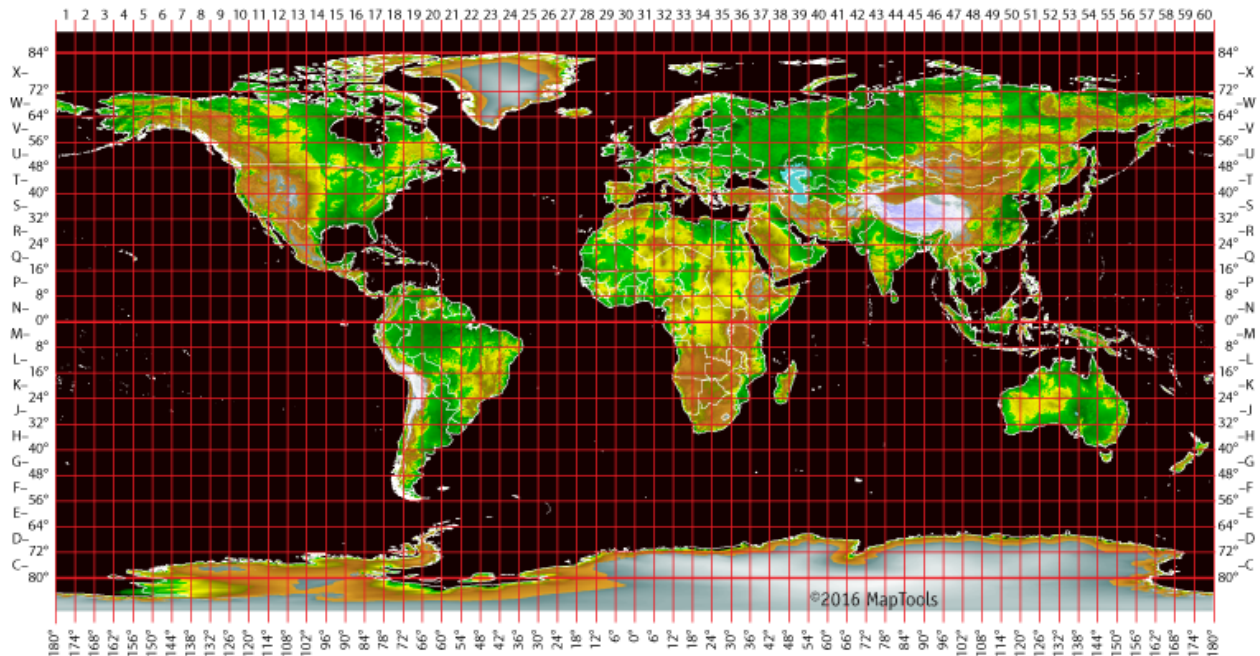
3. Read up to grid line 06. 4. Then measure up another 510 meters. (Think 06.51)

Grid:	Examples:
228058	FDR Memorial: +
231054	George Mason Memorial: +
2338 0710	Zero Milestone: +
2275 0628	DC War Memorial: +
213017	Ft. Scott Park:



More details about UTM Grid Zones

The world's 60 UTM zones

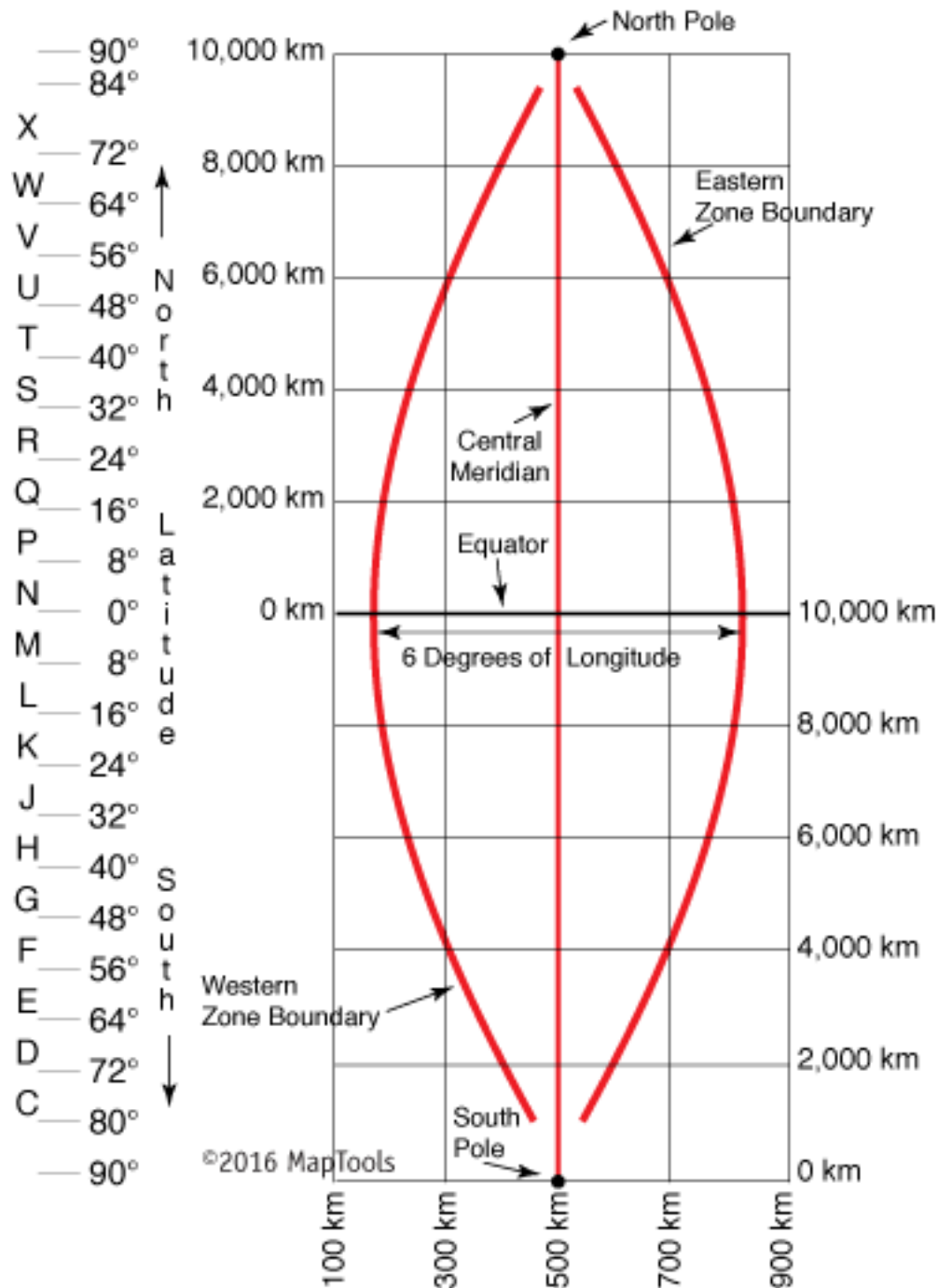


The UTM coordinate system divides the earth into 60 zones each 6 degrees of longitude wide. These zones define the reference point for UTM grid coordinates within the zone. UTM zones extend from a latitude of 80° S to 84° N. In the polar regions the Universal Polar Stereographic (UPS) grid system is used. Note that there are a few exceptions to zone width in Northern Europe to keep small countries in a single zone.

UTM zones are numbered 1 through 60, starting at the international date line, longitude 180°, and proceeding east. Zone 1 extends from 180° W to 174° W and is centered on 177° W.

Each zone is divided into horizontal bands spanning 8 degrees of latitude. These bands are lettered, south to north, beginning at 80° S with the letter C and ending with the letter X at 84° N. The letters I and O are skipped to avoid confusion with the numbers one and zero. The band lettered X spans 12° of latitude.

Eastings and Northings within a zone



A single grid zone measures about 20,000km tall and only about 700km wide. So the above diagram has been compressed in the vertical axis by about 15X. The eastern and western zone boundaries are truly much straighter.

A square grid is superimposed on each zone. It's aligned so that vertical grid lines are parallel to the center of the zone, called the central meridian.

UTM grid coordinates are expressed as a distance in meters to the east, referred to as the "easting", and a distance in meters to the north, referred to as the "northing".

Eastings

UTM easting coordinates are referenced to the center line of the zone known as the central meridian. The central meridian is assigned an easting value of 500,000 meters East. Since this 500,000m value is arbitrarily assigned, eastings are sometimes referred to as "false eastings"

An easting of zero will never occur, since a 6° wide zone is never more than 674,000 meters wide.

Minimum and maximum easting values are:

160,000 mE and 834,000 mE at the equator

465,000 mE and 515,000 mE at 84° N

(Exceptions to this will be found in the unusual zones in northern Europe.)

Northings

UTM northing coordinates are measured relative to the equator. For locations north of the equator the equator is assigned the northing value of 0 meters North. To avoid negative numbers, locations south of the equator are made with the equator assigned a value of 10,000,000 meters North.

Some UTM northing values are valid both north and south of the equator. In order to avoid confusion the full coordinate needs to specify if the location is north or south of the equator. Usually this is done by including the letter for the latitude band.

If this is your first exposure to the UTM coordinate system you may find the layout of zones to be confusing. In most land navigation situations the area of interest is much smaller than a zone. The notion of a zone falls away and we are left with a simple rectangular coordinate system to use with our large scale maps.

Declination

North References for Navigating with Map, Compass and GPS

True North

The True North Pole is the axis of the earth's rotation. The North Star is used as a true north reference. It's position in the sky causes it to appear almost stationary with the other stars rotating around it. Lines or meridians of longitude can also be used as true north reference lines. Meridians of longitude converge at the True North and South Poles. The vertical edges of many maps are defined by a meridian of longitude, and can be used as a true north reference.



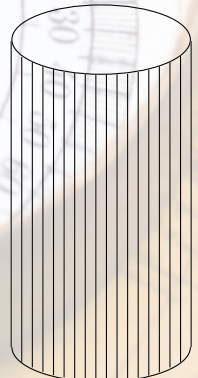
Magnetic North

The magnetic poles are aligned with the earth's magnetic field. A free floating magnetic needle in a compass will align itself with the magnetic field and thus points to the magnetic poles. Declination is the angular difference between true north and magnetic north for a given location. The Magnetic Pole may appear to be either east or west of the True North Pole. Declination changes depending on your position relative to the two poles. Declination also changes over time, because the location of the magnetic poles changes with time. Most GPS receivers will calculate the declination for their current position. This is often referred to as "automatic" north reference.



Grid North

Grid north is useful because it allows you to use the UTM grid lines on your map as your north reference. Grid north is typically within 2° east or west of true north and varies with your position within a UTM zone. When minimal accuracy is all that is required, it is common to treat grid north lines as true north lines without accounting for the small difference.

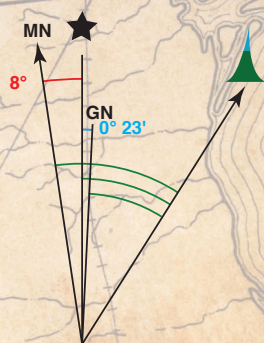
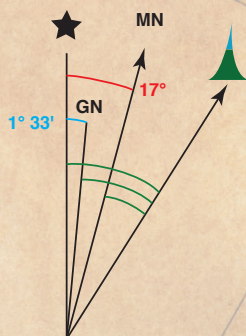


Converting Between North References

The key to converting between the three north references is to add a line representing the bearing to an imaginary target to the declination diagram. Now it is easy to see the different angles measured to the target from each of the north references. Remember the angle is measured from the desired north reference line to the target bearing line. The measured angle's zero degree value is associated with the north reference line and increases in a clockwise direction.

In the example at the right, both magnetic and grid north are east of true north. A true bearing would be 17° larger than a magnetic bearing. Thus to convert from a magnetic bearing to a true bearing you would add 17° .

The angle measured from the target to grid north is also larger than the angle measured from the target to magnetic north. The difference is the 17° angle from true north to magnetic north less the $1^\circ 33'$ angle from true north to grid north. Thus to convert from a magnetic bearing to a grid north reference you would add $15^\circ 27'$. (I would likely round this to $15\ 1/2^\circ$. I might even round to 15° if accuracy was not critical.)



In the example at the left, magnetic north is west of true north and grid north is east of true north. A true bearing would be 8° smaller than a magnetic bearing. Thus to convert from a magnetic bearing to a true bearing you would subtract 8° .

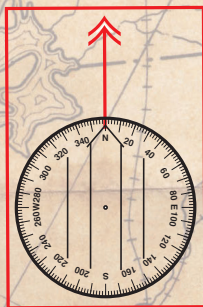
The angle measured from the target to grid north is also smaller than the angle measured from the target to magnetic north. The difference is the 8° angle from true north to magnetic north plus the $0^\circ 23'$ angle from true north to grid north. Thus to convert from a magnetic bearing to a grid north reference you would subtract $8^\circ 23'$. (I would likely round this to $8\ 1/2^\circ$ or just 8° .)

Adjusting the North Reference on Your Compass

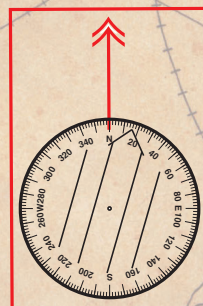
Many compasses allow you to adjust the position of the lines used to align the magnetic needle with respect to the angle measuring dial. The adjustment mechanism is typically either a gear driven one with a small slotted screw and a small brass screwdriver on the lanyard, or a simple friction fit between the capsule and the dial. The choice of adjusting the north reference or not will affect how you work with your compass and should be considered carefully.

Regardless of your decision on whether to adjust the north reference or not, you must occasionally check to see that the compass is set as you expect it to be. This is particularly true for the friction fit mechanisms which may loosen with time and adjust themselves.

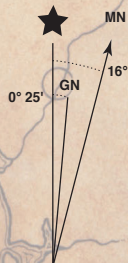
A compass that is not adjusted will read zero degrees when it is aligned with magnetic north. All bearings taken with this compass should be referred to as “magnetic bearings.” Since the compass is a magnetic device this is an intuitive result. It is also the result provided by compasses that cannot be adjusted. To plot a magnetic bearing onto your map you will likely need to convert the bearing to either a true or grid north reference by adding or subtracting the declination for your current location. A baseplate compass can be used as a protractor to plot the bearing on the map. There is no need to change the adjustment based on your location.

