SEARCH AND RESCUE
LAND NAVIGATION

P.A.C.E.

System for Search and Rescue

- PRIMARY – GPS, Phone Apps
- ALTERNATE – Map and Compass
- CONTINGENCY – Terrain Association
- EMERGENCY - PLBs

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This Course Consists Of:

- Compass and Map Basics
- Traveling to a Target
- Topo Map Basics
- Distance Calculations
- Finding Yourself
- UTM Coordinate System
- Using GPS with a Map
- Understanding And Adjusting For Declination

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Compass Types

Baseplate

Accessory

Mirrored – Sighting (Preferred)

Digital

Lensatic

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Bearing Index (Read Bearing Here)

Compass Needle – Red Points To Magnetic North

Orienting Arrow

Orienting Lines

Declination Scale

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Boxing A Compass

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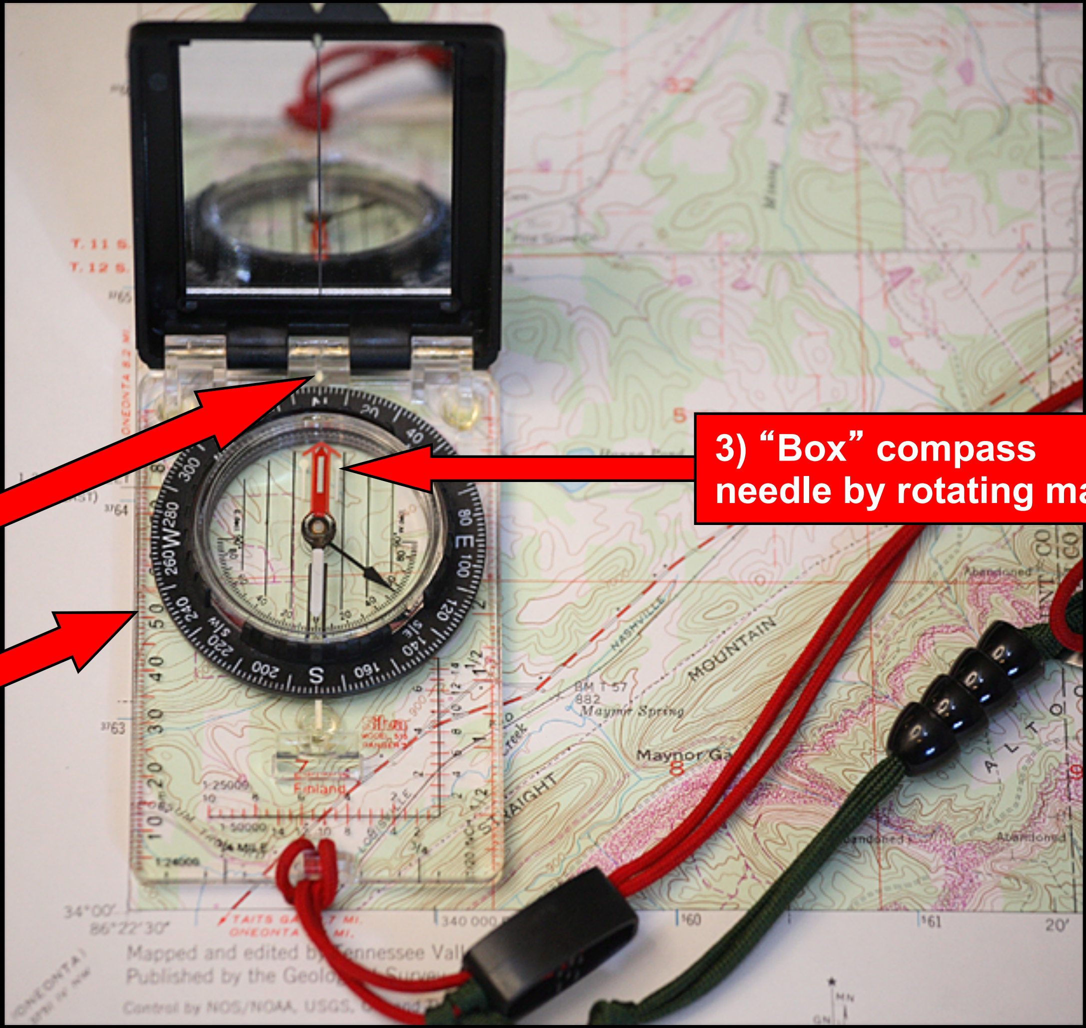
MAP ORIENTATION

With Compass Adjusted For Declination

1) Adjust dial so "N" is at index line.

2) Align edge of compass with north / south reference line.



3) "Box" compass needle by rotating map.

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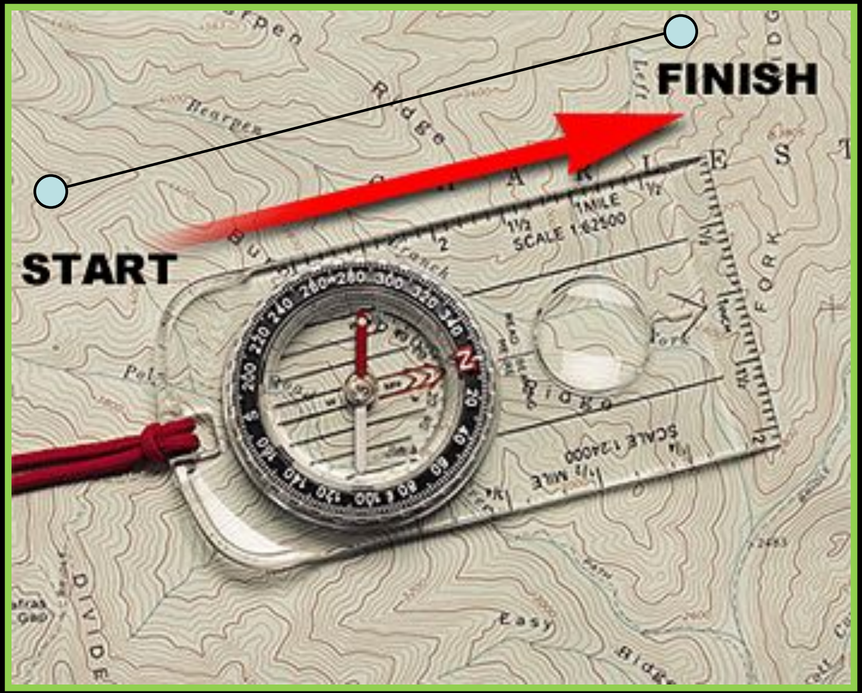
Finding An Azimuth With Compass

(Map without grid line)

Traveling To a Target On The Map – Step 1



1) Draw a line on the map from your starting point to your finish point.
2) Orient the map to north.
3) Place the compass on the map with the edge of the compass on the line and the bearing arrow pointing at your destination

Traveling To a Target On The Map – Step 2

Set Compass Heading - Turn the dial on the compass until “N” outline arrow boxes the compass needle. Your direction to your target (in degrees) is read at the Index Line on the Dial.

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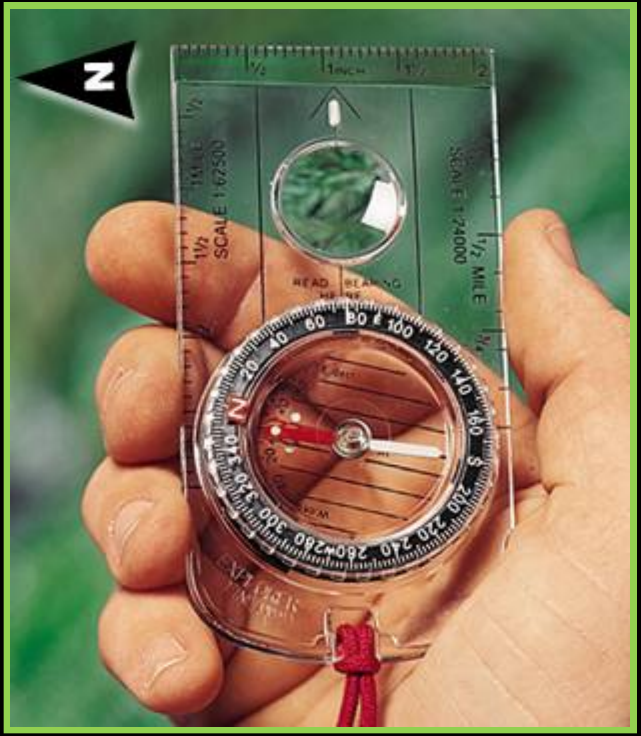
Traveling To a Target On The Map – Step 3



Follow Your Heading - Remove the compass from the map and hold it level, so the Magnetic Needle is free to turn. Turn your body until the red end of the Needle aligns with the Orienting Arrow (boxed) and "N" on the Dial. Using the Direction of Travel Arrow, sight a distant landmark and move to it. Repeat this process until you reach your destination.

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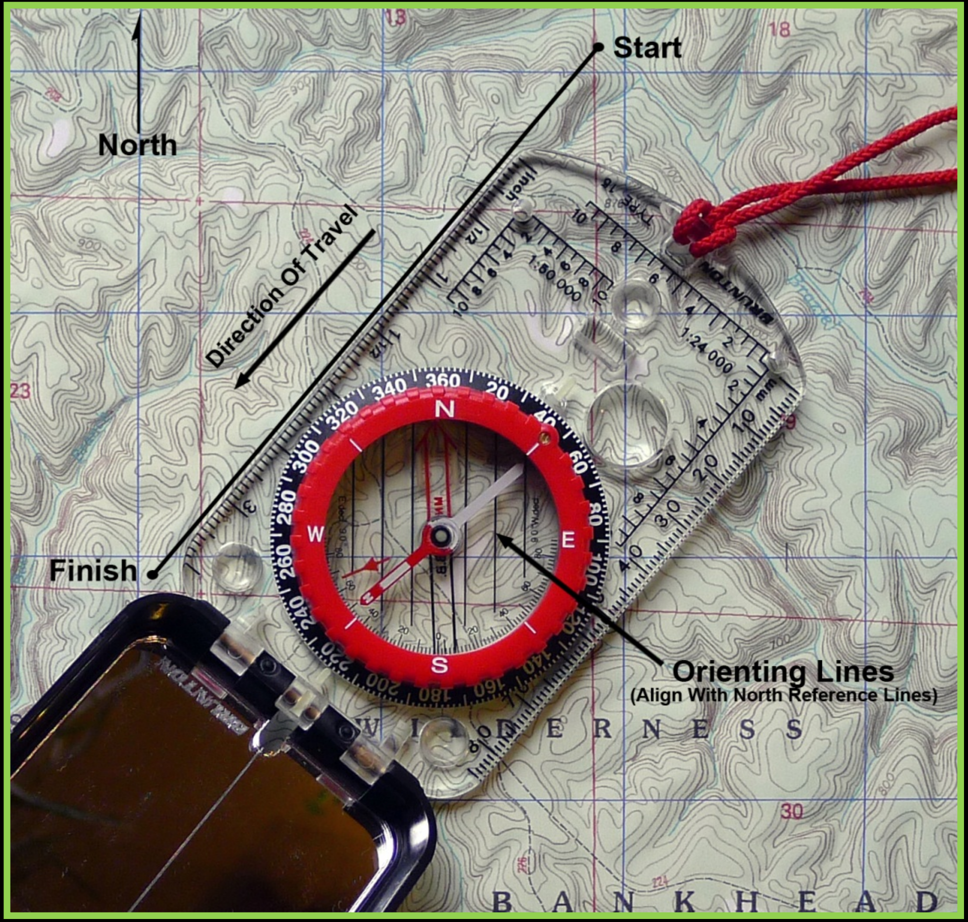
Finding An Azimuth With Compass

(SUGGESTED METHOD - Using Grid Lines)

- Draw a line from start to finish.
- Lay the edge of your compass on the line in the direction you are traveling.
- Rotate the compass bezel until the orienting lines align with your North Reference Lines (Make sure that North is pointing to North on the map).
- Pick up your compass, box and travel to the destination.
- Note: The compass shown has already been adjusted for declination.