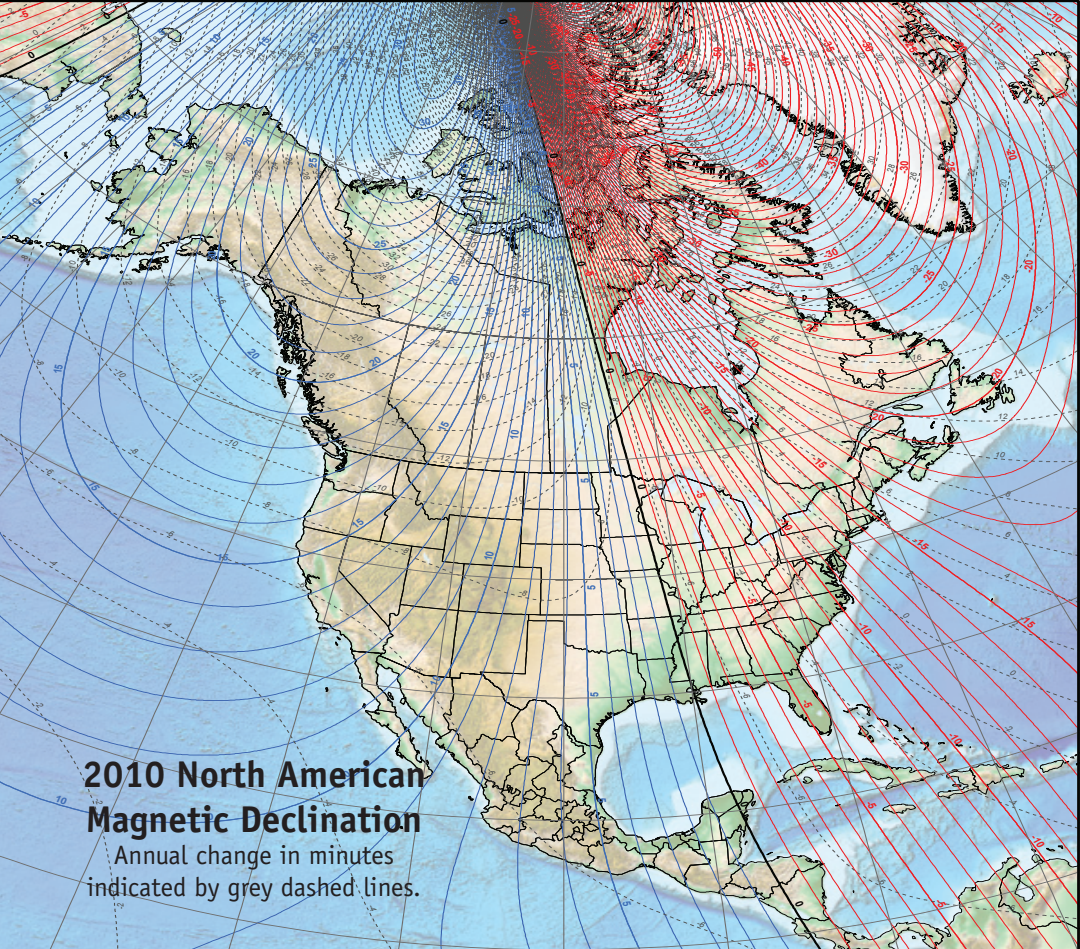


A compass that is adjusted will resemble the declination diagram. The parallel lines in the capsule will be aligned with magnetic north while the zero degree mark on the dial is aligned with either true or grid north. All bearings taken with this compass should be referred to as either “true bearings” or “grid bearings” depending on the north reference you have adjusted to. You will not need to add or subtract values to plot the bearing onto your map. However your baseplate compass cannot be easily used as a protractor to plot or measure on the map, since the parallel capsule lines are not aligned with zero degrees. You will likely want to use a separate protractor. You will also need to remember to change the adjustment to match your current location.



A common trap for beginners occurs when someone adjusts their compass for them, and then they forget what was done and why. An incorrectly adjusted compass is useless for anything beyond a general sense for where north is and may be worse than no compass at all.





Topography and Map Symbols

Topographic Map Symbols

What is a Topographic Map?

A map is a representation of the Earth, or part of it. The distinctive characteristic of a topographic map is that the shape of the Earth's surface is shown by contour lines. Contours are imaginary lines that join points of equal elevation on the surface of the land above or below a reference surface, such as mean sea level. Contours make it possible to measure the height of mountains, depths of the ocean bottom, and steepness of slopes.

A topographic map shows more than contours. The map includes symbols that represent such features as streets, buildings, streams, and vegetation. These symbols are constantly refined to better relate to the features they represent, improve the appearance or readability of the map, or reduce production cost.

Consequently, within the same series, maps may have slightly different symbols for the same feature. Examples of symbols that have changed include built-up areas, roads, intermittent drainage, and some lettering styles. On one type of large-scale topographic map, called provisional, some symbols and lettering are hand-drawn.

Reading Topographic Maps

Interpreting the colored lines, areas, and other symbols is the first step in using topographic maps. Features are shown as points, lines, or areas, depending on their size and extent. For example, individual houses may be shown as small black squares. For larger buildings, the actual shapes are mapped. In densely built-up areas, most individual buildings are omitted and an area tint is shown. On some maps, post offices, churches, city halls, and other landmark buildings are shown within the tinted area.

The first features usually noticed on a topographic map are the area features, such as vegetation (green), water (blue), and densely built-up areas (gray or red).

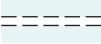
Many features are shown by lines that may be straight, curved, solid, dashed, dotted, or in any combination. The colors of the lines usually indicate similar classes of information: topographic contours (brown); lakes, streams, irrigation ditches, and other hydrographic features (blue); land grids and important roads (red); and other roads and trails, railroads, boundaries, and other cultural features (black). At one time, purple was used as a revision color to show all feature changes. Currently, purple is not used in our revision program, but purple features are still present on many existing maps.

Various point symbols are used to depict features such as buildings, campgrounds, springs, water tanks, mines, survey control points, and wells. Names of places and features are shown in a color corresponding to the type of feature. Many features are identified by labels, such as "Substation" or "Golf Course."

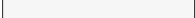
Topographic contours are shown in brown by lines of different widths. Each contour is a line of equal elevation; therefore, contours never cross. They show the general shape of the terrain. To help the user determine elevations, index contours are wider. Elevation values are printed in several places along these lines. The narrower intermediate and supplementary contours found between the index contours help to show more details of the land surface shape. Contours that are very close together represent steep slopes. Widely spaced contours or an absence of contours means that the ground slope is relatively level. The elevation difference between adjacent contour lines, called the contour interval, is selected to best show the general shape of the terrain. A map of a relatively flat area may have a contour interval of 10 feet or less. Maps in mountainous areas may have contour intervals of 100 feet or more. The contour interval is printed in the margin of each U.S. Geological Survey (USGS) map.

Bathymetric contours are shown in blue or black, depending on their location. They show the shape and slope of the ocean bottom surface. The bathymetric contour interval may vary on each map and is explained in the map margin.

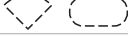
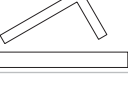
BATHYMETRIC FEATURES

Area exposed at mean low tide; sounding datum line***	
Channel***	
Sunken rock***	

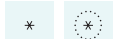
BOUNDARIES

National	
State or territorial	
County or equivalent	
Civil township or equivalent	
Incorporated city or equivalent	
Federally administered park, reservation, or monument (external)	
Federally administered park, reservation, or monument (internal)	
State forest, park, reservation, or monument and large county park	
Forest Service administrative area*	
Forest Service ranger district*	
National Forest System land status, Forest Service lands*	
National Forest System land status, non-Forest Service lands*	
Small park (county or city)	

BUILDINGS AND RELATED FEATURES

Building	
School; house of worship	
Athletic field	
Built-up area	
Forest headquarters*	
Ranger district office*	
Guard station or work center*	
Racetrack or raceway	
Airport, paved landing strip, runway, taxiway, or apron	
Unpaved landing strip	
Well (other than water), windmill or wind generator	
Tanks	
Covered reservoir	
Gaging station	
Located or landmark object (feature as labeled)	
Boat ramp or boat access*	
Roadside park or rest area	
Picnic area	
Campground	
Winter recreation area*	
Cemetery	

COASTAL FEATURES

Foreshore flat	
Coral or rock reef	
Rock, bare or awash; dangerous to navigation	
Group of rocks, bare or awash	
Exposed wreck	
Depth curve; sounding	
Breakwater, pier, jetty, or wharf	
Seawall	
Oil or gas well; platform	

CONTOURS

Topographic

Index	
Approximate or indefinite	
Intermediate	
Approximate or indefinite	
Supplementary	
Depression	
Cut	
Fill	
Continental divide	

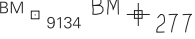
Bathymetric

Index***	
Intermediate***	
Index primary***	
Primary***	
Supplementary***	

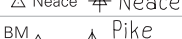
CONTROL DATA AND MONUMENTS

Principal point**	
U.S. mineral or location monument	
River mileage marker	

Boundary monument

Third-order or better elevation, with tablet	
Third-order or better elevation, recoverable mark, no tablet	
With number and elevation	

Horizontal control

Third-order or better, permanent mark	
With third-order or better elevation	
With checked spot elevation	
Coincident with found section corner	
Unmonumented**	

CONTROL DATA AND MONUMENTS – *continued*

Vertical control		
Third-order or better elevation, with tablet	BM	✕ 5280
Third-order or better elevation, recoverable mark, no tablet		✕ 528
Bench mark coincident with found section corner	BM	 5280
Spot elevation		✕ 7523

GLACIERS AND PERMANENT SNOWFIELDS

Contours and limits	
Formlines	
Glacial advance	
Glacial retreat	

LAND SURVEYS

Public land survey system		
Range or Township line		
Location approximate		
Location doubtful		
Protracted		
Protracted (AK 1:63,360-scale)		
Range or Township labels	R1E T2N R3W T4S	
Section line		
Location approximate		
Location doubtful		
Protracted		
Protracted (AK 1:63,360-scale)		
Section numbers	1 - 36	1 - 36
Found section corner		
Found closing corner		
Witness corner		
Meander corner		
Weak corner*		

Other land surveys

Range or Township line		
Section line		
Land grant, mining claim, donation land claim, or tract		
Land grant, homestead, mineral, or other special survey monument		
Fence or field lines		

MARINE SHORELINES

Shoreline	
Apparent (edge of vegetation)***	
Indefinite or unsurveyed	

MINES AND CAVES

Quarry or open pit mine		✕
Gravel, sand, clay, or borrow pit		✕
Mine tunnel or cave entrance		✕
Mine shaft		■
Prospect		x
Tailings		
Mine dump		
Former disposal site or mine		

PROJECTION AND GRIDS

Neatline		39°15' 90°37'30"
Graticule tick		55'
Graticule intersection		
Datum shift tick		

State plane coordinate systems

Primary zone tick		640 000 FEET
Secondary zone tick		247 500 METERS
Tertiary zone tick		260 000 FEET
Quaternary zone tick		98 500 METERS
Quintary zone tick		320 000 FEET

Universal transverse metcator grid

UTM grid (full grid)		273
UTM grid ticks*		269

RAILROADS AND RELATED FEATURES

Standard guage railroad, single track	
Standard guage railroad, multiple track	
Narrow guage railroad, single track	
Narrow guage railroad, multiple track	
Railroad siding	
Railroad in highway	
Railroad in road	
Railroad in light duty road*	
Railroad underpass; overpass	
Railroad bridge; drawbridge	
Railroad tunnel	
Railroad yard	
Railroad turntable; roundhouse	

RIVERS, LAKES, AND CANALS

Perennial stream		
Perennial river		
Intermittent stream		
Intermittent river		
Disappearing stream		
Falls, small		
Falls, large		
Rapids, small		
Rapids, large		
Masonry dam		
Dam with lock		
Dam carrying road		

RIVERS, LAKES, AND CANALS – *continued*

Perennial lake/pond	
Intermittent lake/pond	
Dry lake/pond	
Narrow wash	
Wide wash	
Canal, flume, or aqueduct with lock	
Elevated aqueduct, flume, or conduit	
Aqueduct tunnel	
Water well, geyser, fumarole, or mud pot	
Spring or seep	

ROADS AND RELATED FEATURES

Please note: Roads on Provisional-edition maps are not classified as primary, secondary, or light duty. These roads are all classified as improved roads and are symbolized the same as light duty roads.

Primary highway	
Secondary highway	
Light duty road	
Light duty road, paved*	
Light duty road, gravel*	
Light duty road, dirt*	
Light duty road, unspecified*	
Unimproved road	
Unimproved road*	
4WD road	
4WD road*	
Trail	
Highway or road with median strip	
Highway or road under construction	
Highway or road underpass; overpass	
Highway or road bridge; drawbridge	
Highway or road tunnel	
Road block, berm, or barrier*	
Gate on road*	
Trailhead*	

SUBMERGED AREAS AND BOGS

Marsh or swamp	
Submerged marsh or swamp	
Wooded marsh or swamp	
Submerged wooded marsh or swamp	
Land subject to inundation	

SURFACE FEATURES

Levee	
Sand or mud	
Disturbed surface	
Gravel beach or glacial moraine	
Tailings pond	

TRANSMISSION LINES AND PIPELINES

Power transmission line; pole; tower	
Telephone line	
Aboveground pipeline	
Underground pipeline	

VEGETATION

Woodland	
Shrubland	
Orchard	
Vineyard	
Mangrove	

* USGS-USDA Forest Service Single-Edition Quadrangle maps only.
In August 1993, the U.S. Geological Survey and the U.S. Department of Agriculture’s Forest Service signed an Interagency Agreement to begin a single-edition joint mapping program. This agreement established the coordination for producing and maintaining single-edition primary series topographic maps for quadrangles containing National Forest System lands. The joint mapping program eliminates duplication of effort by the agencies and results in a more frequent revision cycle for quadrangles containing National Forests. Maps are revised on the basis of jointly developed standards and contain normal features mapped by the USGS, as well as additional features required for efficient management of National Forest System lands. Single-edition maps look slightly different but meet the content, accuracy, and quality criteria of other USGS products.