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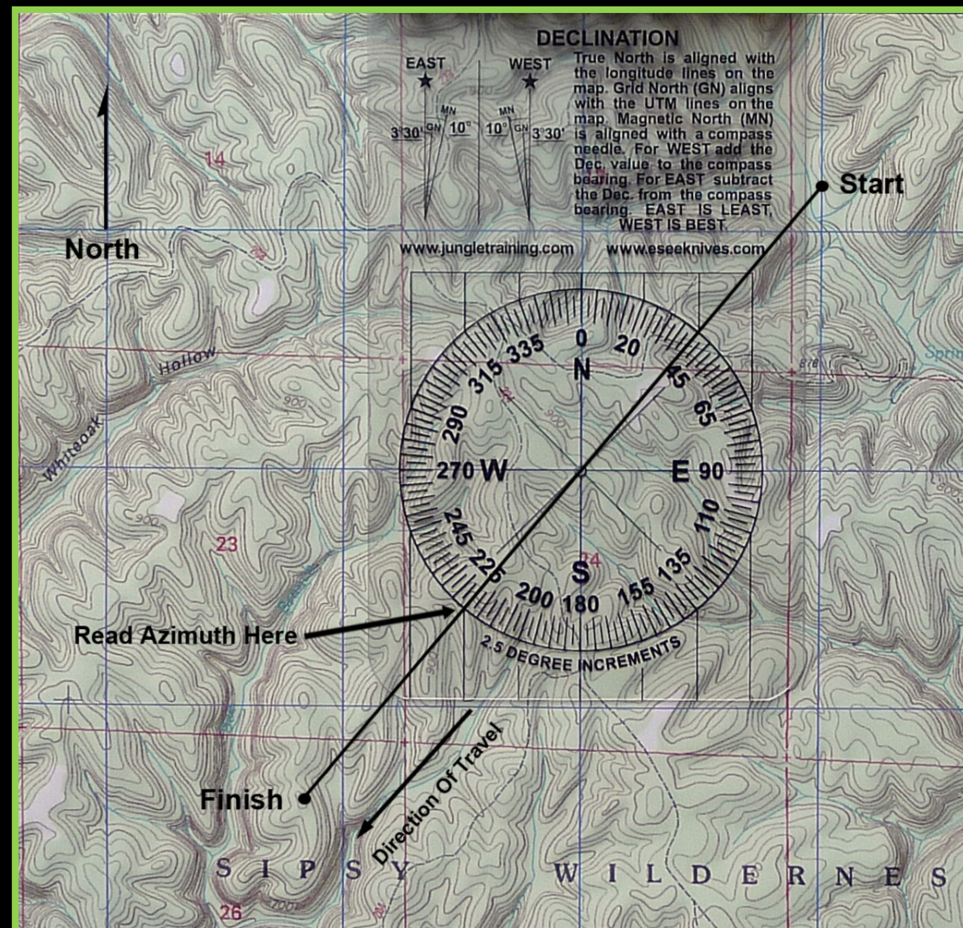
Finding An Azimuth With Compass Card

(Using Grid Lines)

- Draw a line from start to finish.
- Lay the compass rose on the line so the line crosses through the center of the rose.
- Align N / S line or orienting lines on the compass rose with North Reference Line.
- Read your azimuth on the "Finish" side of the compass rose.
- Note: unless you are using a compass adjusted for declination, you will have to add or subtract the declination value to the value that you acquire from the compass rose.



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Traveling To a Target With A Sighting Compass

Posting Up

In addition to using natural landmarks as targets for your direction of travel, you can also post up a member of your team as a target.

Another option is the Back Azimuth.

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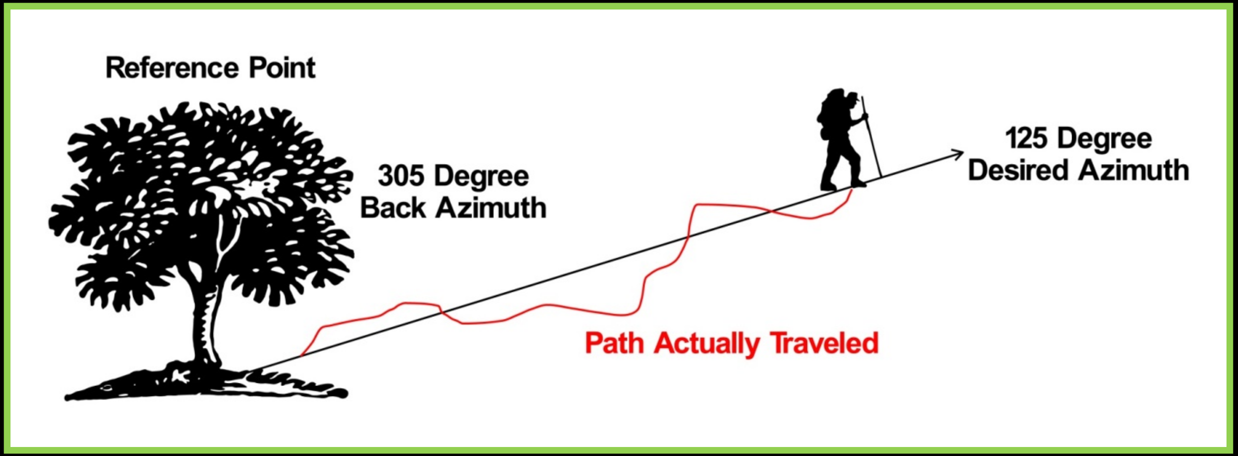
Back Azimuth



Use a Back Azimuth if you need to verify you are still on your desired direction of travel. This is especially handy when crossing rivers or boxing around objects.

Back Azimuth is 180 degrees from your target azimuth. If your target azimuth is more than 180 degrees, then subtract 180. If it is less than 180, then add 180.

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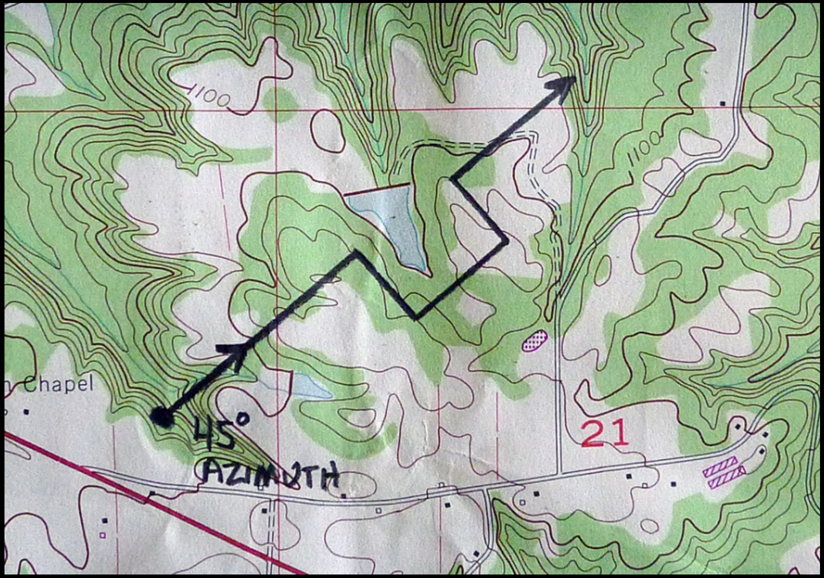
Boxing Around Objects



Right – Add
Left - Subtract

- Example direction of original travel is 45 degrees
- Turn 90 degrees to a new azimuth of 135 (count your paces)
- Turn 90 degrees back to the original azimuth of 45 degrees until you are past obstacle
- Turn 90 degrees to a new azimuth of 315 and pace the same amount as the first turn
- Turn 90 degrees back to the original azimuth of 45 degrees and continue on

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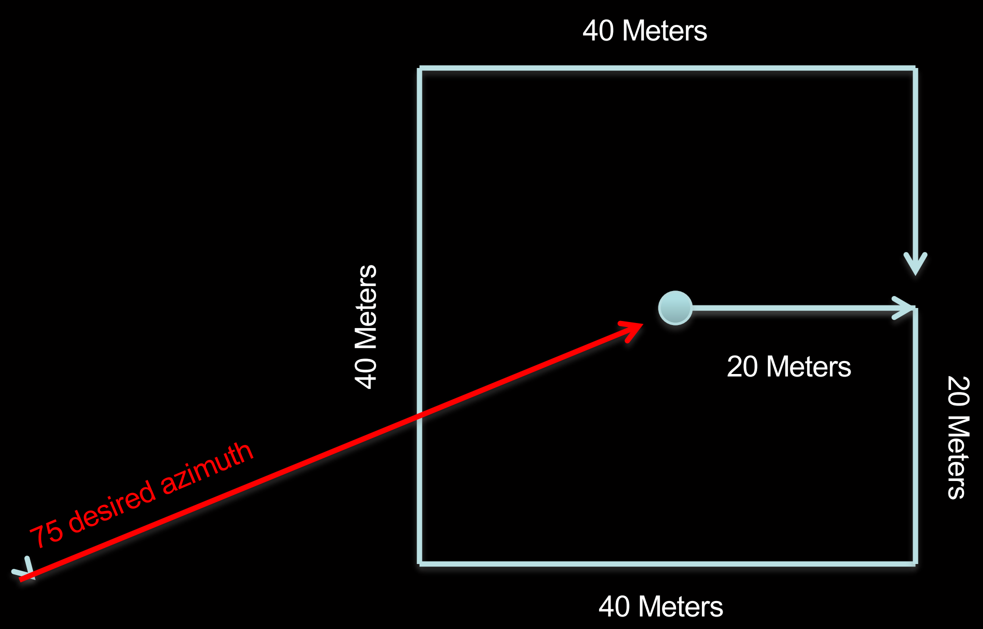
LATERAL DRIFT – MISSING YOUR TARGET

If you cannot find your target after walking your azimuth the correct distance, then mark the spot where you think it should be and began a structured search of the area. Make note of your azimuths, pace count and direction changes. Start your grid small then go larger if you cannot locate the target.

Alternate Methods: Skirmish line as you approach



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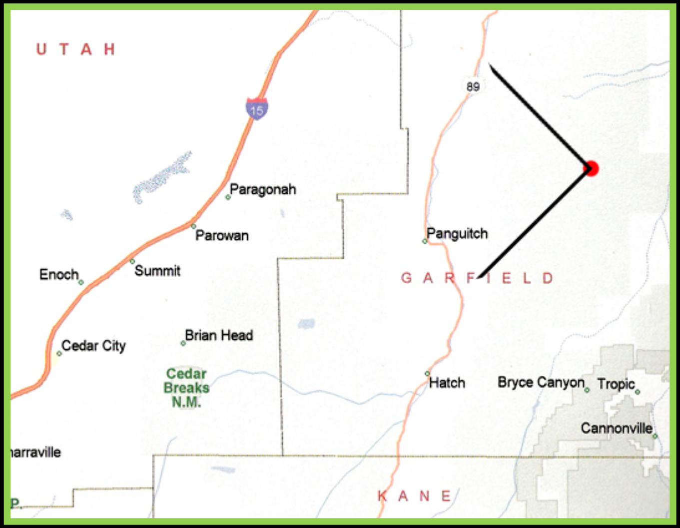
Gross Direction Navigation



As obvious from this simple road map, the lost hiker only needs to travel a westerly direction to cross a road and reach civilization. Always know which general direction crosses a main artery!

When using a map and compass always have a “panic azimuth.”

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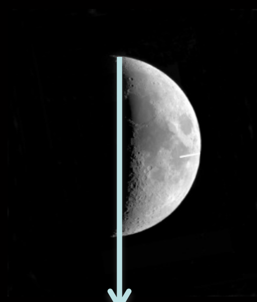
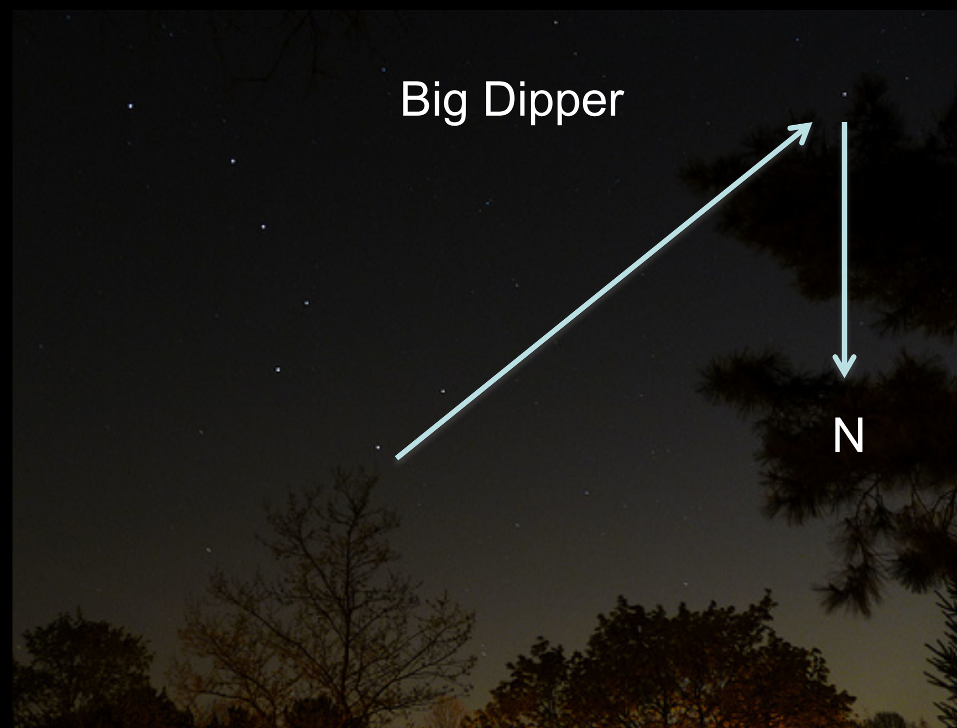
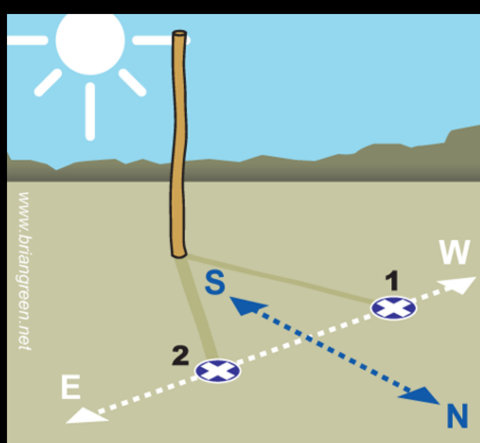
Gross Direction Navigation Aids



Quarter Moon

S





Shadow Stick

Terrain Association Navigation

This is the most widely used method of navigation. The navigator plans his route so that he moves from terrain feature to terrain feature. An automobile driver in a city uses this technique as he moves along a street or series of streets, guiding on intersections or features such as stores, parks or houses. Like the driver, the navigator selects routes or *streets* between key points or *intersections*. These key points can be lakes, mountains, roads or any other terrain feature readily recognized on a map. Before you hike a new area, familiarize yourself with the terrain by studying maps, satellite photos or any other available information.