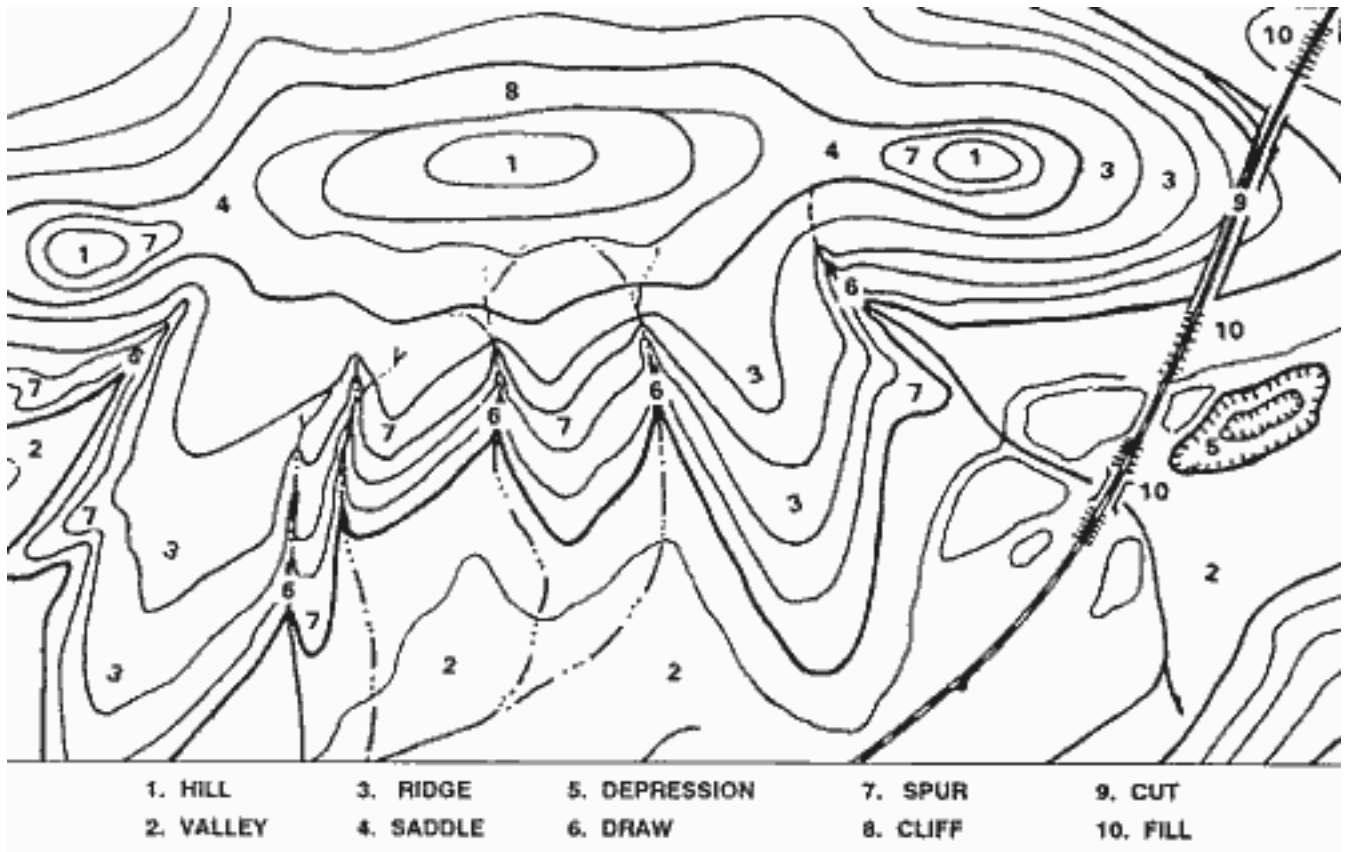
** Provisional-Edition maps only.
Provisional-edition maps were established to expedite completion of the remaining large-scale topographic quadrangles of the conterminous United States. They contain essentially the same level of information as the standard series maps. This series can be easily recognized by the title “Provisional Edition” in the lower right-hand corner.

*** Topographic Bathymetric maps only.

Topographic Map Information

For more information about topographic maps produced by the USGS, please call: 1-888-ASK-USGS or visit us at <http://ask.usgs.gov/>

This example of a very simple topographic map shows many common features. Keep your eyes open to see these features on other maps and you will start to understand how a topo map works.



Even without elevation numbers, clues that #1 is a hill include streams converging away from the hilltop, contour lines pointing sharply towards the hilltop (indicating draws), contour lines pointing widely away from the hilltop (indicating rounded ridges).

Contour Lines

Contour lines are the primary and most important feature on a topo map. They show the shape of the terrain, including its hills, slopes, and depressions, by tracing a constant line of elevation on the map that corresponds with the landscape in the real world. Think of contour lines as imaginary horizontal planes sliced through the terrain surface.

Visualizing Contour Lines

It may be helpful to visualize contour lines as stacked “layers” of the landscape, similar to a layer cake. A large mountain appears as a dense group of lines with a small circle in the center that represents the peak—just picture looking down at a wedding cake from above. Areas with few contours appear relatively flat—more like a 2-tier birthday cake. A topo map provides a bird’s eye view of those concentric circles, allowing you to “see” both the height and shape of the mountain on the map.



From the [USGS Topo on Gaia GPS](#), the summit of Pu'umakanaka, Hawaii is a near-perfect cone as indicated by the evenly spaced and round contour lines. Notice the tick marks on the contour lines in the center of the map. Those marks indicate a crater or depression at the summit.

Knuckle Mountain

Try this quick exercise at home to get a better understanding of contour lines:

1. Make a fist with your hand, taking note of the “features” on your fist. There are four knobs (knuckles), a gentle slope (back of your hand), and four small ridges (fingers) separated by ravines (space between the fingers).
2. With your other hand, mark an “x” on the knuckle that sticks up the highest to mark the “summit.” Using a pen, drop down from the summit a quarter-inch and make a contour line around the peak of “knuckle mountain.” Follow the elevation around the mountain, without dropping or climbing, until you complete the contour line and close the circle. Drop down another quarter of an inch and repeat. Do that again and again, until you’ve mapped out your entire fist.
3. Next, lay your hand flat with your palm on the table. Find the spread out contour lines on the back of your hand, indicating a gentle slope. Notice the “v” shaped topo lines where the ravines were between your fingers. The areas by your fingers have contour lines that are close together, indicating steepness. Find an hourglass-shaped topo line for the saddle between your knuckles.



Reading Slope Steepness on a Topo Map

Contour lines present in very predictable ways on the map. When the slope is gentle, the contour lines are spread far apart. Conversely, when the slope is steep the contour lines pack closely together. On a cliff, the contour lines are stacked on top of each other. A flat meadow is void of contour lines.

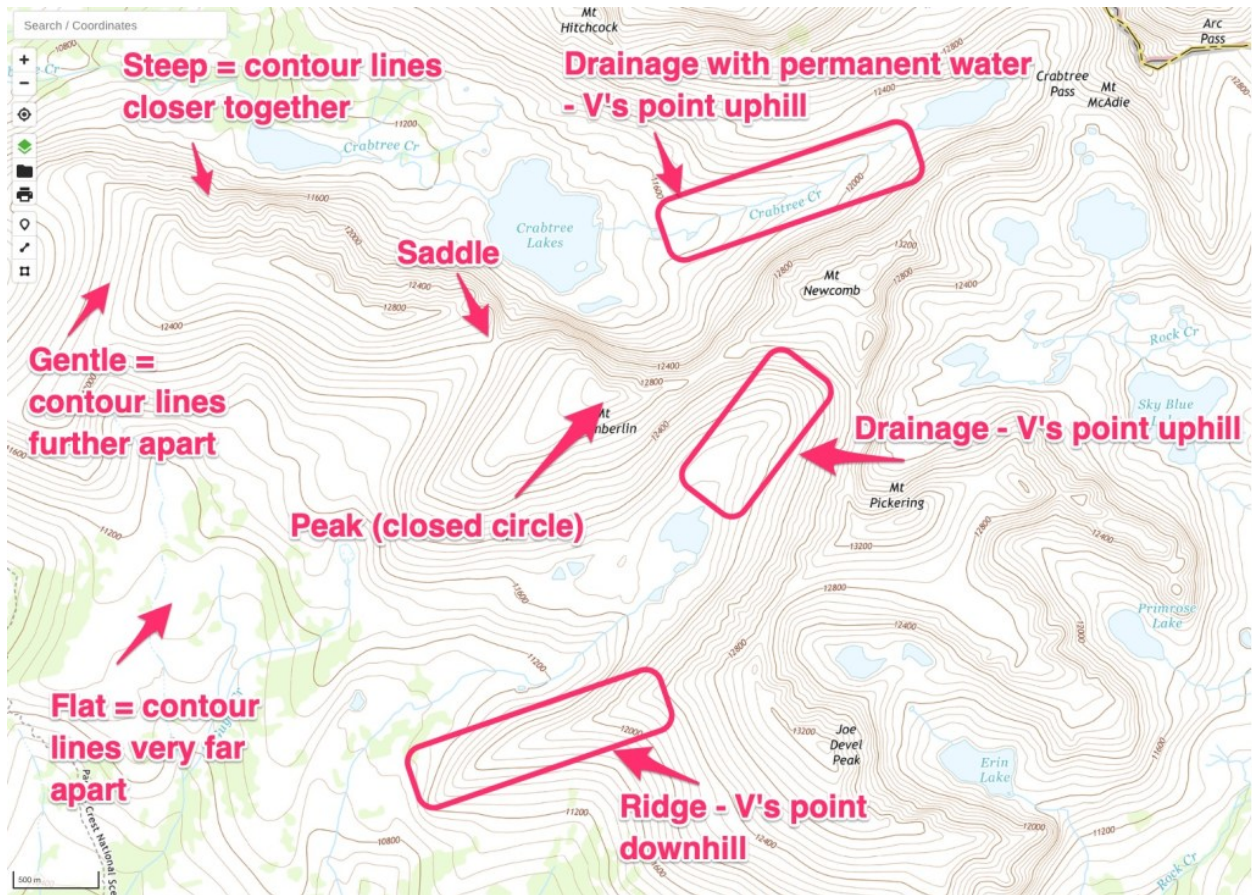


California's Mount Whitney, at 14,505 feet, the tallest mountain in the lower 48 states, is steep on its east face as indicated by the closely spaced contour lines. Whitney's west face is marked by low-angle slopes, as depicted by the wide-spaced contour lines.

Identifying Features with Contour Lines

Contour lines show more than just the steepness of a slope or the elevation of a peak. You can pick out major land features on the map by the way the contour lines are shaped.

- **Peak:** A mountain or hill that is marked by concentric contour lines. The summit may be marked with a name, an "X", or an elevation.
- **Valley:** A landform with a depression in which water, if present, would flow down. Also known as gullies, drainages, ravines, and couloirs, valleys are indicated by "V" or "U" shaped contour lines that "point" uphill, toward higher elevation.
- **Ridge:** A landform with an elevated crest that slopes down on the sides. Ridges are also shown by "V" or "U" shaped contours, but these "point" downhill, toward lower elevations. Remember, water never runs along ridge tops.
- **Saddle:** A low spot between two peaks marked by hourglass-shaped contour lines.



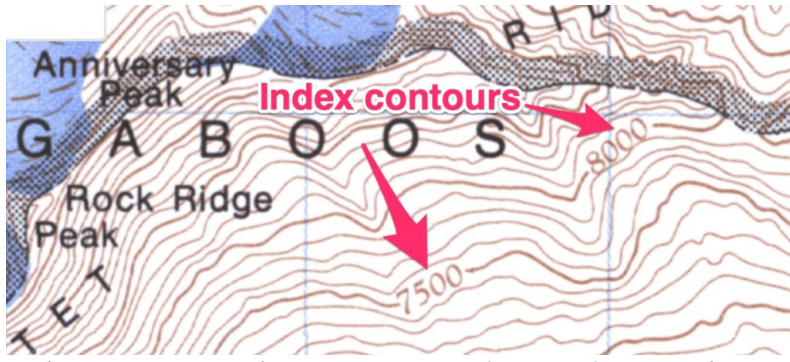
Basic topographic landforms (peak, saddle, ridge, drainage) and a comparison of relative steepness as seen on [US Topo](https://www.gaiagps.com) in [gaiagps.com](https://www.gaiagps.com).



Basic landforms on Thompson Peak, Idaho.

Contour Intervals and Index Marker

The contour interval is the amount of elevation change between each contour line. Contour intervals vary from map to map. Intervals set at 40-feet are common on 1:24,000 scale maps. But many maps, especially small scale maps, have 50-foot or 100-foot intervals. Index contours are the more prominent, bold colored lines with the elevation marked on them.



Index contours on the [NRCAN Canada Topo layer](#). Index contours are every 5th line, and there are 500 feet between index contours, so the contour interval is 100 feet.

Discover the contour interval in two ways:

1. Find the contour interval on the map margin or legend, or
2. Calculate the contour interval between index contours, which are the more prominent, bold-colored lines with the elevation marked on them. First, subtract the lower number from the higher number and then divide the result by the number of contour lines. For example, if the index contours elevations are 8000 and 7500 feet as shown in the picture above, the difference is 500 feet. If every fifth line is bold, then divide by 5. The contour interval is 100 feet.

Topo Map Scales

Map scale is important because it tells you how detailed a topo will be. Map scale is defined as one single unit of measurement equal to a definitive number of *the same* number of units in the real world. You'll find the map scale written as a ratio in the bottom margin of a topo map.

Map scales vary greatly across different topo maps, but the most common scale is 1:24,000 for topo maps created in the United States. On a 1:24,000 scale map, 1 inch on the map is representative of 24,000 inches, or 2000 feet, on the ground. The United States Geological Survey quadrangle maps are scaled to 1:24,000. These are large scale maps and bring a lot of detail into focus.

A map scale of 1:63,360 is common in Forest Service maps, and maps throughout Alaska. These are smaller-scale maps, with less intricate detail. Some National Geographic maps use a scale of 1:65,000, which allows a large area of land to be packed onto a single topo map.

What you need to know is that the bigger the number on the bottom of the ratio, the smaller the scale and the less detail:

- 1:24,000= a large scale map that depicts a smaller region of land in intricate detail

Bearings, Distances, Elevation and Map Use

Plotting a bearing onto your map

- Bearings, Azimuths, Headings, and Course
- Some reasons to plot bearings onto your map
 - Location by Resectioning or "Where am I?"
 - Location by Intersection or "Where is the _____ that I can see in the distance?"
 - Plotting straight line course segments for route finding
- The example problem used in this tutorial
- Understand your north references
- Understanding forward and back bearings
- Techniques for plotting a bearing:
 - Plotting a bearing using a protractor (/tutorials/plotting/protractor)
 - Plotting a bearing using a baseplate compass (/tutorials/plotting/compass)
 - Plotting a bearing using a baseplate compass adjusted for declination (/tutorials/plotting/compass-declination)
 - Plotting a bearing using a straight edged lensatic compass (/tutorials/plotting/straight-lensatic)
 - Plotting a bearing using a round lensatic compass (/tutorials/round-lensatic)
- Plotting a second and third bearing to confirm your position (/tutorials/plotting/more-bearings-to-confirm-location)
- Using bearings to locate a distant target (/tutorials/plotting/bearings-to-locate-target)
- Some exercises to download and try
 - Plotting Bearings Exercise Map
(../bundles/maptoolsstaticpages/pdfs/tutorials/compass/PlottingExerciseMap.pdf)
This file is just the map. The description of the problem and the answers are in the lecture slides. (see link below) Here is the map with the answers plotted Plotting Bearings Answers
(../bundles/maptoolsstaticpages/pdfs/tutorials/compass/PlottingExerciseAnswers.pdf)
 - Locating the Smoke Exercise
(../bundles/maptoolsstaticpages/pdfs/tutorials/compass/LocateTheSmoke.pdf) This is a complete exercise for locating an unknown location using intersecting bearings. This is the answer map.
(../bundles/maptoolsstaticpages/pdfs/tutorials/compass/LocateTheSmokeAnswer.pdf)
There is also a set of lecture slides (/teaching_resources#LocateTheSmoke) for this exercise.
- Lecture Slides for this topic are available from the Resources for Navigation Instructors (/teaching_resources#PlottingABearing) page.

There are many different scenarios that lead to plotting a bearing on a map. Most of them involve a known location, an unknown location, and a north reference. The bearing is the angle formed by two lines that start from the point the measurement is made. One line extends from this point towards

North. The other line extends from this point to some distant target. The point at which the measurement is made may be either the known or unknown location.

A single known point and a bearing, is not enough information to determine the location of the unknown point. It will define a line along which the unknown point is located. To locate the unknown point we need at least one more piece of information. That could be another bearing from a different known point. Or it could be a distance from the original known point. Or it could be a map feature that we know the unknown point is located along, like a road, trail, or stream, or a contour line of a given elevation.



A bearing from a known location X to an unknown location ?, measured relative to a north reference line.