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Backstops, Handrails & Aiming Off

BACKSTOPS are features that typically run perpendicular to your azimuth and located beyond your target point. If you run into your backstop then you know you have traveled too far and missed your target point. Backstops can be rivers, roads, mountains, railroad tracks or any other useable feature.

HANDRAILS are features that run parallel to your azimuth. They can be rivers, roads, mountains, or any other useable feature that the navigator can use to continue traveling in the desired direction.

AIMING OFF is a process of deliberately adding or subtracting to the desired azimuth so the navigator knows which way to go once they reach a feature (such as a trail or road) that leads to the target.

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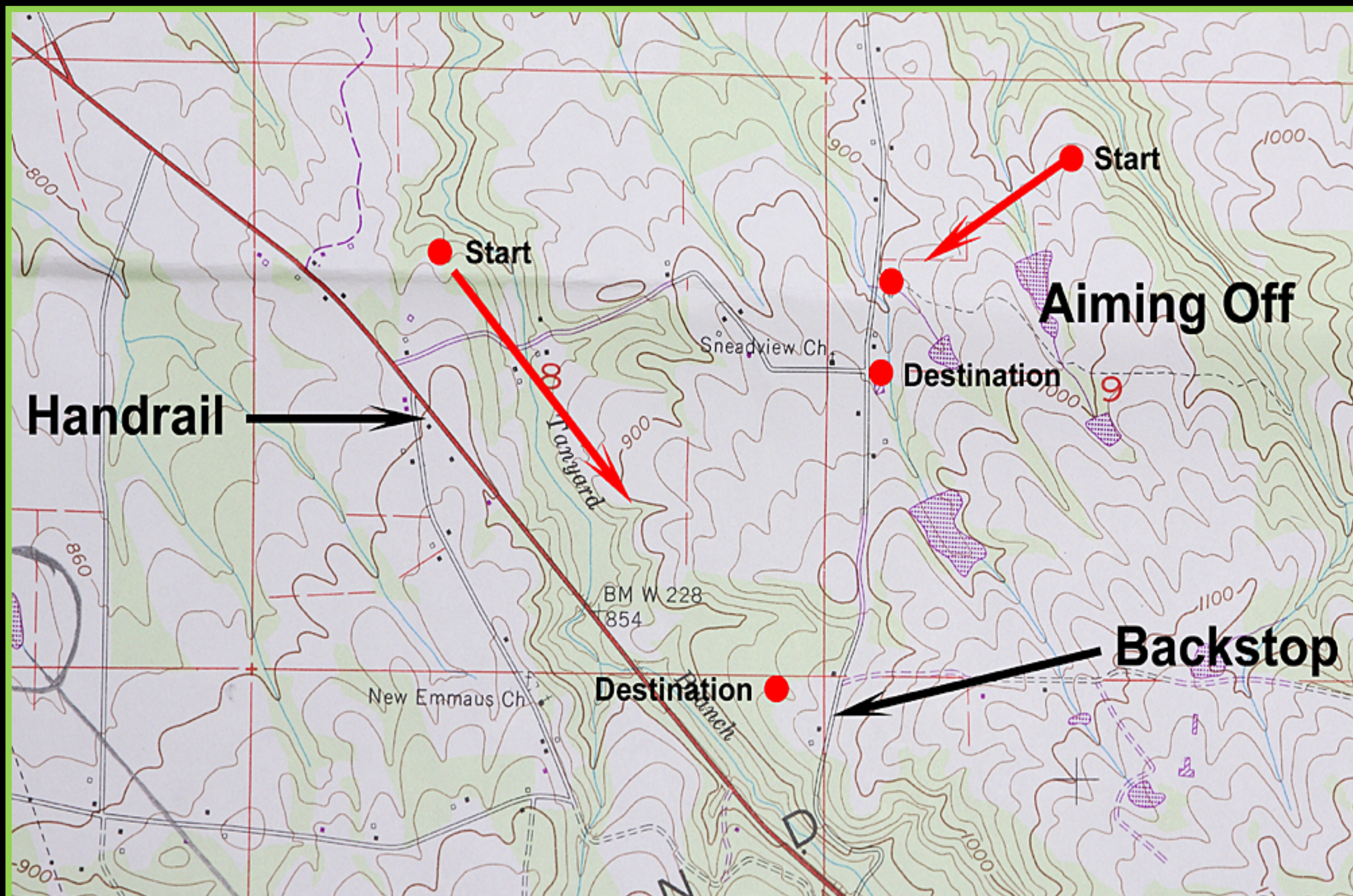
Backstops, Handrails & Aiming Off



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TOPO MAP BASICS

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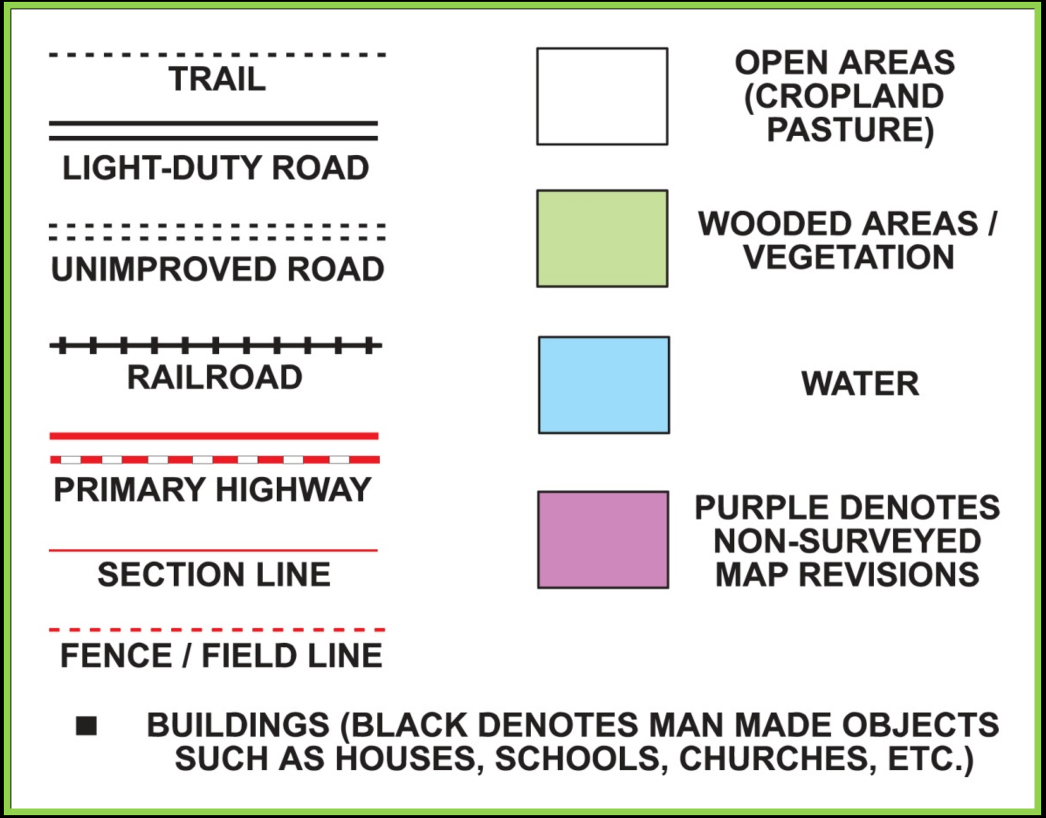
BASICS SYMBOLS



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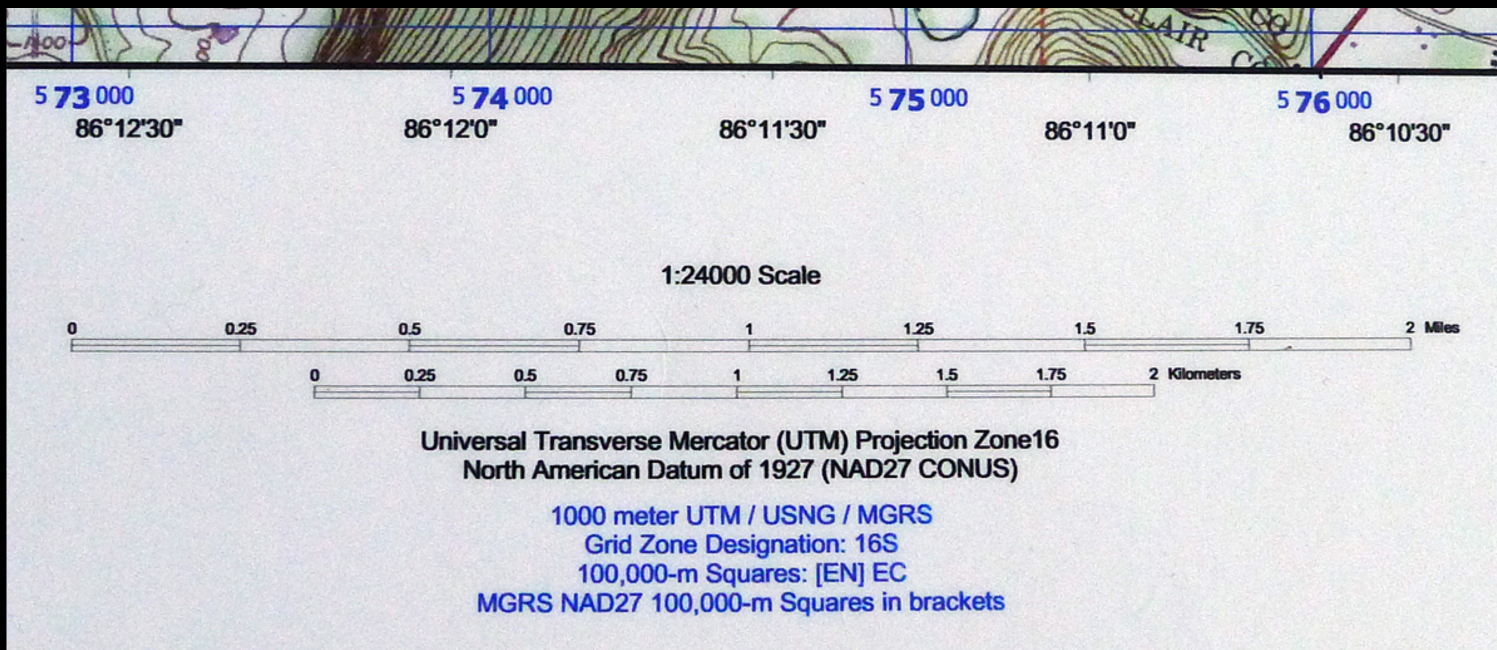
Map Scale & Datum



Always set your GPS to the map datum shown on your map!
Always use the proper scale card for measuring on a map!

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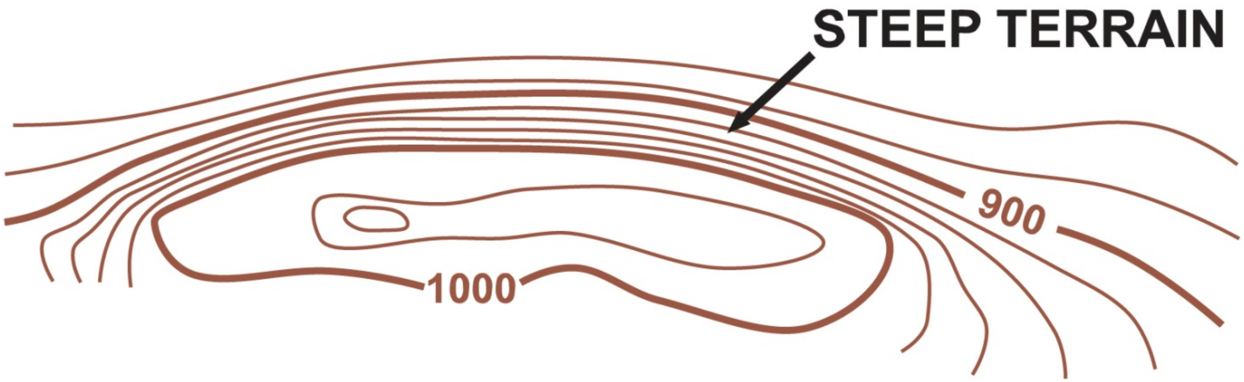
CONTOUR LINES

The closer the contour lines, the steeper the terrain. Check the map for the contour intervals. Contour lines will also have elevation markings.



Example above shows a map with contour intervals of 20 feet.

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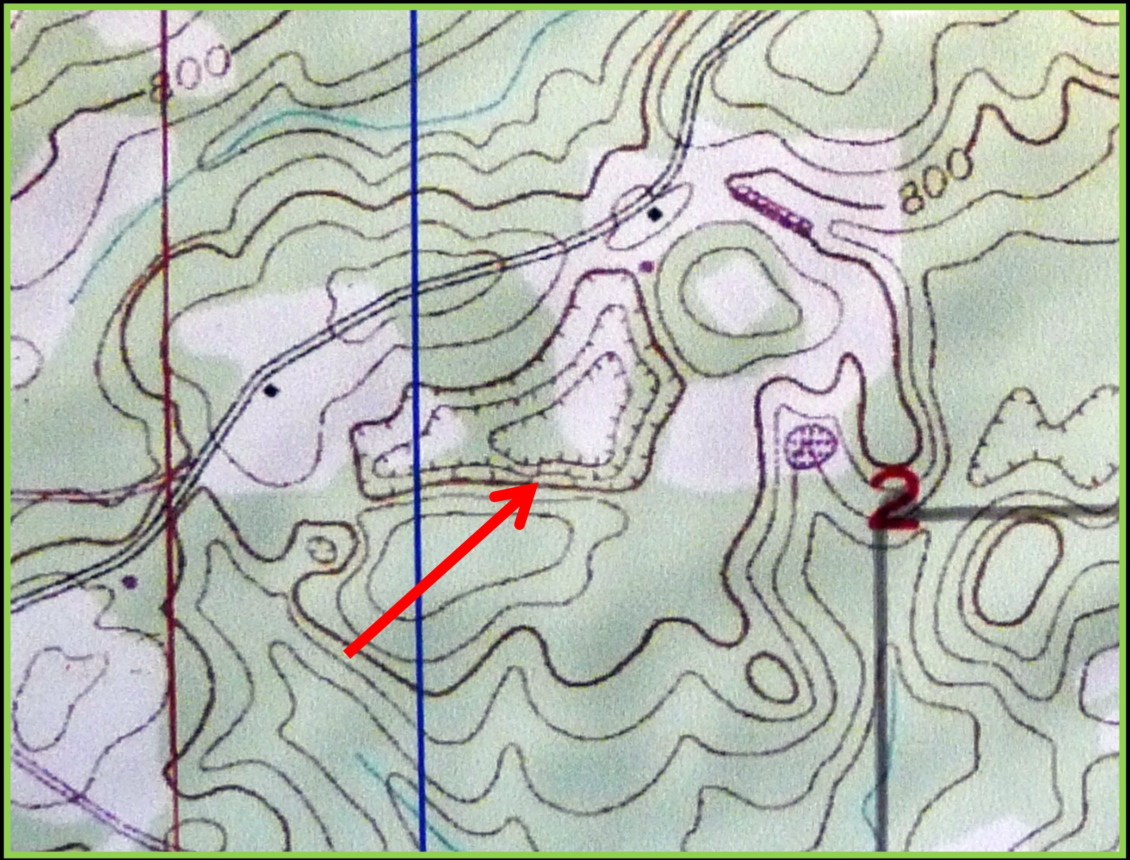

Depression

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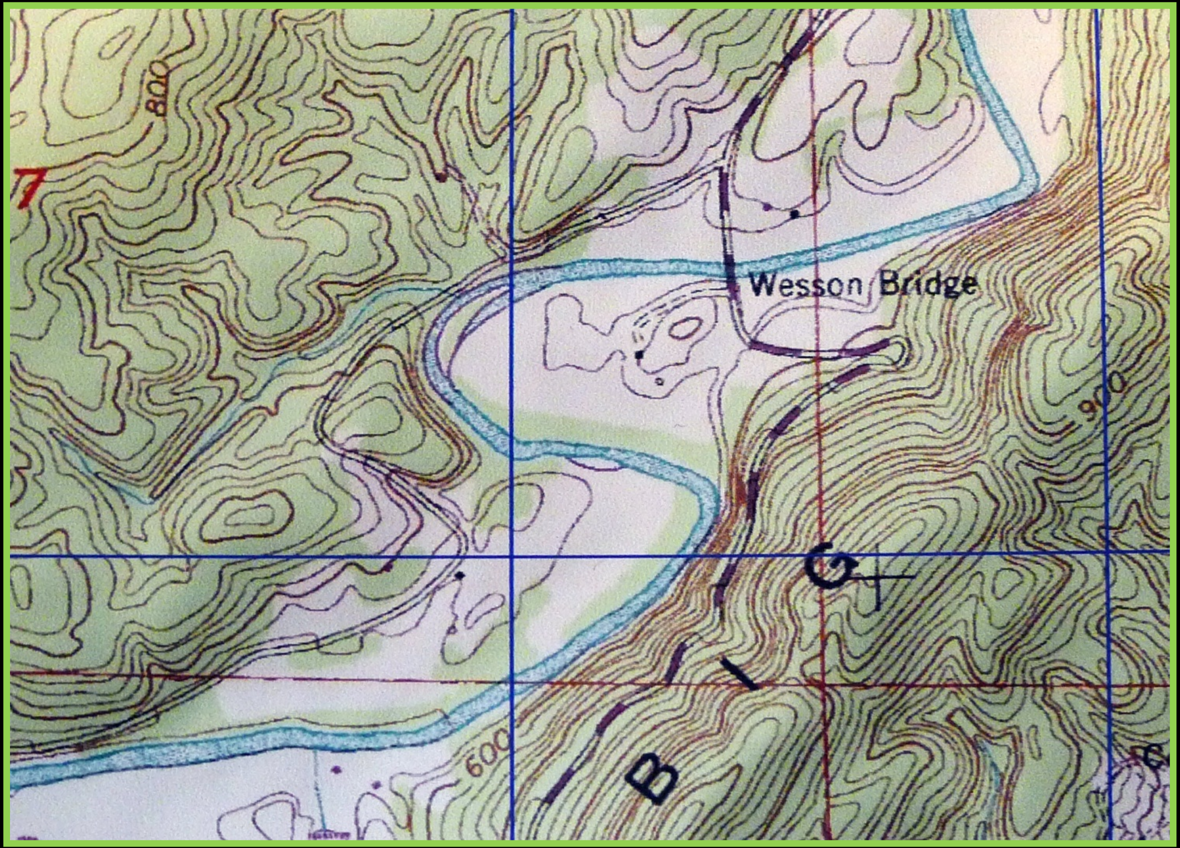

Continuous Water Flow

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Intermittent Water Flow

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Clear Areas / Fields

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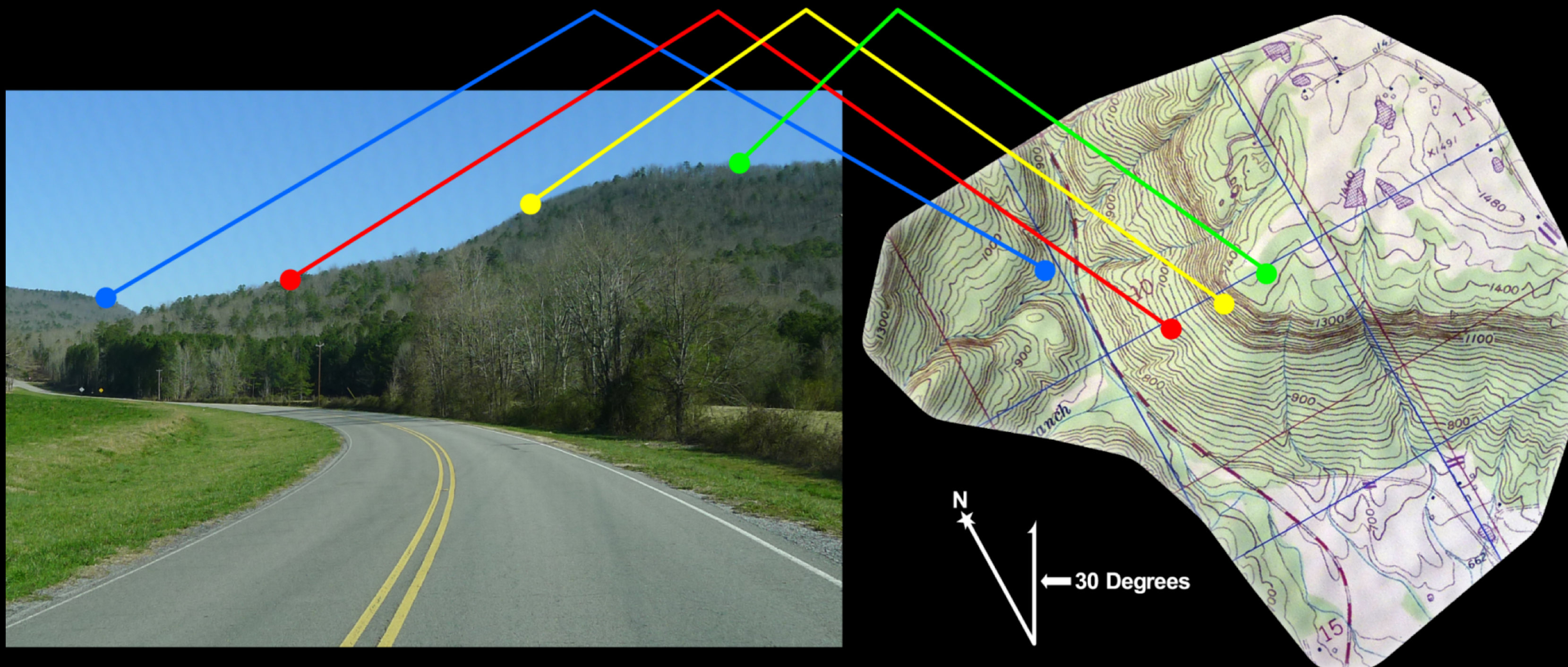

Actual View **Topo View**

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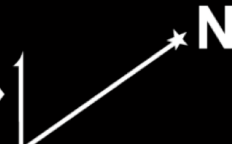
Actual View

Topo View

300 Degrees



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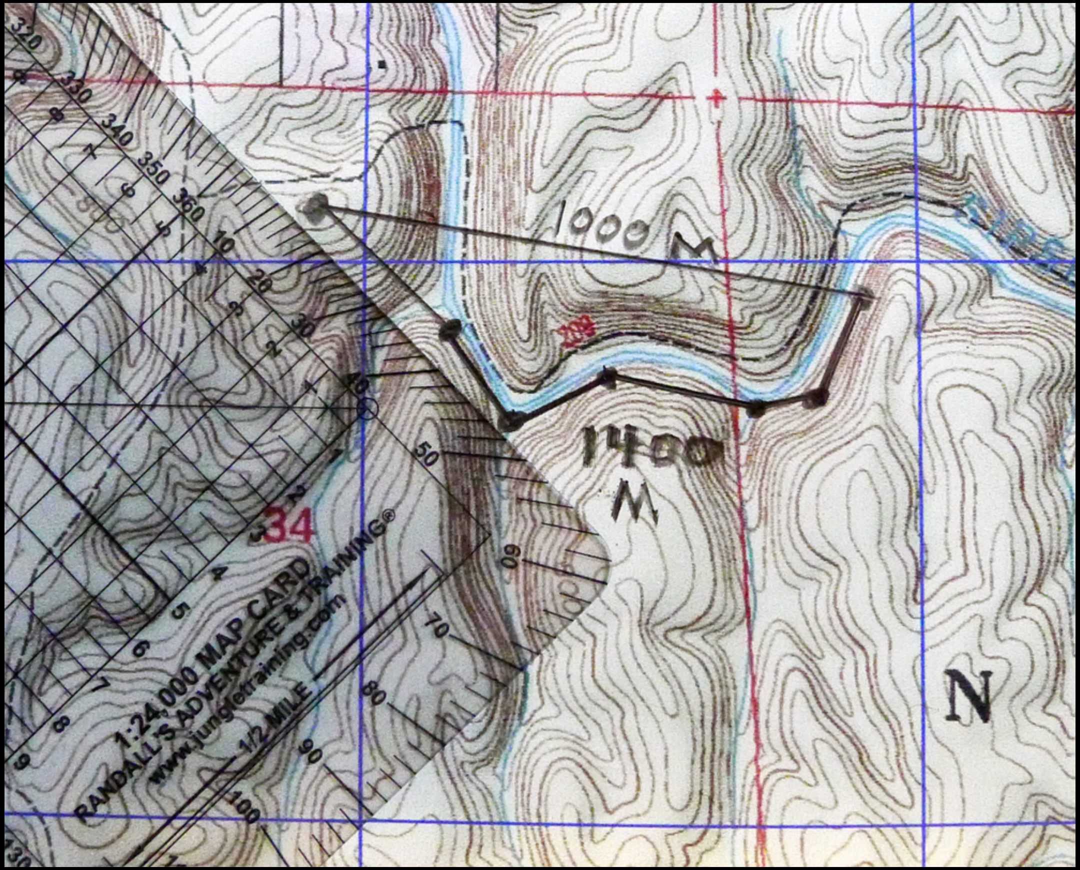
Determining Distance On Map



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DETERMINE DISTANCE TRAVELED BY PACE COUNT

(Not a preferred method. Use checkpoints instead.)