Bearings, Azimuths, Headings, and Course

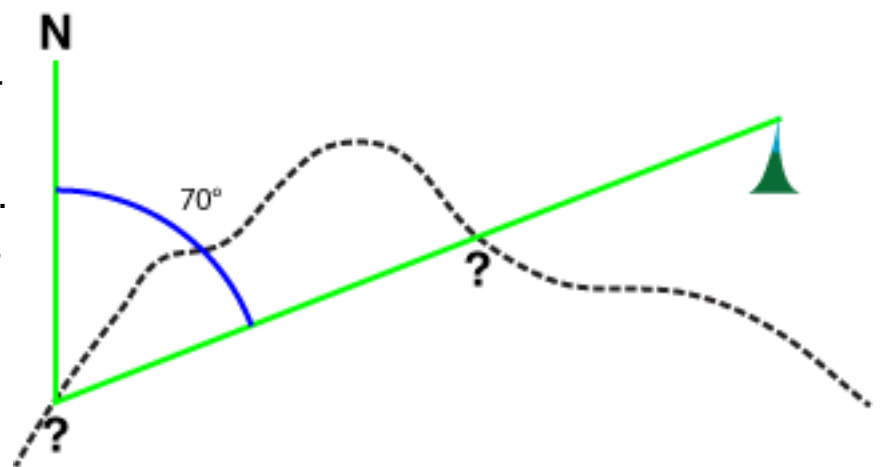
The disciplines of navigation, surveying, and astronomy all have slightly different definitions of these terms. Here are some simple definitions that will serve you well for land navigation.

- Bearing - A horizontal arc or angle measured from a north reference line, in a clockwise direction, to a point of interest some distance away from the point of measurement. In land navigation the terms bearing and azimuth are interchangeable.
- Azimuth - See bearing. In land navigation the terms bearing and azimuth are interchangeable.
- Heading - Your forward facing direction of travel. In air and sea navigation heading refers to the forward facing direction of your aircraft or vessel.
- Course - Your desired direction of travel. Your course will be different from your heading when you are "off-course." In air and sea navigation, your course or "course over ground" is the direction of travel of your aircraft or vessel. Here your course may differ from your heading due to influences of wind and current. This is rarely a problem when navigating by foot.

Some reasons to plot bearings onto your map

Location by Resectioning or "Where am I?"

If you can see at least two and preferably three locations that you can identify on your map, you can take compass bearings to these locations, and plot them on your map. Your location will be where the bearing lines cross.



It is often difficult to identify more than one known location that you can see. In this case you can often combine other information about your location to use with a single bearing line. If you are on a trail that you can identify on the map, but you are not sure of your exact location along the trail, You can take a bearing to a known peak, plot that bearing, and know that you are where the bearing line crosses the trail. Note, it is possible the bearing intersects the trail in more than one place. In this case, you will need additional information to determine which crossing is your present location.

You can use any of the following linear features to intersect with one or more bearings. Provided you can identify the feature on the map and you are sure your position is somewhere along the feature you have identified.

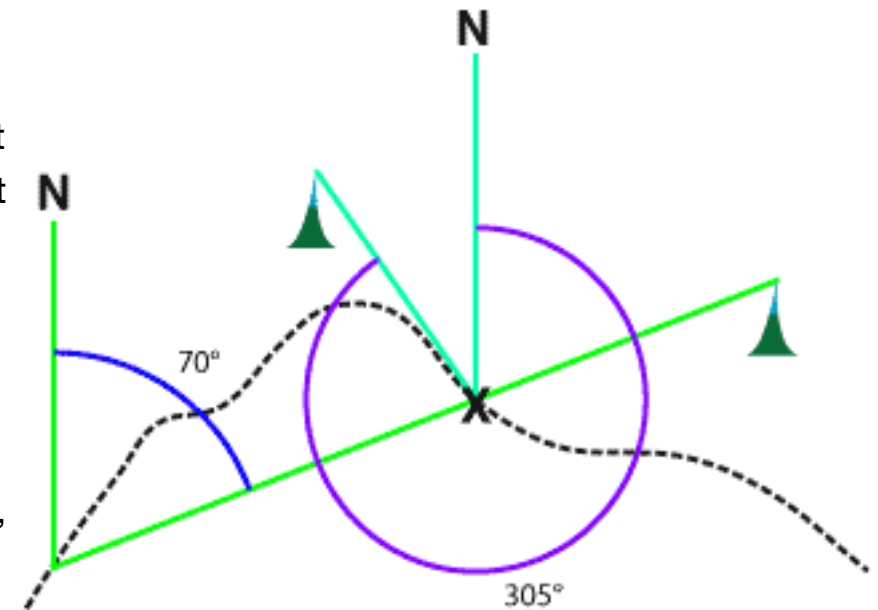
- Roads and trails
- Rivers, streams and shorelines
- Ridge lines and spurs
- Fence or power lines
- A contour line at your current elevation

A special case of location by resectioning is useful when you are using a GPSr with a map that does not have a coordinate grid. Rather than using your compass to sight a bearing to a known location, you enter the coordinates of a known location into your GPSr. Using the GOTO Waypoint feature, your GPS will calculate both the bearing and distance from your current location, to the known location on the map. Look for a new tutorial on this method in the coming weeks.

Location by Intersection or "Where is the _____ that I can see in the distance?"

You see something off in the distance, say a plume of smoke. You know where you are and you take a compass bearing from your location to the smoke. Now you can plot a line on your map and know that the source of the smoke is somewhere along that line. Moving to a new, known location and taking a bearing, will result in another line. The source of the smoke should be at the intersection of the two bearing lines. Moving to yet another known location, taking a bearing and plotting it, will

A single bearing to a peak resulting in two possible locations along the trail.



A bearing to a second peak, identifies the location along the trail.

provide you some protection from any error you may have made. If the three bearings all cross in close proximity, you can be confident of your results. With only two bearings, errors will not be apparent.

Plotting straight line course segments for route finding

One technique for route finding is to combine a series of straight line "course legs" to reach the desired destination. The techniques discussed in this tutorial can be used to plot these legs onto a map.

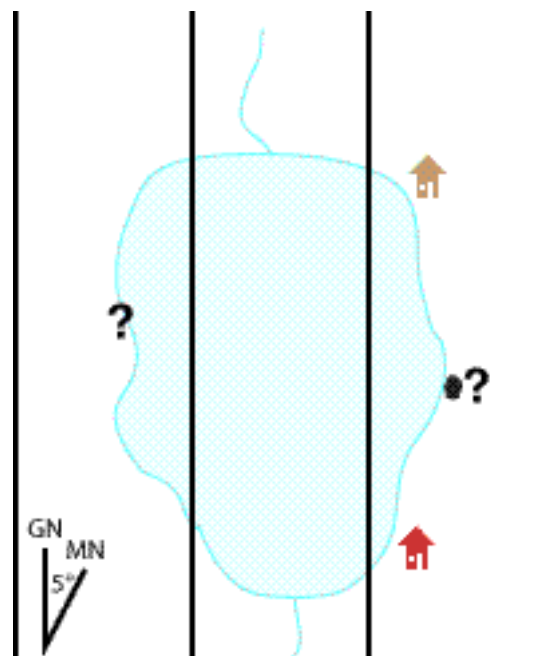
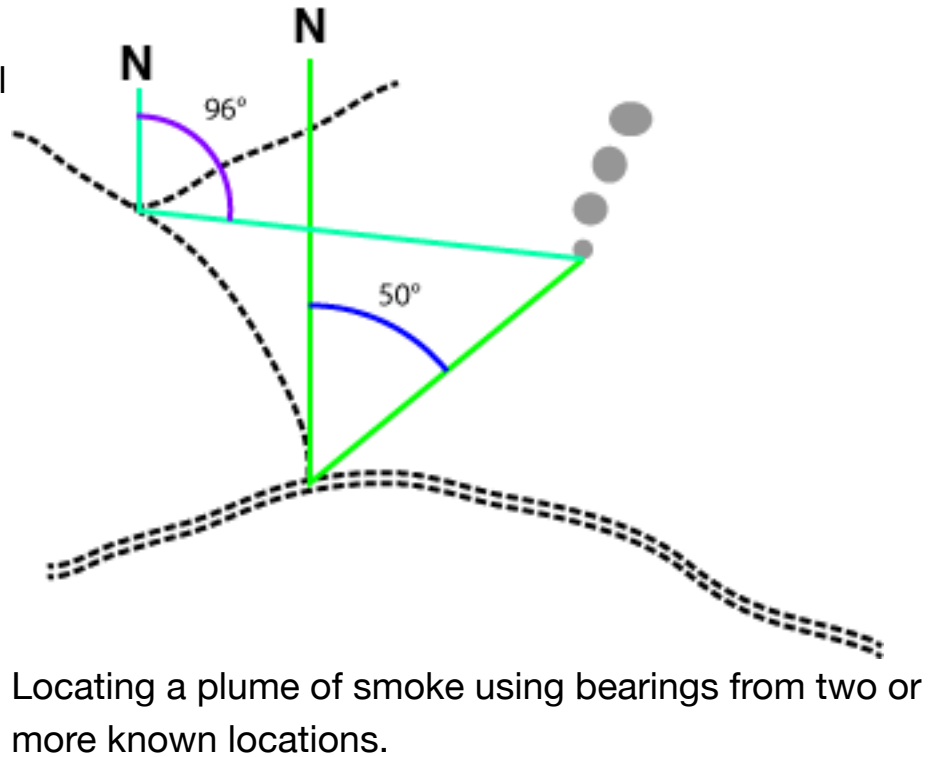
The example problem used in this tutorial

We are staying at a cabin on a small lake somewhere in the north woods. We decide to take a hike around the shore of the lake. At some point on our hike we stop and look across the lake. We can see our cabin. We can also see what looks like a cave entrance along the lake shore. We would like to know where this cave is on our map.

Our cabin is a known location that we can identify on the map. We also know that all three of these locations are along the shoreline of the lake. We do not know our current location, nor do we know the location of the cave.

There will be two parts to solving this problem. First we will take a bearing to our cabin, and plot it on our map. Our location will be where the bearing to our cabin crosses the lake shore. Ideally we could find some other known location and plot a second bearing to give us more confidence in our location.

Now we are ready to locate the cave. We take a bearing from our location to the cave entrance, and plot it on the map. The cave is located where the



A map of a small lake, somewhere in the north woods.

bearing crosses the lake shore across the lake from our location. To improve the confidence in our result, we should move to a new position along the shore line and repeat the entire procedure to give us a second bearing line to the cave.

We will return to this example as we continue through this tutorial.

Understand your north references

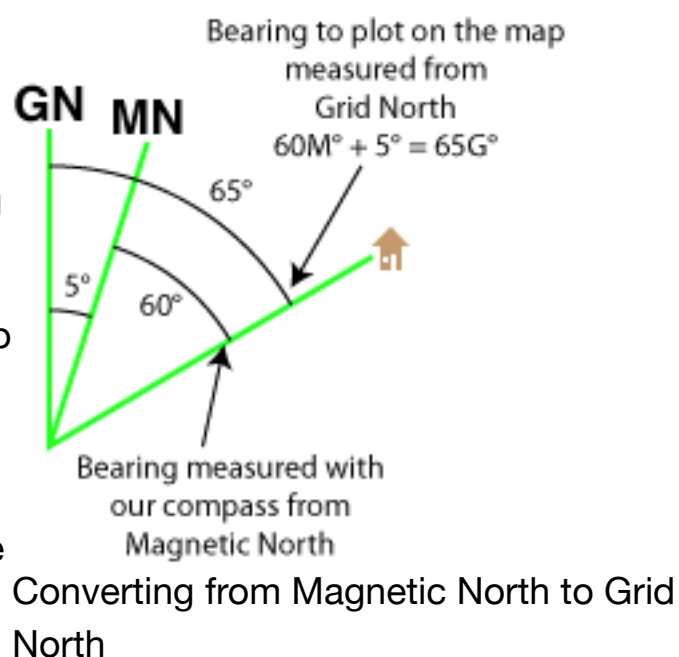
So far we have not been very specific about what North means. But there are three different Norths commonly used in navigation and it is very likely that the North our compass uses and the North we see on our map are different.

If you don't already understand north references and converting between them, you should take a detour to our North Reference Tutorial. (/north_reference)

For our example at the lake in the north woods, we will assume that our compass bearings are taken relative to Magnetic North and our map plotting is done using Grid North. In this part of the north woods, Magnetic North is 5° east of Grid North.

We will likely need to make any adjustments to our north references as we move bearing between our compass and our map. Let's take a look at a declination diagram that shows both Grid and Magnetic North along with the bearing line to the cabin.

The angle between the line to Magnetic North and the line to your cabin, is what we measured with our compass. The angle between the line to Grid North and the line to your cabin, is what we will be plotting on our map. Note the the angle from your cabin to Grid North is 5° bigger than the the angle from the cabin to Magnetic North. Thus to convert from a Magnetic North bearing to a Grid North bearing we need to add on 5° . Learning to draw diagram like this one will allow you to figure out all of your north reference conversions, wherever you are in the world. Make sure you use current declination information for your location.



Understanding forward and back bearings

The first compass bearing we need to take at the lake is from our unknown location to our cabin on the far shore. The bearing we end up with represents the angle between a line from Magnetic North to our location, and a line from our location to the cabin. This bearing is a "forward bearing."

But when we go to plot this bearing on our map, we can't plot the angle from our current location since that is what we are trying to find. Instead we plot a bearing from the cabin, as if someone there took a bearing "looking BACK towards our location." This would be called a "back bearing" and will

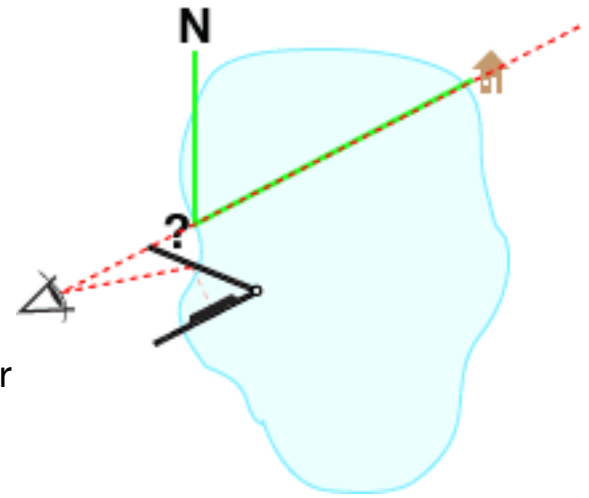
be 180° different from our "forward bearing."

If you took the bearing from the known location, you will be plotting a forward bearing, starting at the known location.

If you took the bearing from the unknown location, you will be plotting a back bearing, starting at the known location.

For more information on forward and back bearings, see our tutorial on forward and back bearings (</tutorials/plotting/forward-and-back-bearings>).

This tutorial will show you how to plot a bearing using different techniques and equipment. I usually start my students off using a protractor. A protractor has no moving parts and is conceptually simpler to use.



Taking a forward bearing.

Techniques for plotting a bearing...

- Plotting a bearing using a protractor (</tutorials/plotting/protractor>)
- Plotting a bearing using a baseplate compass (</tutorials/plotting/compass>)
- Plotting a bearing using a baseplate compass adjusted for declination (</tutorials/plotting/compass-declination>)
- Plotting a bearing using a straight edged lensatic compass (</tutorials/plotting/straight-lensatic>)
- Plotting a bearing using a round lensatic compass (</tutorials/round-lensatic>)

Continue this tutorial on plotting a bearing with these links:

Plotting a second and third bearing to confirm your position (</tutorials/plotting/more-bearings-to-confirm-location>)

Using bearings to locate a distant target (</tutorials/plotting/bearings-to-locate-target>)

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For more information please contact us (</contact>)



Triangulation

Triangulation is the process of pinpointing the location of something by taking bearings to it from two remote points.

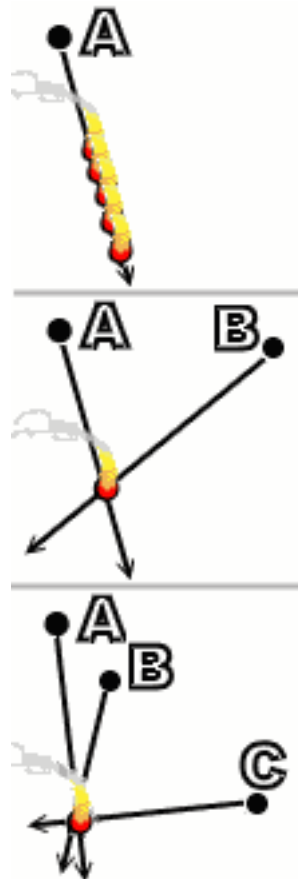
Forest fire lookout towers used triangulation to locate spot fires.

A ranger at **Tower A** would see smoke in the distance and take a bearing to it on his compass. This single line was not enough information to locate the fire because it could be anywhere along that line, close or many miles away.

The ranger would radio **Tower B** and tell him the general direction of the fire. Tower B would then find the fire from his viewpoint and take a bearing. Where the two bearings crossed would pinpoint the fire and firefighters could be efficiently dispatched to put it out.

Sometimes, a third tower would be used to verify the location, but two readings are all that is usually necessary. If a fire occurs directly between two towers or off in a direction that causes their bearings to be similar, then a third bearing is necessary.

This type of triangulation is used by two fixed spots to find a third unknown spot. What you need to do while in the outdoors is similar, but you need to find out where you are, not where something else is.



Finding Yourself

In order to successfully triangulate, known features must exist on your map. In other words, you must have some idea of where you are or be able to identify a well-known landmark from your viewpoint.

By taking bearings to the distant landmarks, you can plot your current location on your map in this way:

- Make sure you have adjusted your compass correctly for **declination** in this area.
- **Orient your map** so map north is facing true north.
- Take a bearing to one landmark. Point the direction of travel arrow at it and turn the compass dial until **RED is in the Shed**.

- Place your compass on the map so that the orienting lines are parallel to the map's north-south meridian lines.
- Move your compass so the top end of one edge of its baseplate ends at the landmark, keeping it aligned with the map's meridians.
- Draw a line along the edge of your compass from the landmark along the bearing you took. You are somewhere on this line.
- Repeat taking a bearing and drawing a line for a second landmark.
- Where these two lines intersect is your approximate location.

If you are standing on a known landmark such as a road, river, or ridgeline but don't know where on that landmark you are, a single remote landmark is enough to plot your position. Where your bearing line to the remote landmark and the landmark you are on intersect is where you are - as long as you take accurate readings and transfer them accurately. :-)

Triangulation Example

This example will step you through the process of triangulating your location based on bearings to two or more known landmarks.

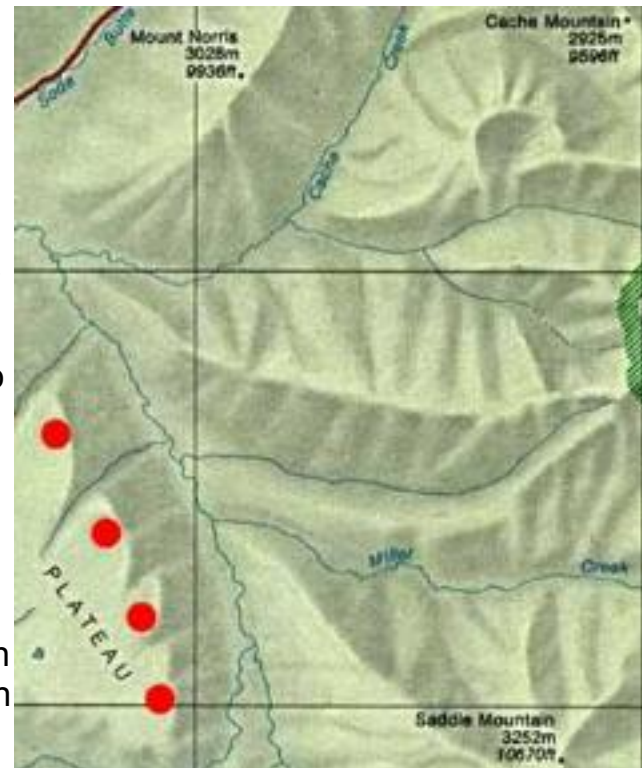
Look at this section of map - it has mountains, streams, and hills as indicated by the shaded relief enhancements. Notice it does not have contour lines but that doesn't matter when we are just finding directions.

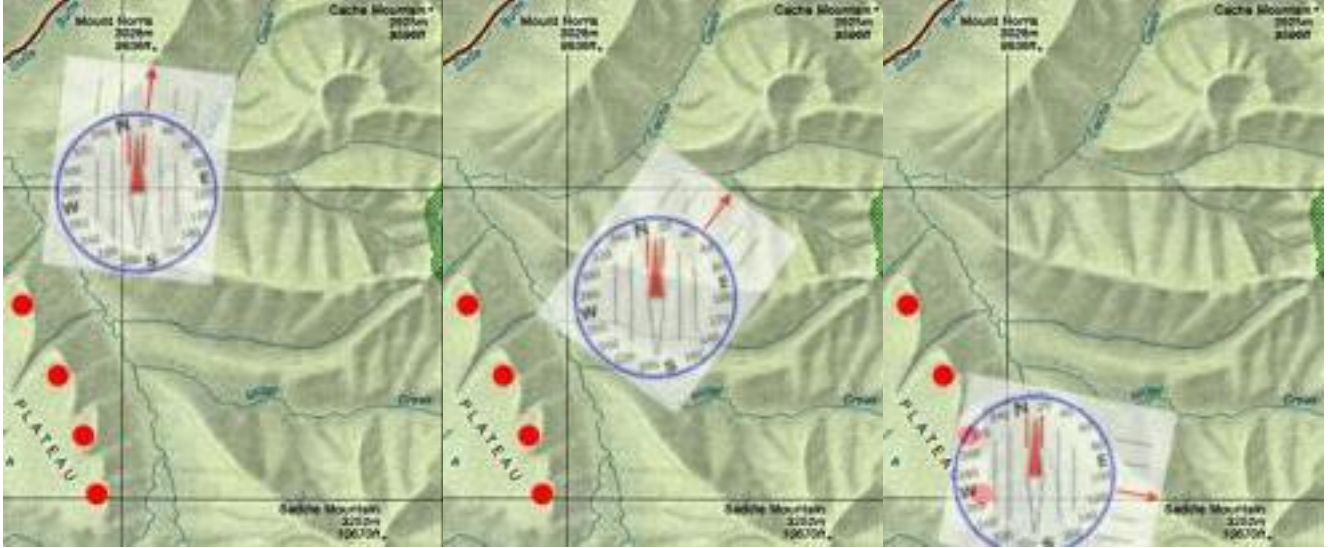
You might find it useful to print the image and actually do these steps.

Print the map and lay it on the floor.

Orient the map for North right where you are and imagine that you can see mountains off in the distance.

You have just climbed the plateau in the southwest, coming up from the southwest. You do not know at which of the 4 red spots you are currently standing, but you can see 3 mountains off in the distance towards the north and east.





For your triangulating, you take bearings to the mountains and get:

- 16 degrees to Mt. Norris
- 48 degrees to Cache Mountain
- 112 degrees to Saddle Mountain

To simulate taking each of these bearings, turn your compass dial until that bearing is at the index pointer. Then, turn the compass until **RED is in the Shed** and the direction-of-travel arrow will be pointing along that bearing.

Transfer your bearings to the map and find out where they intersect. If you oriented your map, took correct bearings, and transferred them accurately, your map should look close to:



Now you know where you are on the map and in the real world. If you didn't do too good on this one or want to try another, here's **another exercise** to try.



Why was longitude boiling mad?

Because it was 360 degrees



Triangulation Exercise

Another Triangulation Exercise

If you came directly to this page from some other site, you should start on the home page or at least read the [Triangulation Page](#) first.



Look at the section of map up above - you might find it useful to print that image and actually do these steps. Print the map and lay it on the floor. Orient the map for North right where you are and imagine that you can see mountains off in the distance.

You have just climbed the highlighted ridge after fishing in Miller Creek. You do not know where

along the ridge you are standing, but you can see 3 mountains off in the distance north and south.

You take bearings to the mountains and get:

- 333 degrees to Mt. Norris
- 33 degrees to Cache Mountain
- 161 degrees to Saddle Mountain

To simulate taking each of these bearings, turn your compass dial until that bearing is at the index pointer. Then, turn the compass until **RED is in the Shed** and the direction-of-travel arrow will be pointing along that bearing.

Transfer your bearings to the map and find out where they intersect. If you oriented your map, took correct bearings, and transferred them accurately, your map should look close to:

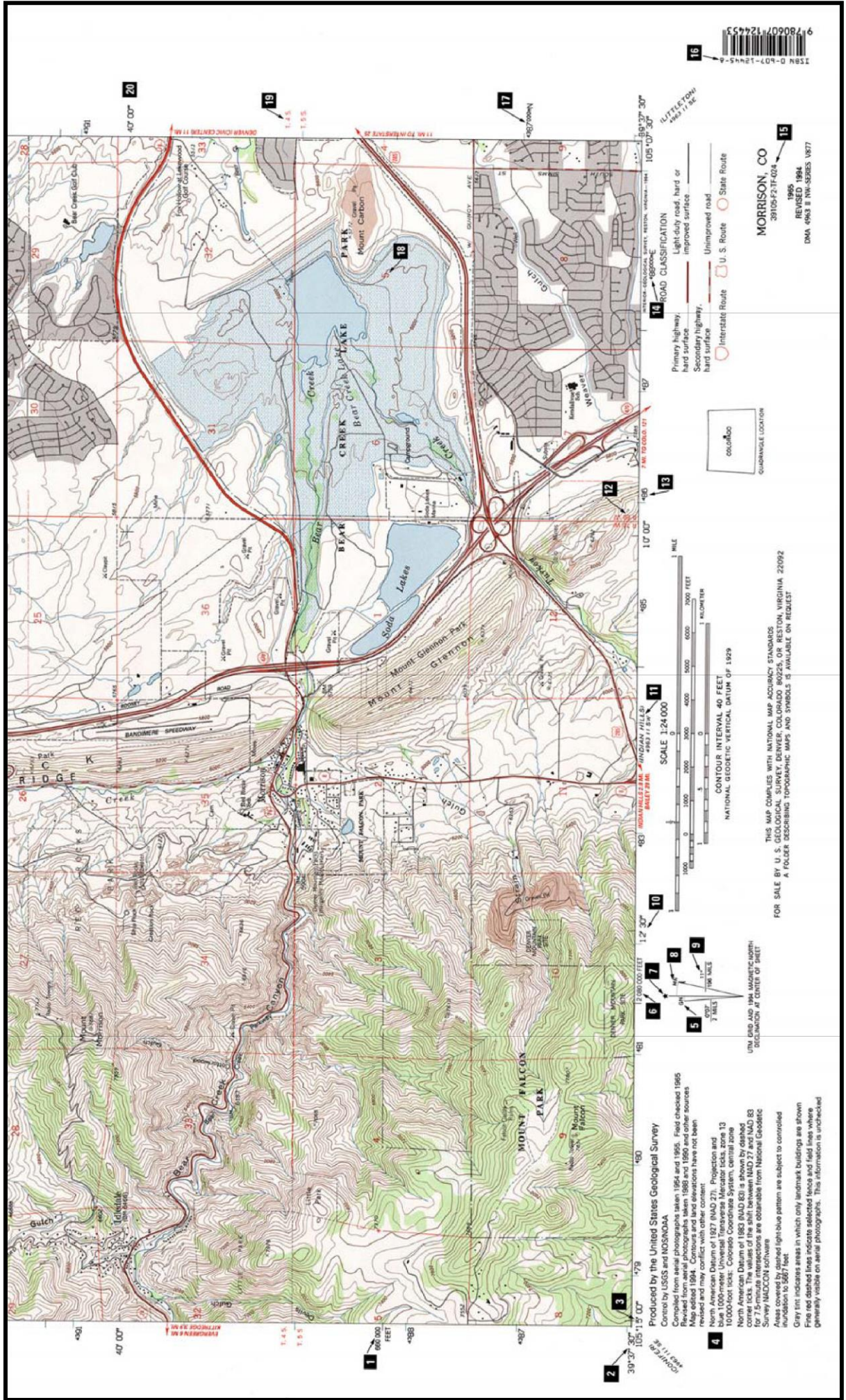


Notice that two bearings that are nearly opposite each other do not do a good job of triangulating. It is important to get another landmark at approximately right angles with one of your landmarks. Mount Norris and Saddle Mountain have a wide possible intersection but Mount Norris and Cache Mountain have a much smaller intersection area.

More Map and Compass Resources at CompassDude.com

Map Margin Information

Map Margin Information



Map Margin Information

Ever wonder what all those little numbers are on the borders of your map? Here are the facts...

1. State plane coordinate system -- 660,000 feet north from origin within the state plane grid system.
This coordinate system was established by the U.S. Coast and Geodetic Survey for use in defining positions of points in terms of plane rectangular (x, y) coordinates. There is usually one system for each state and each state determines the measurement unit (i.e., feet or meters).
2. Latitude -- 39 degrees, 37 minutes, 30 seconds (north of the Equator, which is at 0 degrees latitude).
3. Longitude -- 105 degrees, 15 minutes, 00 seconds (west of Meridian of Greenwich, also called Prime Meridian, which is at 0 degrees longitude).
4. North American Datum of 1927 -- horizontal datum. Required for GPS users. Also identifies UTM zone and state plane coordinate system.
5. GN -- UTM grid north (at the center of the map).
6. State plane coordinate system -- 2,080,000 feet east of origin.
7. ★ -- true or geographic north -- points to the north geographic pole.
8. MN -- magnetic north -- the approximate direction (at the center of the map) to the north magnetic pole at the date given, in this case 1994. The direction to which a magnetic compass needle points.
9. 11 east -- magnetic declination or variation of the compass -- the number of degrees a compass needle at a particular location bears away from true north and points to the north magnetic pole. 196 MILS -- military angular measurement.
10. Adjoining USGS quadrangle name "Indian Hills." The notation "4963 II SW" is the NGA (National Geospatial-Intelligence Agency, the Department of Defense mapping agency) sheet designator for the same map.
11. Range 69 West -- 69th range west of 6th Principal Meridian (which is at Meades Ranch, Kansas).
Public Land Subdivisions: In 1785 Congress adopted a plan for surveying public lands. According to this plan, land was divided into townships approximately six miles square, which were further subdivided into 36 sections approximately one mile square. Principal meridians and base lines were established as a reference system for the township surveys.
12. UTM (Universal Transverse Mercator) easting value -- 486,000 meters false easting (last 3 zeroes omitted for brevity) (Zone13).
13. UTM easting value -- 488,000 meters false easting (Zone 13).
14. Map reference code:
39 -- degrees north latitude
105 -- degrees west longitude
F2 -- index number (area reference code) TF -- Topographic map with contour values in Feet
024 -- 1:24,000 scale
15. ISBN number -- International Standard Book Number.
16. UTM northing value -- 4,387,000 meters north from the Equator. "Northings" in the southern hemisphere begin with the Equator value = 10,000,000 meters and decrease in value.
17. Section number 5. See Public Land Subdivisions.
18. Township 4 South -- 4 townships south of base line (Base Line of 1855, in this case). See Public Land Subdivisions.
19. Latitude again -- another 2.5 minute grid tick -- 39 degrees (understood), 40 minutes, 00 seconds.