In thick jungle, where landmarks can not always be seen to track your position, pace counting is the best way of measuring distance. Pace counting will allow the navigator to estimate where he is at any given time. To be accurate, the navigator must practice pacing over different types of terrain. First you have to do some calculations. Measure out exactly 100 meters on three types of ground. Flat easy terrain, rougher terrain with some slope and then steep hill terrain. Then on each measured course count your paces (every time your left foot touches the ground or every 2 steps = 1 pace). You will have 3 different pace counts for different types of terrain. Once finished, memorize your pace count for all 3 types.

Averages		
Flat easy terrain	100 meters	65 paces
Rougher terrain with some slope	100 meters	75 paces
Steep hill terrain	100 meters	95 paces

General Rule: You have never traveled as far as you think you have.

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Ranger Pace Count Beads

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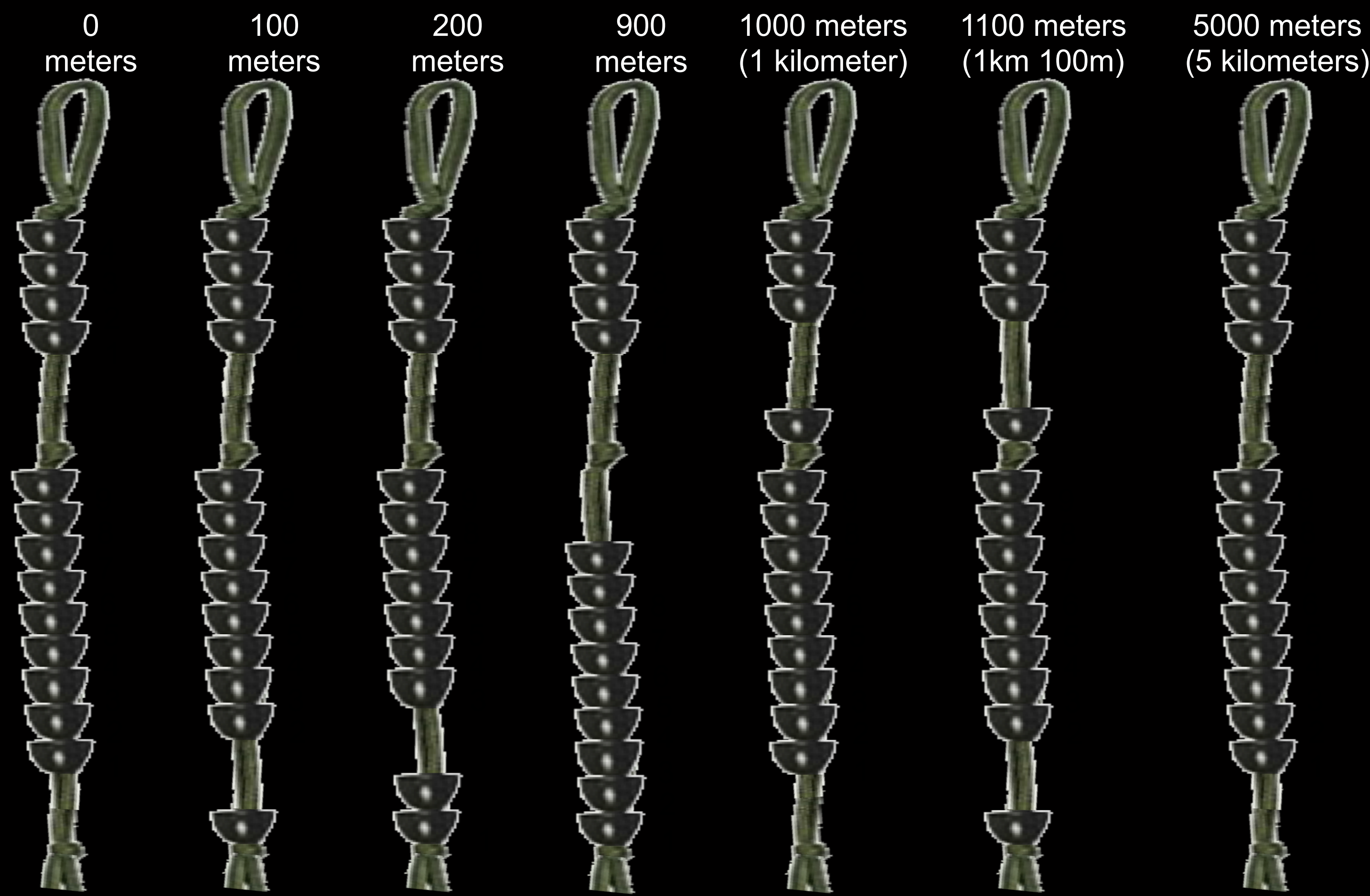

CONDITIONS THAT AFFECT PACE COUNT

- Slopes – Your pace lengthens on a downslope and shortens on an upgrade.
- Winds – A headwind shortens the pace and a tailwind increases it.
- Surfaces – Sand, gravel, mud, snow and similar surfaces tend to shorten your pace.
- Elements – Falling rain or snow causes the pace to be reduced in length.
- Clothing – Excess clothing or shoes with poor traction affect the pace length.
- Visibility – Poor visibility due to rain, snow, or fog will shorten your pace.

FINDING YOURSELF

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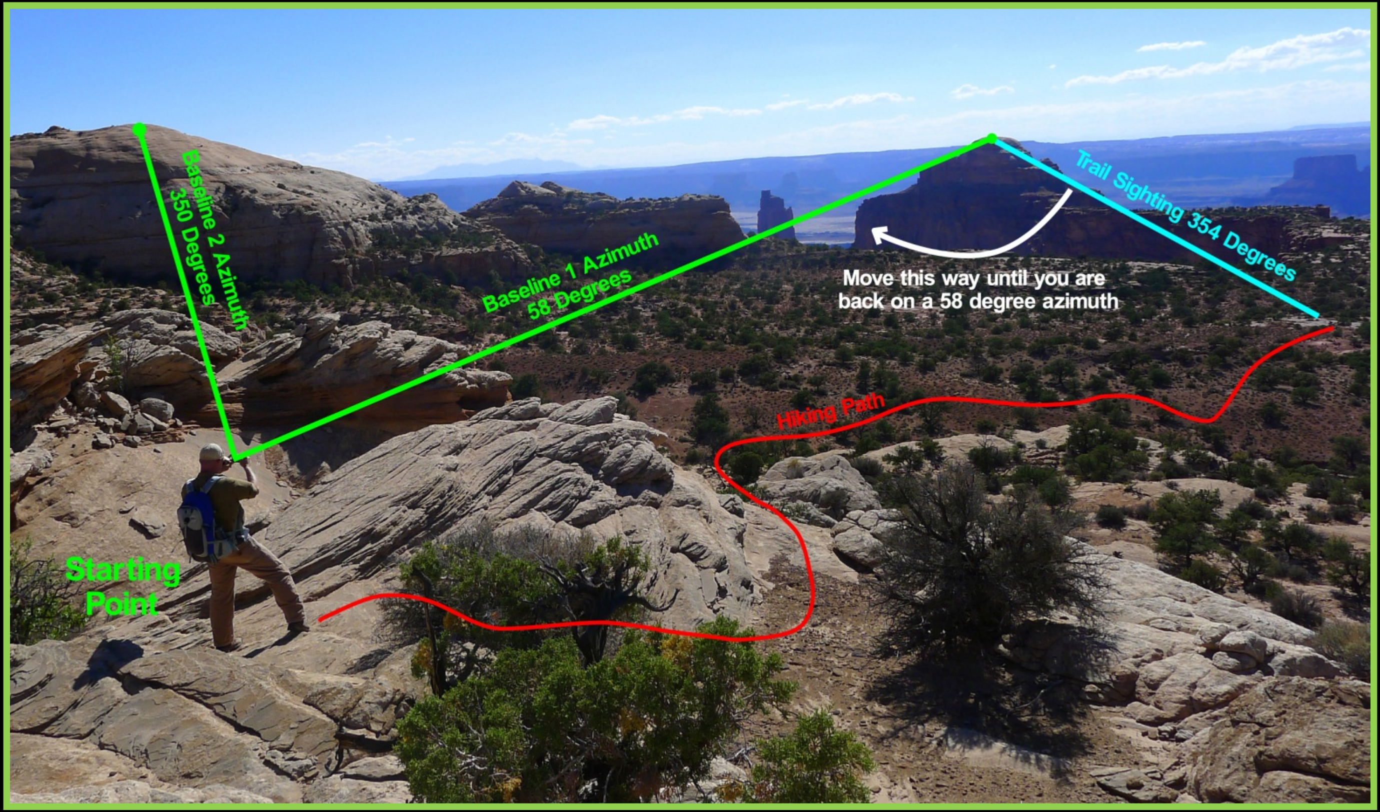
Baselines



Find two prominent features. Shoot an azimuth to the first one and write it down. Shoot an azimuth to the second one and write it down. You can now travel freely. If you get lost, shoot an azimuth to the first feature and move until you get back on your first azimuth. Shoot an azimuth to your second feature and move until you get back on your second azimuth. You will be back at your starting point once both azimuths are the same as the ones you wrote down.

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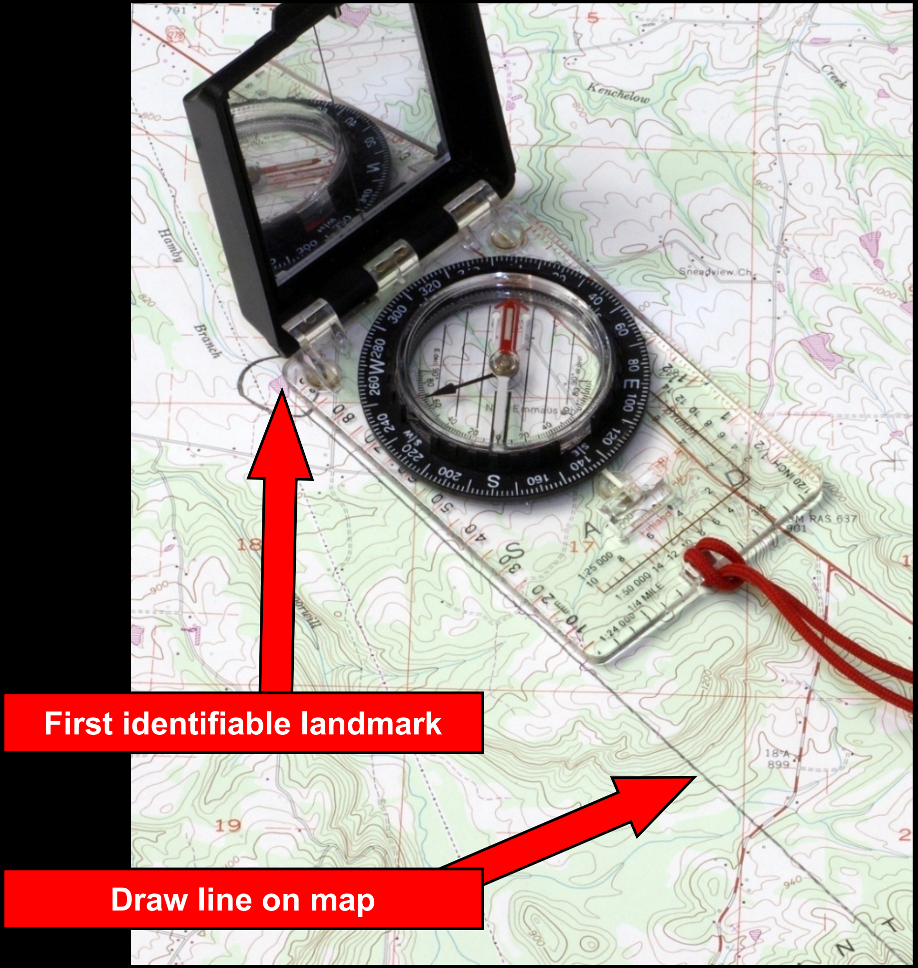
RESECTION (without grid lines)

- Orient your map and secure its position. Locate a landmark on the map that you can actually see in the landscape. Take a compass bearing to that landmark by sighting and then rotating compass dial until the needle is boxed. Once you have a bearing, do not move the compass dial. Lay the corner of the compass on the map landmark and rotate the whole compass (not the dial) until the needle is boxed. If done properly the corner of the compass will still be over your landmark. Draw a line along the edge of the compass base.



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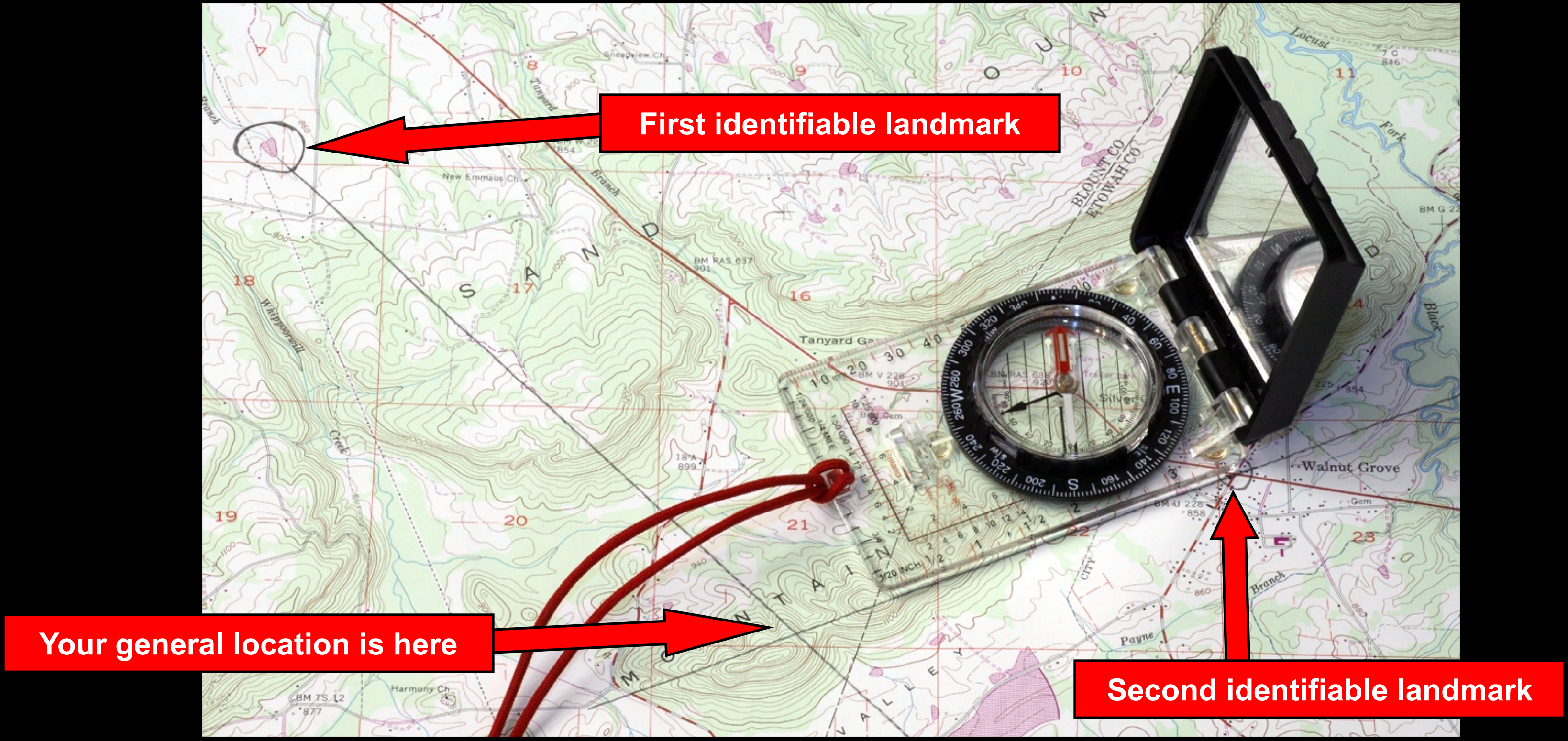
RESECTION - Step 2

- Find a second identifiable landmark on the map and repeat the process from the previous slide. Where the two lines intersect is roughly where you are on the map.
- Finding a third point on the map and repeating the process is called “triangulation” and increases the accuracy of finding your location.



if you are already on a known location (such as a road, river or mountain ridge) but not sure exactly where you are on this feature, you may only need to shoot one azimuth to determine your exact position on the map

INTERSECTION is the reverse of RESECTION. An example of intersection is seeing smoke from a forest fire and determining where the fire is located on a map.

PLOTTING COORDINATES

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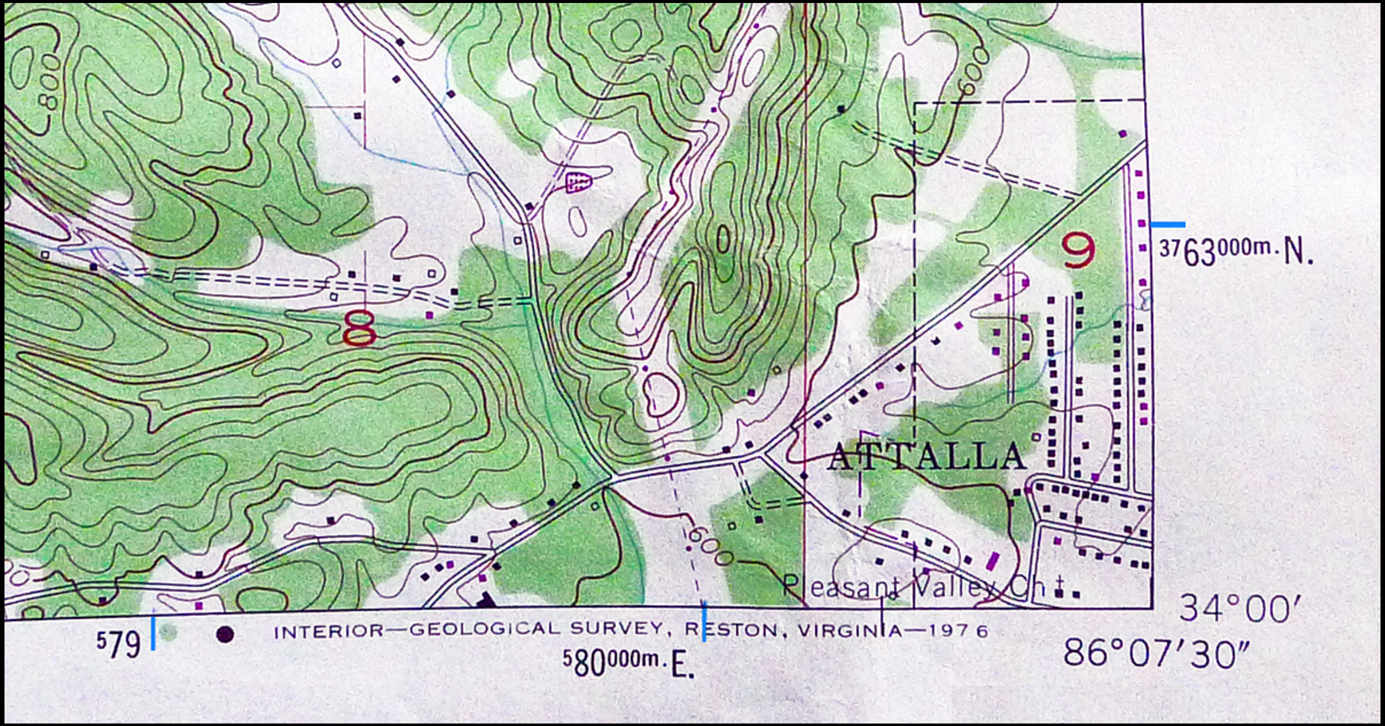
Map Grids



When using a GPS with a map, always set your GPS to the grid system you are using on the map.

Universal Transverse Mercator (UTM)

UTM is a rectangular coordinate system based on the latitude and longitude (geographic) coordinate system. With UTM, the earth is divided into 60 zones that allows it to be projected onto maps with minimal distortion. All coordinates are expressed in meters.

The UTM/USNG grid system is the easiest method of relaying your position to others, finding yourself on a map after getting a location fix with a GPS unit, or navigating to a position on a map using a GPS unit.

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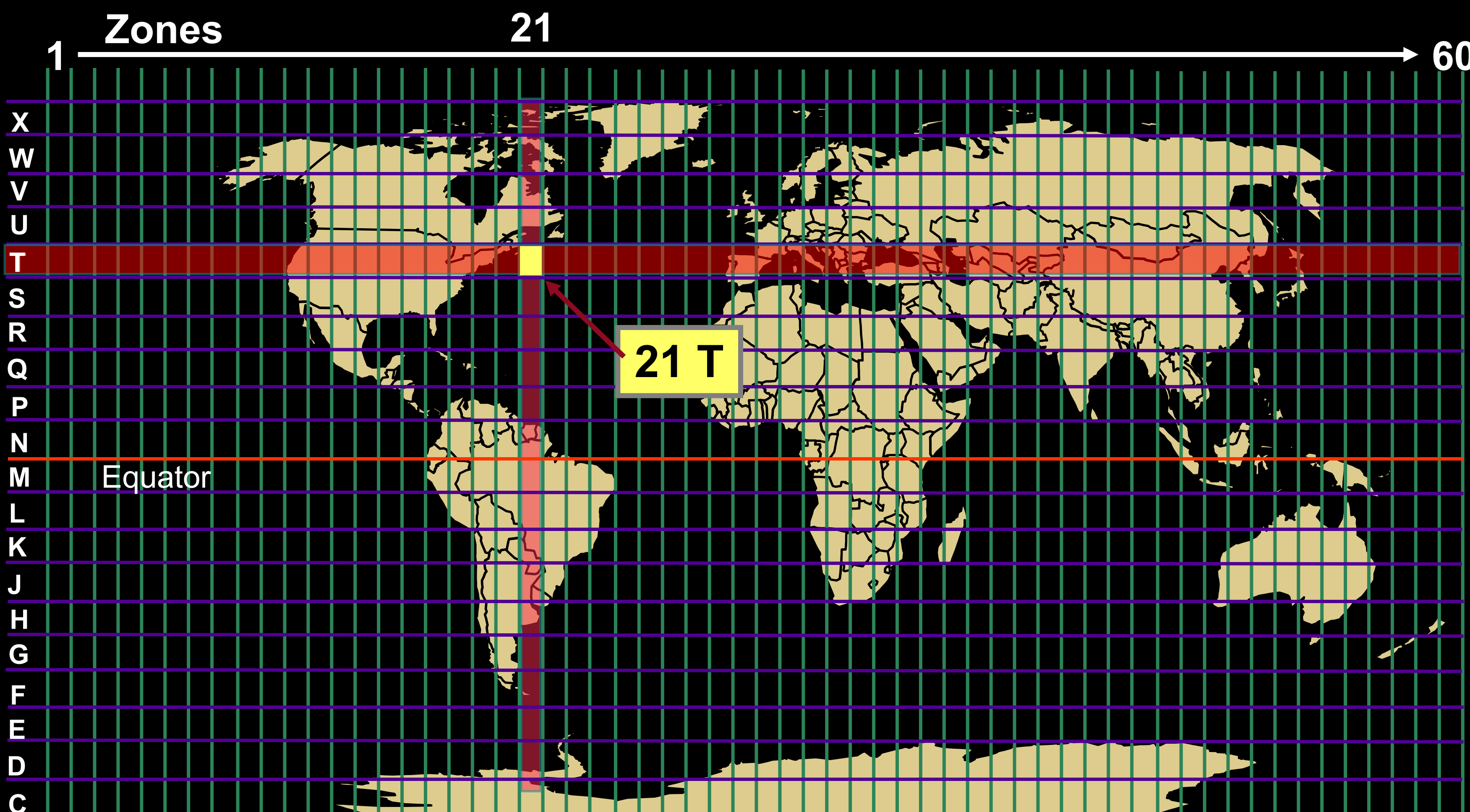
UTM: 60 Zones and 20 Latitude Bands