Additional Information

For information on USGS products and services, contact USGS Science Information Services at: phone: 1-888-ASK-USGS (1-888-275-8747) or online form: <http://www.usgs.gov/ask>

Topographic Map Margins Information for Educators

An abbreviated, [two page version](#) of this document is an excellent quick reference.

The neatline is the line separating the body of a topographic map from the map margin, or collar. The space outside the neatline on published USGS maps identifies and explains the map. This marginal information corresponds somewhat to the table of contents and introduction of a book – it tells briefly how the map was made, where the quadrangle is located, what organizations are responsible for the contents, and gives other information to make the map more useful.

Each map is identified in the upper right margin by its quadrangle name, the state or states in which it is located, and the map series and type (7.5–Minute Series, Topographic). The quadrangle name and state are repeated in the lower right margin.

The Department of the Interior – Geological Survey heading in the upper left margin is accompanied by the USGS identifier (logo) in maps published after 1995.

Refer to the attached map for the location of all the numbered elements below. The example map is a 1:24,000-scale topographic map, also called a 7.5-minute map because it covers 7.5 minutes of longitude and 7.5 minutes of latitude:

1. [State plane coordinate system](#) grid tick and value. In this example, 660,000 feet north of origin within the state plane grid system. This coordinate system was established by the U.S. Coast and Geodetic Survey (renamed the [National Geodetic Survey](#)) for use in defining positions of points in terms of plane rectangular (x, y) coordinates. There is usually at least one system for each state with a specific origin point. Each state determines whether the units will be measured in feet or meters.
2. Latitude. In this example, 39 degrees, 37 minutes, 30 seconds (north latitude; north of the equator, which is 0 degrees latitude). Geographic coordinates (latitude and longitude) are shown at all four corners of the map; the minutes and seconds are additionally shown at 2.5-minute intervals along the neatlines. This latitude is in the degrees-minutes-seconds format. Have students convert these to decimal-minutes format. For example, 30 seconds / 60 seconds = .5 minutes. Therefore, the decimal-minute format for this latitude is 39 degrees 37.5 minutes. Next, have students convert degrees-minutes-seconds to decimal-degree format: 30 seconds / 3600 = .008333 degrees. 37

minutes / 60 = .61666 degrees. Add them together (.008333 + .61666 + 39) for a decimal-degree reading of 39.625 degrees. Use a GPS unit and try all three formats there as well.

3. Longitude. In this example, 105 degrees, 15 minutes, 00 seconds (west longitude; west of the Prime Meridian of Greenwich, England, which is at 0 degrees longitude). Convert these degrees-minutes-seconds longitude values to decimal-minutes and decimal-degrees values as you did for latitude.
4. North American Datum of 1927 (NAD27). This is the horizontal datum; the reference for all x-y coordinates. It is the datum used for most USGS topographic maps printed before 2009. Note that the North American Datum of 1983 (NAD83), which is used on maps printed after 2009, is also indicated on this map by dashed crosses that are [slightly offset](#) from each corner of the map. On some maps, the dashed crosses are absent but the amount of offset is given in the text. If you are using GPS along with a topographic map, you must make sure that the GPS datum matches the datum used on the map. The default datum for most GPS units is the World Geodetic System of 1984 (WGS84), which is virtually identical to NAD83.

This section also identifies the [State plane coordinate system](#) used on the map; in this example, Colorado Coordinate System, Central Zone. You could create a grid across the map by connecting all of the 10,000-foot margin ticks. How much land is covered by the resulting rectangles that are 10,000 feet x 10,000 feet? The [Universal Transverse Mercator](#) (UTM) zone is identified as Zone 13, which spans 102 to 108 degrees west longitude.

This entire block of text is called the credit legend. It also lists the name of the mapping agency, the name of the agency that furnished the geodetic control, methods by which the mapping was performed, credit note for any hydrological information, and informative and explanatory notes.

5. GN, or Grid North. This is [UTM](#) grid north; measured at the center of the map. The numbers directly below indicate the angle between grid north and true north. That angle is given in minutes (top) and MILS (bottom). MILS is an angular measurement used by the military.
6. [State plane coordinate system](#) coordinate. This tick mark is 2,080,000 feet east of the origin of the Colorado Central Zone.
7. ★ This star indicates true or geographic north. The star and line point to the north geographic pole.
8. MN, or Magnetic North. This is the approximate direction (at the center of the map) to the north magnetic pole at the date given, in this case 1994. Remember that the magnetic pole, and thus the magnetic declination, [change over time](#). This is the direction to which a magnetic compass needle points. Take a topographic map outside and use it with a standard compass or with a GPS unit with a compass.
9. 11 east. This is the [magnetic declination](#) or variation of the compass – the number of degrees a compass needle at a particular location bears away from true north and points to the north magnetic

pole. 196 MILS indicates the military angular measurement of the angle, which is used for artillery settings. This entire diagram of lines and arrows is called the magnetic declination diagram.

10. Adjoining USGS quadrangle name “Indian Hills.” The notation “4963 II SW” is the NGA (National Geospatial-Intelligence Agency, formerly NIMA, National Image and Mapping Agency) sheet designator for the same map.

Under this text is the scale. Use it to measure distances and create topographic profiles. Compare this 1:24,000-scale map to a USGS map of the same area at 1:100,000 scale, 1:250,000 scale, and 1:500,000 scale. How much area does each map cover? What detail is visible on each map?

Under the scale bar is the contour interval, which is the vertical distance between each contour line. Compare this contour interval to one in a flatter or steeper area on a different map. How are contour intervals chosen? This block also indicates the vertical datum used to reference the vertical distances. On maps published prior to 1975, the vertical datum is mean sea level. After that date, the National Geodetic Vertical Datum of 1929 is used.

11. Range 69 West. This is part of the [Public Land Survey System](#) (Township and Range System). This is the 69th range west of 6th Principal Meridian (which is at Meades Ranch, Kansas). Each range is 6 miles wide; therefore, the origin is $69 \times 6 = 414$ miles to the east.

In 1785, Congress adopted a plan for surveying public lands. According to this plan, land was divided into townships approximately 6 miles square, which were further subdivided into 36 sections approximately 1 mile square. Each section was divided into smaller plots, for example, of 640 acres. [Principal meridians and base lines](#) were established as a reference system for the township surveys.

Pull up some online legal descriptions or lots for sale, and note how the Public Land Survey System pervades modern law. It is yet another way to “reference,” or “address” locations on the Earth’s surface.

12. UTM ([Universal Transverse Mercator](#)) easting value. Here, the point is 486,000 meters false easting (last 3 zeroes are omitted for brevity) (Zone 13). The Central Meridian in Zone 13 is at 500,000 meters easting, which is 14,000 meters, or 14 kilometers, to the east of this line (in downtown Denver). Change the units of your GPS to UTM and have students walk directly east. The eastings should increase by 1 meter with each large step they take. Then, walk north and watch the distance to the equator increase. Meters are an easier unit to work with than the fractions of a degree with latitude-longitude, and therefore, UTM is quite useful and logical to use in the classroom. In addition, a meter is the same everywhere across the Earth’s surface, unlike a degree, which changes depending on where a person is on the planet.
13. UTM ([Universal Transverse Mercator](#)) easting value. This line is 488,000 meters false easting (Zone 13). Have the students draw the 1000-meter grid lines across the map using the UTM

coordinates in the margins. Each resulting grid section will be 1000 meters x 1000 meters or 1 square kilometer.

14. Map Name. Maps are usually named after the most prominent cultural (airport, town) or physical (mountain, valley, lake) feature on the map. What is considered most prominent might have changed since the map was created. For example, Eastlake, Colorado was named after a railroad siding, but the map is now nearly covered by the suburb of Thornton. Discuss with your students the types of changes that can occur to make the original map name obsolete. If you were to name this section of the Earth, what would you name it?

This block might also contain the map reference code, which begins with the geographic position of the corner of the map nearest the Greenwich meridian and the Equator:

39 = Degrees North Latitude

105 = Degrees west longitude

F2 = index number (area reference code)

TF = Topographic map with contour values in Feet

024 = 1:24,000 scale

The date of the map and any revision dates are given below the name. What has changed since the map was made? What was added when the map was revised? What has stayed the same? Some maps contain purple revisions to help identify the changes.

15. ISBN number – International Standard Book Number.
16. UTM northing value. In this example, the tick mark is 4,387,000 meters north from the Equator. “Northings” in the southern hemisphere begin with the Equator value = 10,000,000 meters and decrease in value as one moves toward the South Pole.
17. Section number 5. A part of the [Public Land Survey System](#) subdivisions; each section is 1 square mile. Have students note how corrections were made on maps in the original survey, where the section lines deviate from being east-west and north-south (western side of the map). Which section on the map would you say has the greatest population density? Why?
18. Township 4 South in the [Public Land Survey System](#). This township is 4 townships (or 4 x 6 = 24 miles) south of the base line. In this part of the country, the [Base Line of 1855](#) is used; the base line is on the 40 degrees north latitude line.
19. Latitude reading. This is another 2.5 minute grid tick. In this example, 39 degrees is understood; 40 minutes, 00 seconds are indicated.

Resources:

Map Margins (2 page version of this document) <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mm.pdf>

Teaching About and Using Coordinate Systems <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/coordinatesystems.pdf>

UTM Coordinates

<https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/The%20Universal%20Transverse%20Mercator%20%28UTM%29%20Grid.pdf>

State Plane Coordinate System

<https://www.usgs.gov/faqs/how-state-plane-coordinate-system-set-can-gps-provide-coordinates-these-values-what-about>

Datum Shifts and Map Coordinate Displays http://thor-f5.er.usgs.gov/drg/datum_shifts_v2.pdf

Public Land Survey System

<https://www.usgs.gov/media/images/public-land-survey-system-plss>

Principal Meridians and Base Lines

https://www.blm.gov/sites/blm.gov/files/meridianmap09_1.jpg

Magnetic Declination

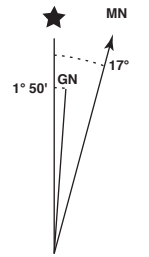
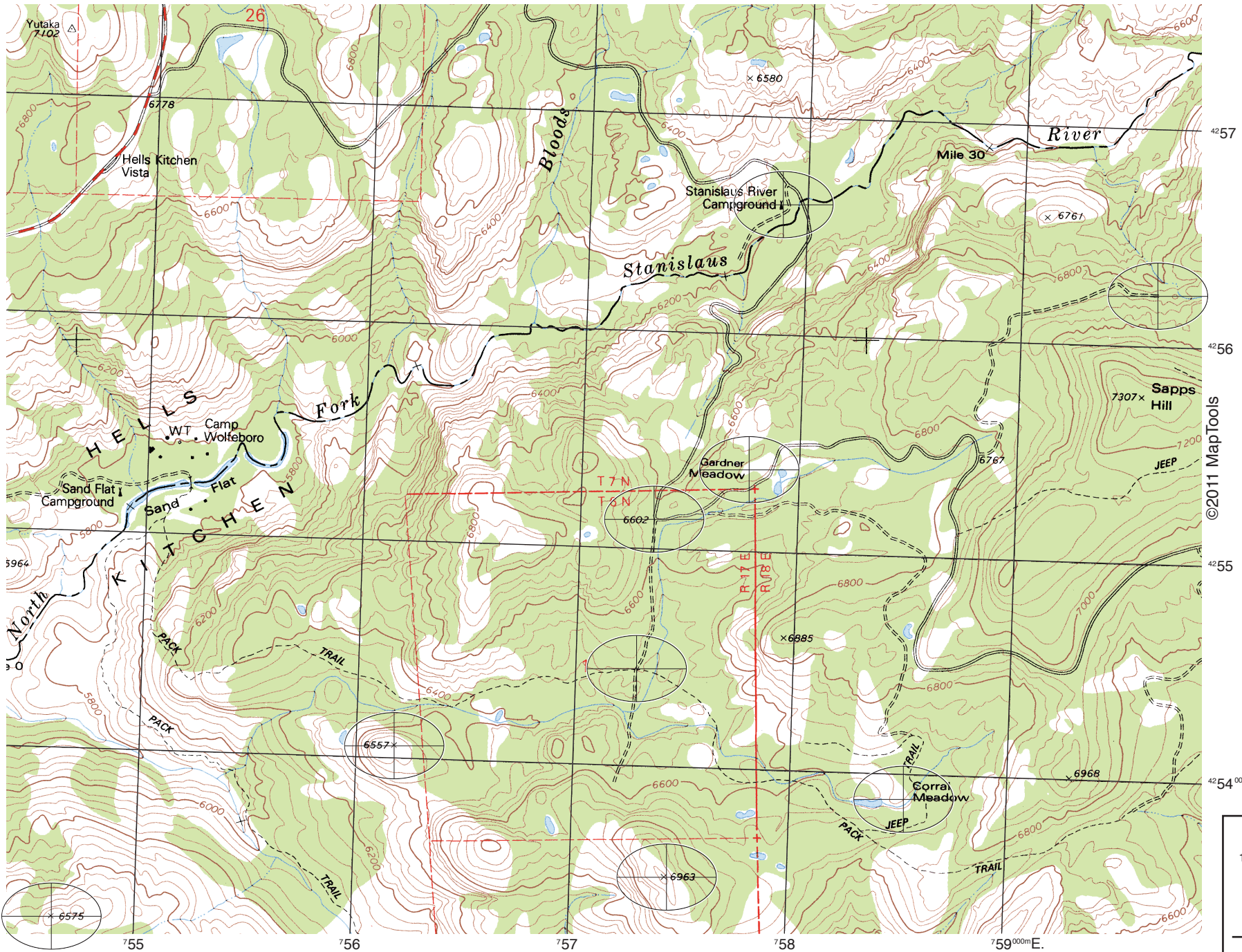
https://www.usgs.gov/faqs/what-declination?qt-news_science_products=0#qt-news_science_products

How to obtain USGS Topographic Maps

- Download free digital topographic maps in a GeoPDF format by going to the USGS Store (<http://store.usgs.gov/>) and clicking on “Map Locator & Downloader”. Choose from two different kinds of topographic maps. Both are available as free digital downloads or they can both be purchased as paper products:
 - US Topo maps: Computer-generated topographic maps that are updated every three years. They come in layers that can be turned on and off and include an orthoimage (air photo) layer. Free analytical tools can be downloaded https://www.usgs.gov/core-science-systems/national-geospatial-program/us-topo-maps-america?qt-science_support_page_related_con=0#qt-science_support_page_related_con
 - Historical USGS topographic maps at multiple scales: Maps that were produced until about 2003. These maps were made by hand and were designed for maximum readability. The standard 1:125,000-scale maps are indicated as “7.5x7.5 grid” maps. Students who are just learning about topographic maps might find these easier to work with than the computer-generated US Topo maps. <http://nationalmap.gov/historical>
- Digital historical topographic maps can also be downloaded in several formats from our topoView site. <https://ngmdb.usgs.gov/topoview/>

Questions? Need help? Call 1-888-ASK-USGS (1-888-275-8747) or go to <https://answers.usgs.gov/>

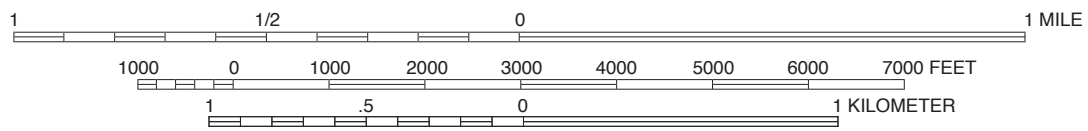
Map Exercises



©2011 MapTools

42° 54' 00" N.