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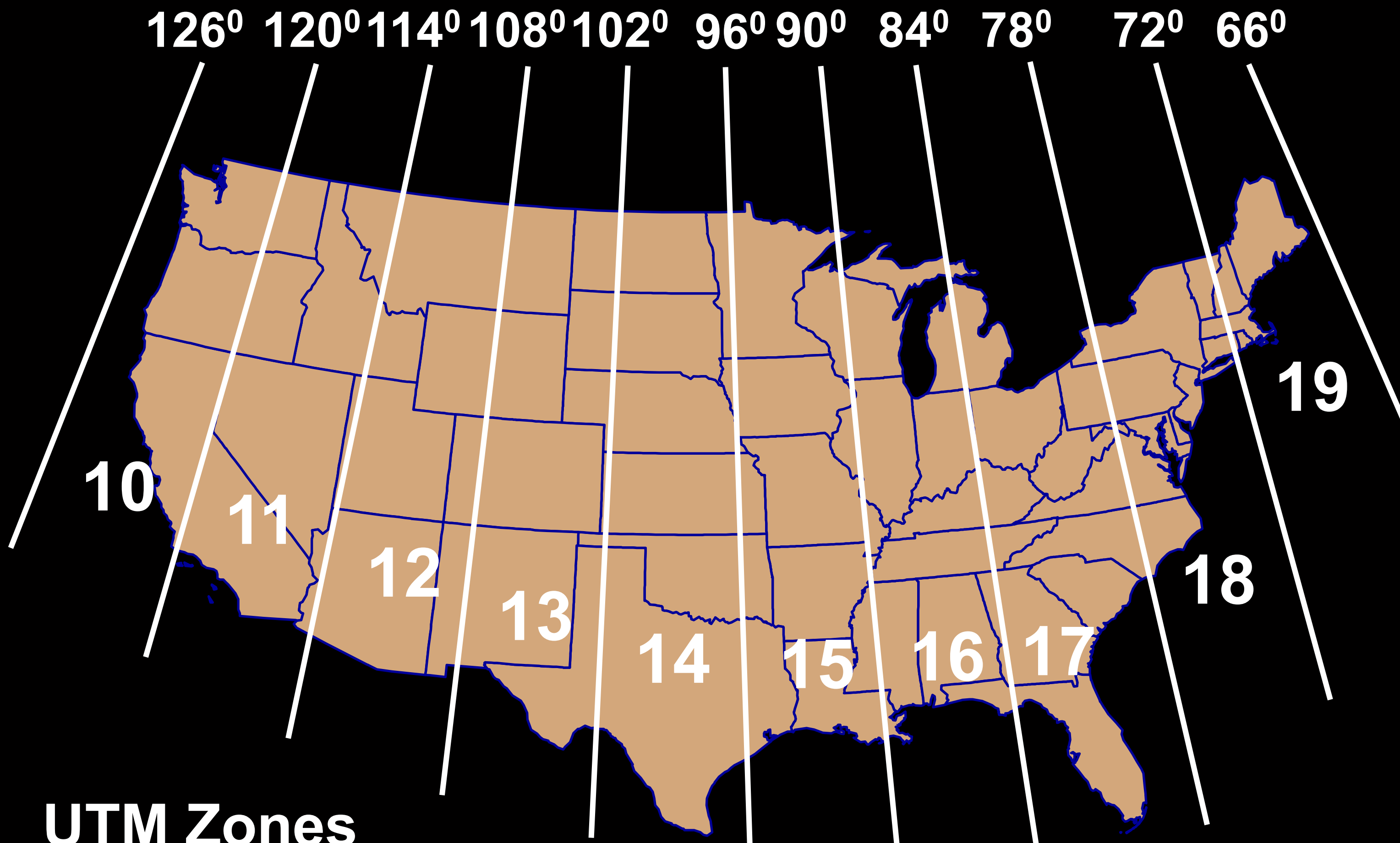

UTM Zones

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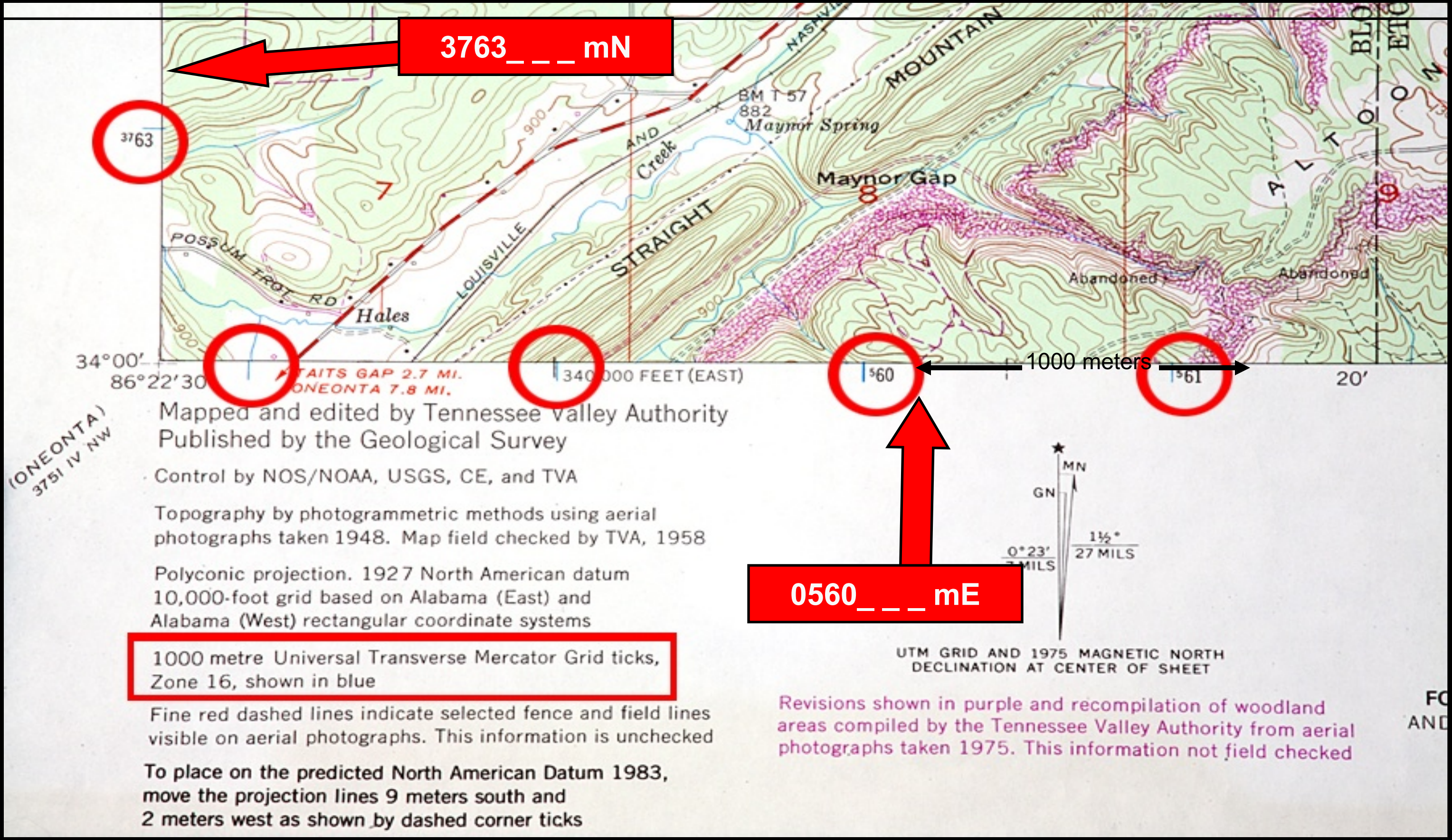
Universal Transverse Mercator (UTM)



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Easting:

Is a 6-digit number to designate the EAST/WEST position in the grid. The grids are the widest at the equator. Since each grid has a different width, a system was created to measure the distance across a grid starting from the vertical center-line of each grid as opposed to starting from the left or right edge of a grid. The center line of each grid is called the central meridian. The central meridian is always assigned an easting value of 500,000 meters East. It is expressed as 500,000 mE. As you move west of the central meridian the easting will be a number less than 500,000. As you move to the east of the central meridian the easting will be a number greater than 500,000. An easting of zero will never occur, since a zone is never more than 674,000 meters wide.

Northing:

The second number is called the Northing. It is a 7-digit number that designates how many meters you are north or south of the equator. 0 North begins at the Equator for measurements going north. To avoid negative numbers, the number 10,000,000 has been set at the Equator as a starting point for Northing values south of the Equator. Northing values count down from this number going south of the Equator.

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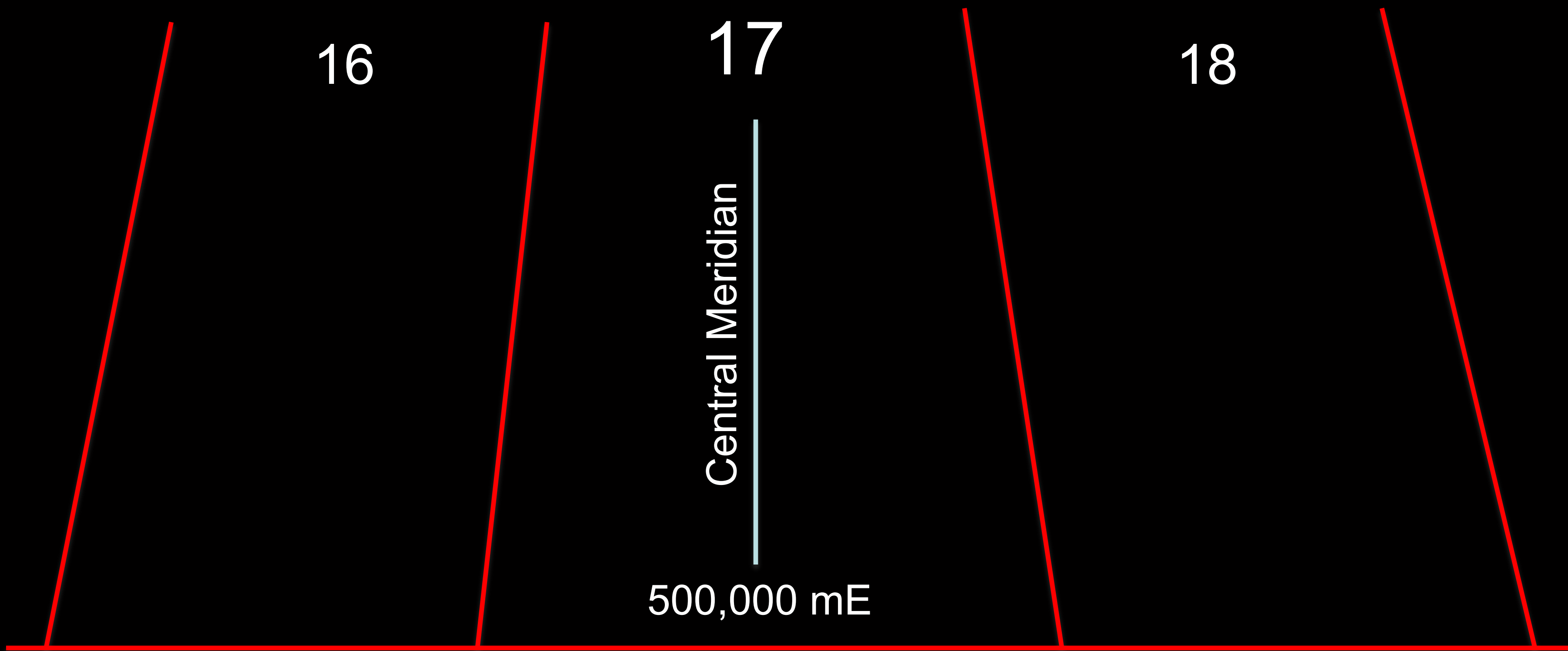

At the Equator the widest zone is 674,000 meters. So the zone would start at 163,000 meters on the left and end at 837,000 meters on the right at the Equator.

674,000 / 2 = 337,000. 500,000 – 337,000 equals 163,000

NORTHING

The Northing values on the map are the number of meters north or south of the Equator. To avoid negative numbers, Northing values start at 10,000,000 M at the Equator (when going south) and count down.