U.S. National Grid
100,000-m Square ID
GH
Grid Zone Designation
10S



www.MapTools.com

1:24,000

1000-meter Universal Transverse Mercator grid, zone 10.
1927 North American Datum

Questions

Using a 1:24,000 scale UTM Grid Tool,
determine the UTM Coordinates with 100m accuracy
for the following points:

#1

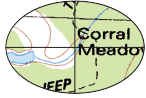


Gardner Meadow

Determine what features are located at
the following coordinates:

#10 755.3km E 4255.4km N

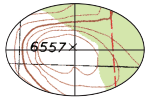
#2



Corral Meadow

#11 759.2km E 4254.0km N

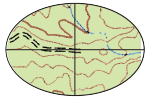
#3



x 6557

#12 754.7km E 4256.6km N

#4



End of Road

#13 759.5km E 4255.7km N

#5



x 6575

#14 757.7km E 4257.1km N

#6



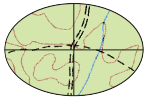
Road Junction at 6602

#15 754.8km E 4255.1km N

Determine the UTM Coordinates with 10m accuracy
for the following points:

#16 754.59km E 4257.30km N

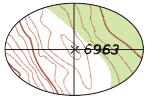
#7



Road & Trail Junction

#17 758822m E 4255473m N

#8



x 6963

#18 10S GH 5795 5461

Determine the Full USNG Coordinates with 10m accuracy,
and the 100m short format, for the following point:

#19 5911 5658

#9



Stanislaus River Campground

Answers

#1 757.7km E 4255.3km N

#2 758.5km E 4253.8km N

#3 756.1km E 4254.0km N

#4 759.6km E 4256.2km N

#5 754.6km E 4253.2km N

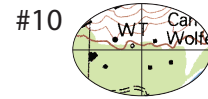
#6 757.3km E 4255.1km N

#7 757.28km E 4254.45km N

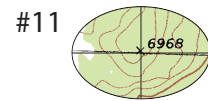
#8 757.45km E 4253.49km N

#9 10S GH 5789 5660

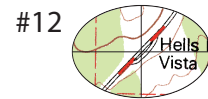
578 566



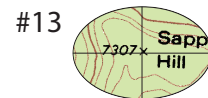
Camp Wolfboro



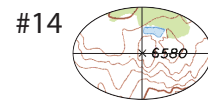
x 6968



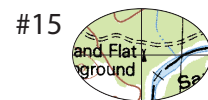
Hells Kitchen Vista



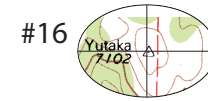
Sapps Hill



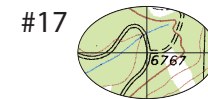
x 6580



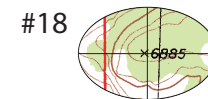
Sand Flat Campground



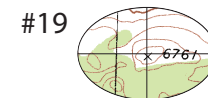
Yutaka 7102



Junction at 6767

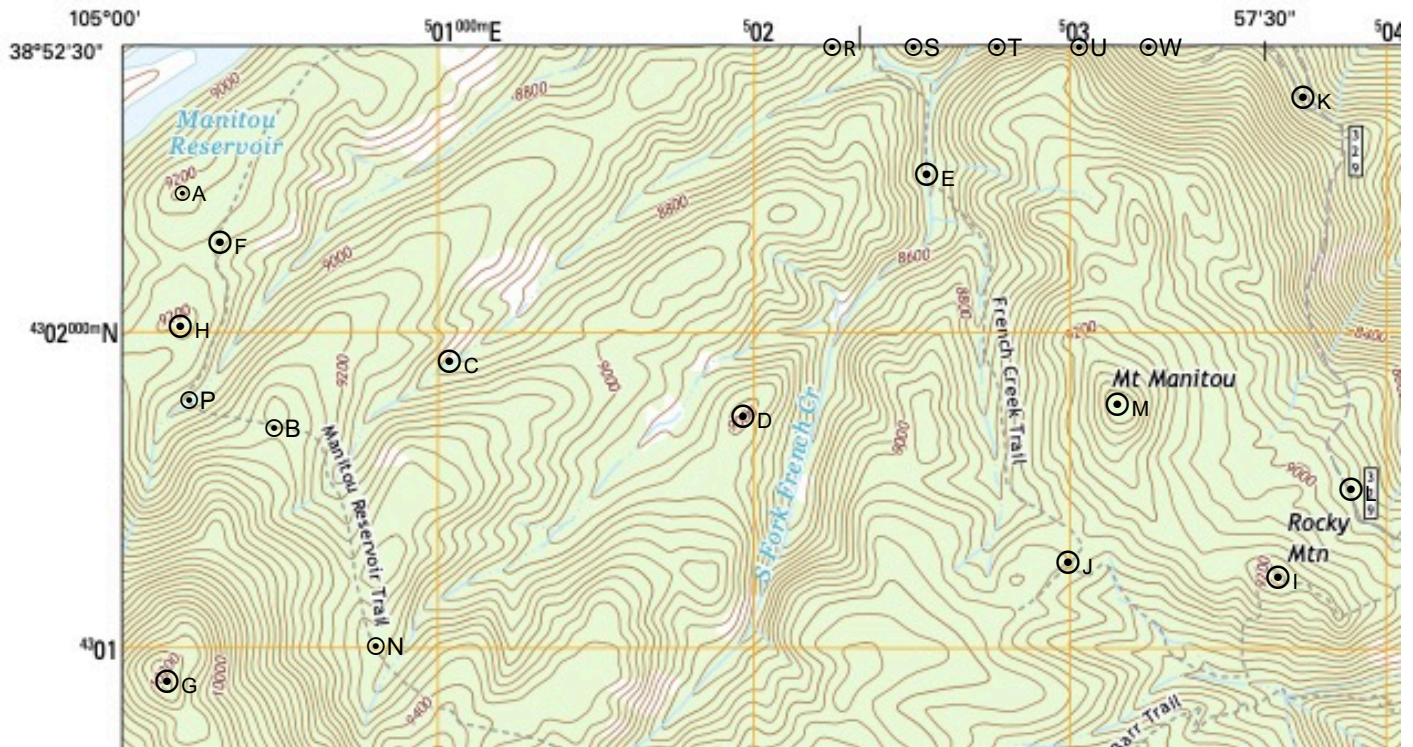


x 6885

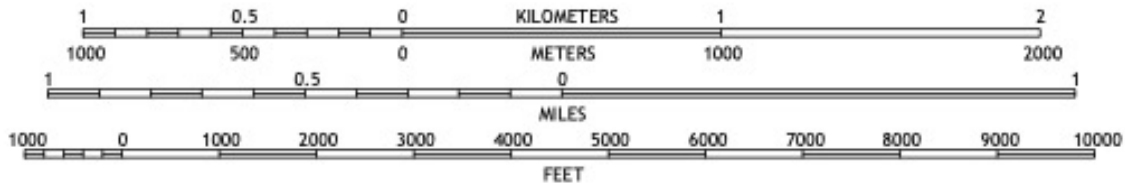


x 6761

For questions 12-19 use the map and information contained on this page. You may refer to the full quadrangle map if you wish. Copies are located in the testing area.



SCALE 1:24 000



CONTOUR INTERVAL 40 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the
National Geospatial Program US Topo Product Standard, 2011.
A metadata file associated with this product is draft version 0.6.19



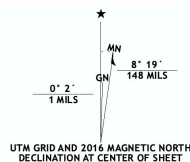
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Produced by the United States Geological Survey

North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 13S
10 000-foot ticks: Colorado Coordinate System of 1983 (central
zone)

This map is not a legal document. Boundaries may be
generalized for this map scale. Private lands within government
reservations may not be shown. Obtain permission before
entering private lands.

Imagery.....NAIP, September 2013
Roads.....U.S. Census Bureau, 2015 - 2016
Roads within US Forest Service Lands.....FSTopo Data
with limited Forest Service updates, 2012 - 2016
Names.....GNIS, 2016
Hydrography.....National Hydrography Dataset, 2013
Contours.....National Elevation Dataset, 2003
Boundaries.....Multiple sources; see metadata file 1972 - 2016
Public Land Survey System.....BLM, 2011
Wetlands.....FWS National Wetlands Inventory 1977 - 2014



U.S. National Grid	
100,000-m Square ID	
ED	4000
EC	
Grid Zone Designation	
13S	



1	2	3
4	5	6
7	8	9

ADJOINING QUADRANGLES

ROAD CLASSIFICATION	
Expressway	Local Connector
Secondary Hwy	Local Road
Ramp	4WD
Interstate Route	US Route
PS Primary Route	PS Passenger Route
	PS High Clearance Route

Check with local Forest Service unit
for current travel conditions and restrictions.

MANITOU SPRINGS, CO
2016

MANITOU SPRINGS QUADRANGLE COLORADO 7.5-MINUTE SERIES

12. What general direction does the intermittent creek at point C flow? _____
13. What is the bearing from point J to point D? _____
14. Plot a bearing of 34° from point D. at what point does this bearing intersect the top of the map?

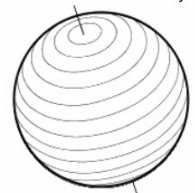
(for questions 15-17) You are traveling on Forest Service Road 329 from point L to point K.

15. What is the distance along the road traveled in kilometers? _____
16. Are you ascending or descending? _____
17. What is the change in elevation? _____
18. You are somewhere on the Manitou Reservoir Trail but are not sure where. You decide to use triangulation to find your location by taking bearings of visible landmarks. Nearby mountain tops are the most visible landmarks and can be easily located on your map. Your bearing taken for point D is 89° , to point G is 204° and to point H is 317° . What point is your location?

19. Handheld Global Positioning System (GPS) units have become increasingly popular and are quite accurate for back country navigation, but you must be very familiar with the unit's operation in order for it to properly guide you. If you are using a GPS unit with this map, what datum set will you correctly set on your GPS? (Circle the correct answer)

a.NAD27 b.NAD83 c.GPS2020 d.NATRF2022

20. The lines depicted on this globe are lines of _____



21. The lines depicted on this globe are lines of _____



Pace Chart

Pace	Yards	Feet	Paces	Yards	Feet	Paces	Yards	Feet	Paces	Yards	Feet	Paces	Yards	Feet	Paces	Yards	Feet	Paces
1.2	10	30	12	30	90	36	50	150	60	70	210	84	90	270	108	110	330	132
	11	33	13	31	93	37	51	153	61	71	213	85	91	273	109	120	360	144
	12	36	14	32	96	38	52	156	62	72	216	86	92	276	110	130	390	156
	13	39	16	33	99	40	53	159	64	73	219	88	93	279	112	140	420	168
	14	42	17	34	102	41	54	162	65	74	222	89	94	282	113	150	450	180
	15	45	18	35	105	42	55	165	66	75	225	90	95	285	114	160	480	192
	16	48	19	36	108	43	56	168	67	76	228	91	96	288	115	170	510	204
	17	51	20	37	111	44	57	171	68	77	231	92	97	291	116	180	540	216
	18	54	22	38	114	46	58	174	70	78	234	94	98	294	118	190	570	228
	19	57	23	39	117	47	59	177	71	79	237	95	99	297	119	200	600	240
	20	60	24	40	120	48	60	180	72	80	240	96	100	300	120	210	630	252
	21	63	25	41	123	49	61	183	73	81	243	97				220	660	264
	22	66	26	42	126	50	62	186	74	82	246	98				230	690	276
	23	69	28	43	129	52	63	189	76	83	249	100				240	720	288
	24	72	29	44	132	53	64	192	77	84	252	101				250	750	300
	25	75	30	45	135	54	65	195	78	85	255	102				260	780	312
	26	78	31	46	138	55	66	198	79	86	258	103				270	810	324
	27	81	32	47	141	56	67	201	80	87	261	104				280	840	336
	28	84	34	48	144	58	68	204	82	88	264	106				290	870	348
	29	87	35	49	147	59	69	207	83	89	267	107				300	900	360
	Uphill will take MORE steps					Downhill will take FEWER steps												

Practice Compass Course

Compass Course Layout instructions:

Horton 3/22/10

2 people make this easy, but one can do it. Assume the course is 100 yards in diameter. At the end is a description of how to make the 50 yard course if you don't have enough room. After I'm done laying it out, I spray a foot of roundup around each stake.

Needed: 2 sighting compasses, 20 yellow tent pegs, permanent fat black marker, 50 yards of twine looped around a 3 foot metal pipe, hammer (a range finder makes this easier).

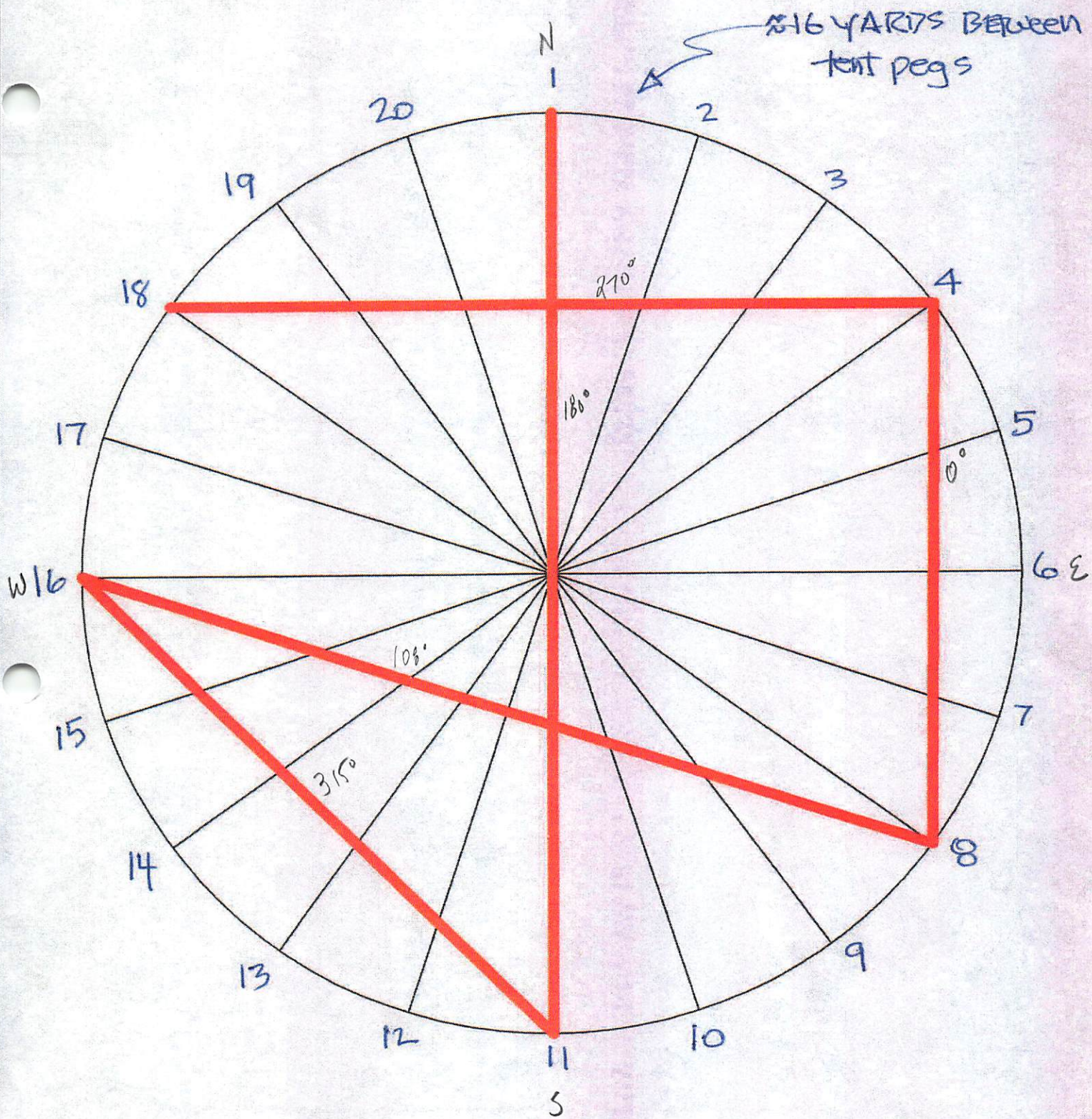
- Find a field at least 100 yards across.
- Hammer the metal pipe into the ground in the center of the field leaving a couple of feet sticking up out of the ground.
- Unwind the 50 yards of twine from the pipe.
- Shoot 0 degrees (magnetic north) with your compass and walk to the end of the twine.
- Tap a tent peg down at your feet a few inches. It will be moved a little bit later. Mark it peg "1."
- Your buddy should shoot 180 degrees and walk the twine south to the end of it.
- You and your buddy should now reach consensus as to where 0 degrees and 180 degrees are with your compasses and the center stake as a guide. You are 100 yards apart from each other. This step is critical.
- Now each of you can go ahead and hammer your tent pegs in solidly. The one at the north end (0 degrees) is marked "1" and the one at the south end is marked "11". Both should be 50 yards from the center metal pipe sticking up.
- Every 16 yards around the circle (using the twine to define the arc) put another tent peg in the ground and number it in ascending order, going clockwise – starting to the east from stake "1". I generally take another two-man shot at 90 to 270 degrees on the circle as well (stakes 6 & 16), just to keep the stakes evenly apart because the 16 yard number between stakes is really 15.7 yards and it's hard to measure exactly 15.7 yards in an arc. Done a different way, each stake is 18 degrees from the next as measured from the pipe in the center of the circle.

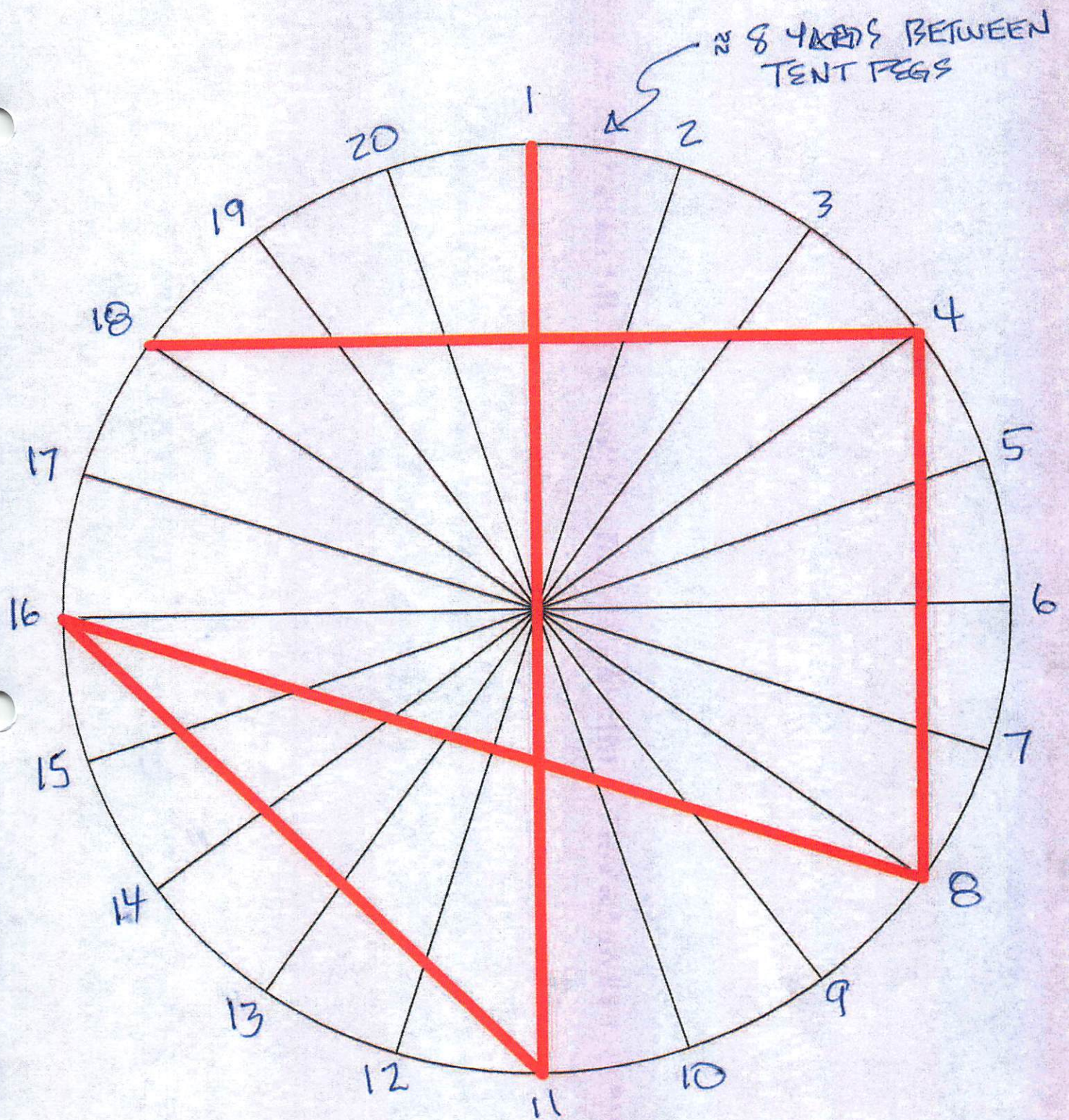
Now the course is laid out. The only difference between the 100 yard course set up and the 50 yard course set up is that the 50 yard course is half the diameter and the distance between the stakes is 8 yards (7.9 yards actually). The adobe attachment to this e-mail shows the two courses (page 1 and page 2) looking down from above the course. The red lines represent the course the first 4Her would take from stake "1".

Now, print out the appropriate excel file for either the 100 yard or 50 yard course. The print range and print area have already been defined, so you ought to be able to just hit the print icon with your cursor. Cut out the slips of paper and hand them out. Up to 20 4Hers can run this course at the same time if you give them different starting numbers. Each excel file has the way-point numbers listed off to the right and at the top of the sheet as well, so you know if they get it right when they walk the course.

The object of the course is for the 4Her to start at the stake designated on his/her directions. The first leg of the course always goes through the center stake and is always the distance of the diameter of the circle (100 or 50 yards). His course is defined as so-many-degrees and so-many-yards. After getting to the stake at the opposite end of where he started, he writes the number of the stake in the box provided. Then the 4Her takes his instructions from the next line of the directions on the slip of paper, treks off to the next stake and writes that number down in the box. Etc. Then, when the course is complete, you get to check it against the correct answers that were at the top of the excel sheet. They are the same numbers for the 50 and 100 yard course. Then, if he got it right, give him a direction slip with a different starting stake and send him out again. 3 times is probably enough for one practice session before they get burned out.

100 yard course is laid out just like the Arkansas State YHEC competition course has been for the last 7 years. Only the bearings and distances have changed. It's a great training tool.





COMPASS CIRCLE 50 YARDS IN DIAMETER

3/30/06 J

100 d
50yd Ken

50 Yard course

Answer key:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10
16	17	18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7
4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3
18	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Start at stake # 1

Then go 180 degrees and 100 yards to stake #
Then go 315 degrees and 71 yards to stake #
Then go 108 degrees and 95 yards to stake #
Then go 0 degrees and 59 yards to stake #
Then go 270 degrees and 81 yards to stake #

Start at stake # 2

Then go 198 degrees and 100 yards to stake #
Then go 333 degrees and 71 yards to stake #
Then go 126 degrees and 95 yards to stake #
Then go 18 degrees and 59 yards to stake #
Then go 288 degrees and 81 yards to stake #

Start at stake # 3

Then go 216 degrees and 100 yards to stake #
Then go 351 degrees and 71 yards to stake #
Then go 144 degrees and 95 yards to stake #
Then go 36 degrees and 59 yards to stake #
Then go 306 degrees and 81 yards to stake #

Start at stake # 4

Then go 234 degrees and 100 yards to stake #
Then go 9 degrees and 71 yards to stake #
Then go 162 degrees and 95 yards to stake #
Then go 54 degrees and 59 yards to stake #
Then go 324 degrees and 81 yards to stake #

Start at stake # 5

Then go 252 degrees and 100 yards to stake #
Then go 27 degrees and 71 yards to stake #
Then go 180 degrees and 95 yards to stake #
Then go 72 degrees and 59 yards to stake #
Then go 342 degrees and 81 yards to stake #

Start at stake # 6

Then go 270 degrees and 50 yards to stake #
Then go 45 degrees and 35 yards to stake #
Then go 198 degrees and 48 yards to stake #
Then go 90 degrees and 29 yards to stake #
Then go 0 degrees and 41 yards to stake #

Start at stake # 7

Then go 288 degrees and 50 yards to stake #
Then go 63 degrees and 35 yards to stake #
Then go 216 degrees and 48 yards to stake #
Then go 108 degrees and 29 yards to stake #
Then go 18 degrees and 41 yards to stake #

Start at stake # 8

Then go 306 degrees and 50 yards to stake #
Then go 81 degrees and 35 yards to stake #
Then go 234 degrees and 48 yards to stake #
Then go 126 degrees and 29 yards to stake #
Then go 36 degrees and 41 yards to stake #

Start at stake # 9

Then go 324 degrees and 50 yards to stake #
Then go 99 degrees and 35 yards to stake #
Then go 252 degrees and 48 yards to stake #
Then go 144 degrees and 29 yards to stake #
Then go 54 degrees and 41 yards to stake #

Start at stake # 10

Then go 342 degrees and 50 yards to stake #
Then go 117 degrees and 35 yards to stake #
Then go 270 degrees and 48 yards to stake #
Then go 162 degrees and 29 yards to stake #
Then go 72 degrees and 41 yards to stake #

Start at stake # 11

Then go 0 degrees and 50 yards to stake #
Then go 135 degrees and 35 yards to stake #
Then go 288 degrees and 48 yards to stake #
Then go 180 degrees and 29 yards to stake #
Then go 90 degrees and 41 yards to stake #

Start at stake # 12

Then go 18 degrees and 50 yards to stake #
Then go 153 degrees and 35 yards to stake #
Then go 306 degrees and 48 yards to stake #
Then go 198 degrees and 29 yards to stake #
Then go 108 degrees and 41 yards to stake #

Start at stake # 13

Then go 36 degrees and 50 yards to stake #
Then go 171 degrees and 35 yards to stake #
Then go 324 degrees and 48 yards to stake #
Then go 216 degrees and 29 yards to stake #
Then go 126 degrees and 41 yards to stake #

Start at stake # 14

Then go 54 degrees and 50 yards to stake #
Then go 189 degrees and 35 yards to stake #
Then go 342 degrees and 48 yards to stake #
Then go 234 degrees and 29 yards to stake #
Then go 144 degrees and 41 yards to stake #

Start at stake # 15

Then go 72 degrees and 50 yards to stake #
Then go 207 degrees and 35 yards to stake #
Then go 0 degrees and 48 yards to stake #
Then go 252 degrees and 29 yards to stake #
Then go 162 degrees and 41 yards to stake #

Start at stake # 16

Then go 90 degrees and 50 yards to stake #
Then go 225 degrees and 35 yards to stake #
Then go 18 degrees and 48 yards to stake #
Then go 270 degrees and 29 yards to stake #
Then go 180 degrees and 41 yards to stake #

Start at stake # 17

Then go 108 degrees and 50 yards to stake #
Then go 243 degrees and 35 yards to stake #
Then go 36 degrees and 48 yards to stake #
Then go 288 degrees and 29 yards to stake #
Then go 198 degrees and 41 yards to stake #

Start at stake # 18

Then go 126 degrees and 50 yards to stake #
Then go 261 degrees and 35 yards to stake #
Then go 54 degrees and 48 yards to stake #
Then go 306 degrees and 29 yards to stake #
Then go 216 degrees and 41 yards to stake #

Start at stake # 19

Then go 144 degrees and 50 yards to stake #
Then go 279 degrees and 35 yards to stake #
Then go 72 degrees and 48 yards to stake #
Then go 324 degrees and 29 yards to stake #
Then go 234 degrees and 41 yards to stake #

Start at stake # 20

Then go 162 degrees and 50 yards to stake #
Then go 297 degrees and 35 yards to stake #
Then go 90 degrees and 48 yards to stake #
Then go 342 degrees and 29 yards to stake #
Then go 252 degrees and 41 yards to stake #

Resources:

<https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination>

<https://www.maptools.com>

<http://www.compassdude.com/default.php>

<https://store.usgs.gov/maps>

<https://www.gaiagps.com>

<https://caltopo.com>

Recommended compass:

SUUNTO MC-2 G USGS MIRROR COMPASS (Feb 2021 price on Amazon is \$44)

Recommended Practice Maps:

USGS 7.5 minute quadrangle map. Please use the latest version and choose a local map with a variety of topographic features if possible.