North of the Equator, the numbers on the map are the actual number of meters from the Equator.

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10,000 meter digit

100,000 meter digit(s)

1,000 meter digits

16 S 0572450 E

3763650 N

Map Zone

You only have to plot the last 3 numbers. The rest of the coordinate values are provided on the map

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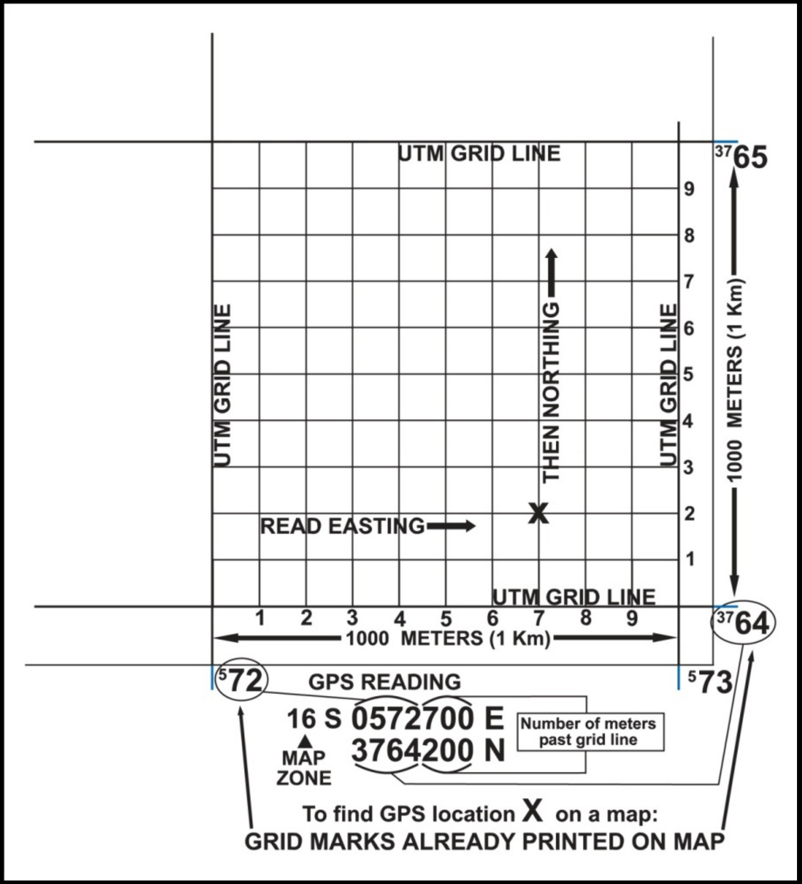

Read EASTING First

Then Read NORTHING

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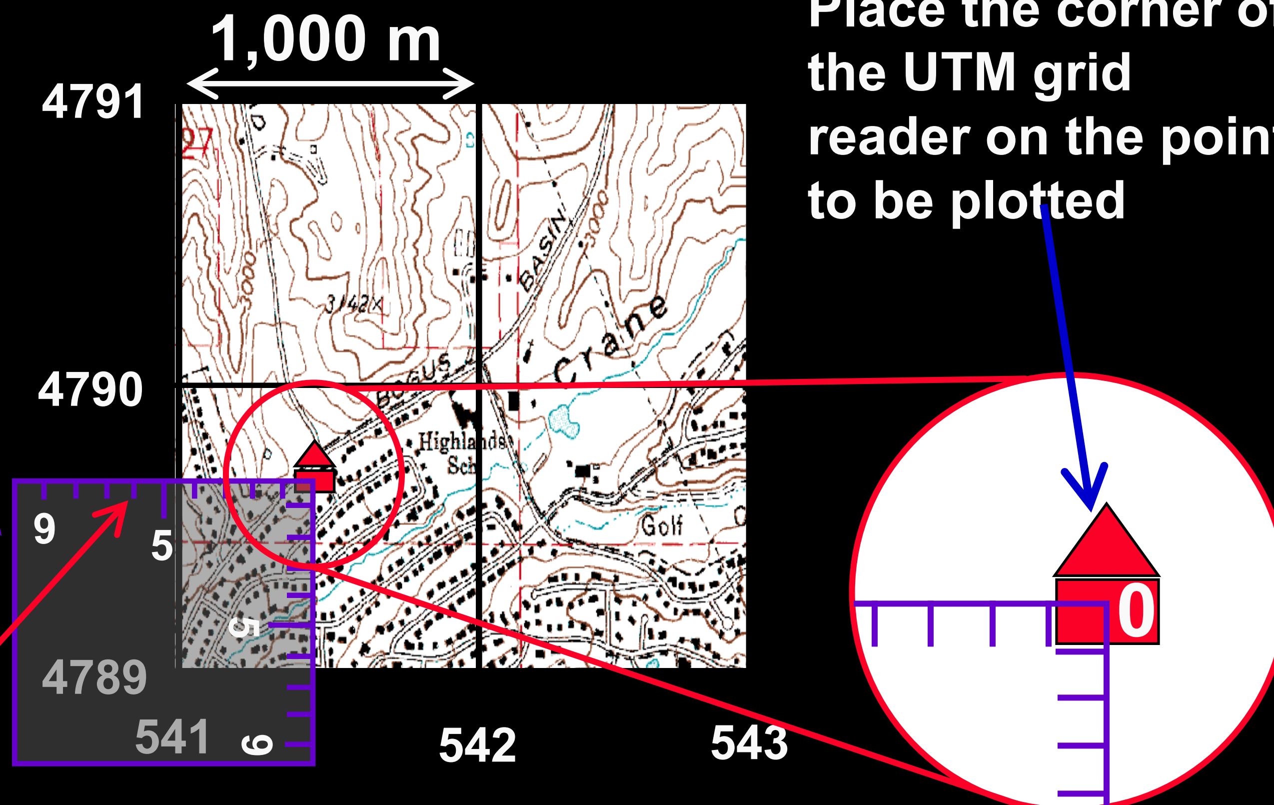
UTM grid reader

Place the corner of the UTM grid reader on the point to be plotted



Each tic = 100 meters on this grid reader

House coordinates = 0541450mE 4789650mN

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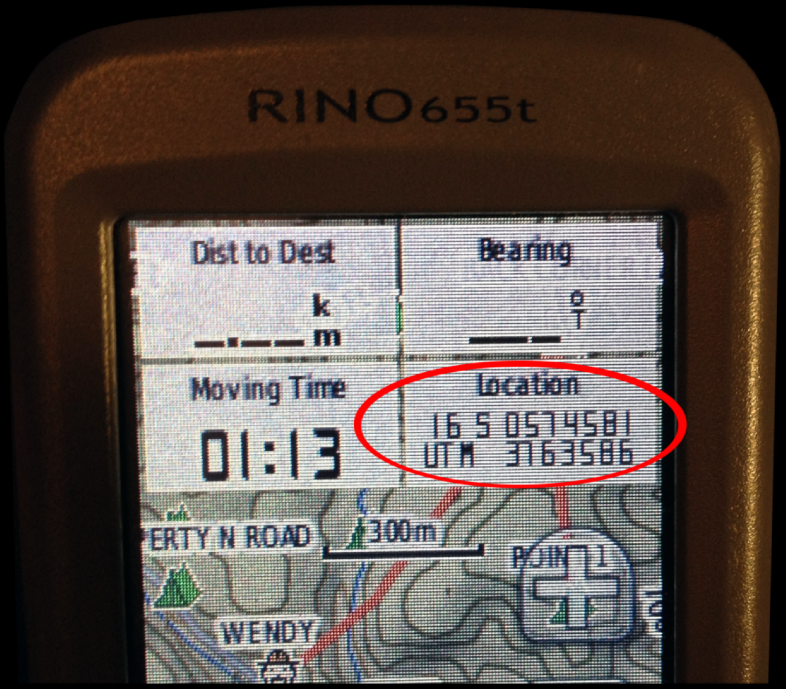
Using GPS with Map/Compass



Plotting GPS to Map

1) Find current location with GPS
2) Use scale card to plot current location on the map

Plotting Map to GPS

1) Plot location on map of where you want to go with a scale card
2) Enter plotted coordinates into the GPS as a new waypoint

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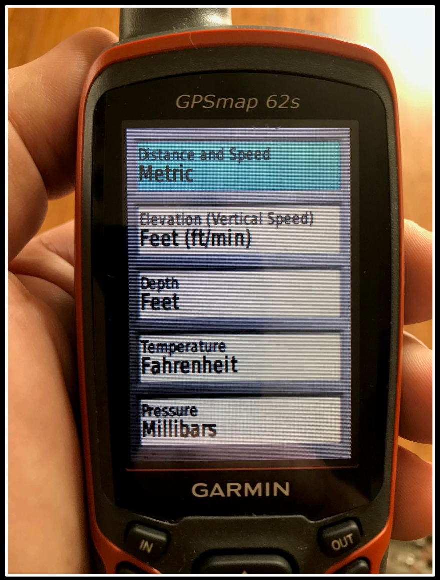
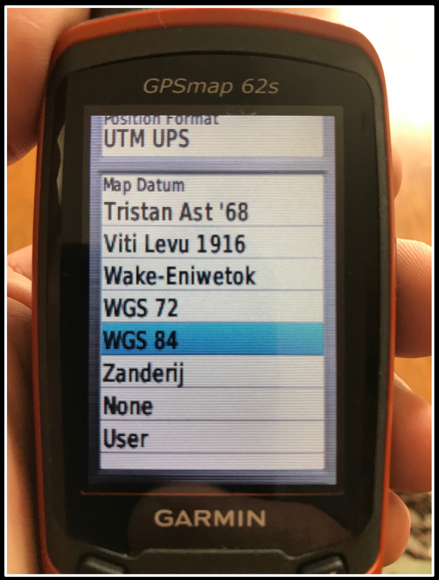
GPS Setup

GPS units vary on how to set them up, but the following items should be setup on any unit prior to use. Settings should match the format and datum being used.



Distance

Position Format



Map Datum

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Communicating Location

If you are lost and can communicate with search personnel, try to give them the following info:

- General Location (big picture)
- Type Of Navigation Grid Used
- Grid Location (Easting Then Northing)
- Direction Of Travel If Moving

Note:
A 4/4 grid will put you within 10 meters. It is communicated by dropping the last digit in a 5-digit grid. For example, if your full 5-digit grid is 74356 / 63982, a 4/4 grid will be called out as 7435 / 6398

Declination

Magnetic Declination is the difference between True North (Longitude Line) and Magnetic North (where the compass needle points).

A compass needle ALWAYS points to Magnetic North.

Grid Declination is the difference between a Grid Reference Line and Magnetic North.

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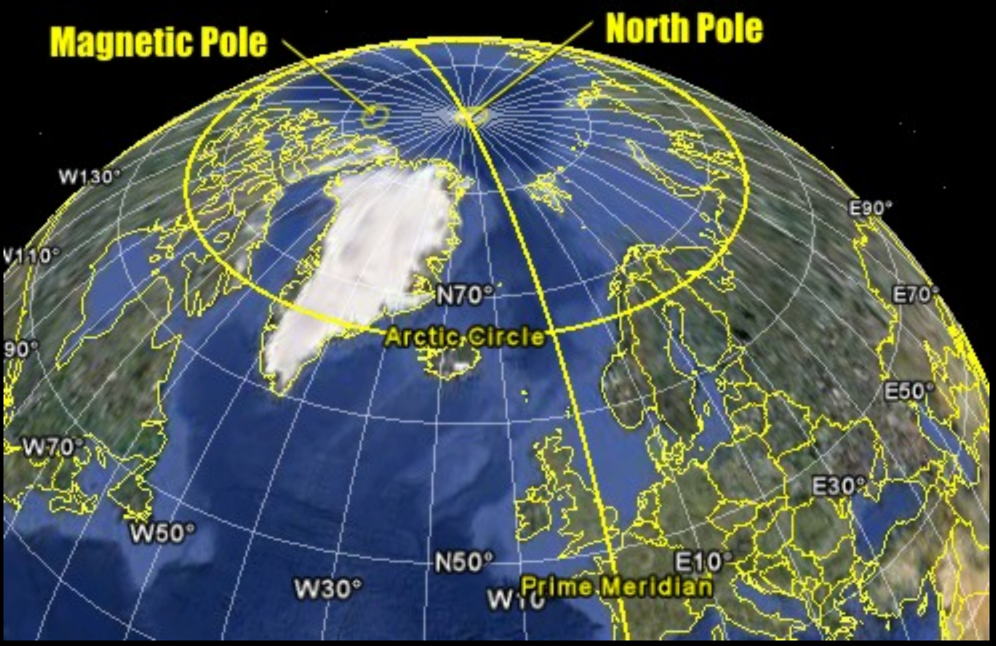
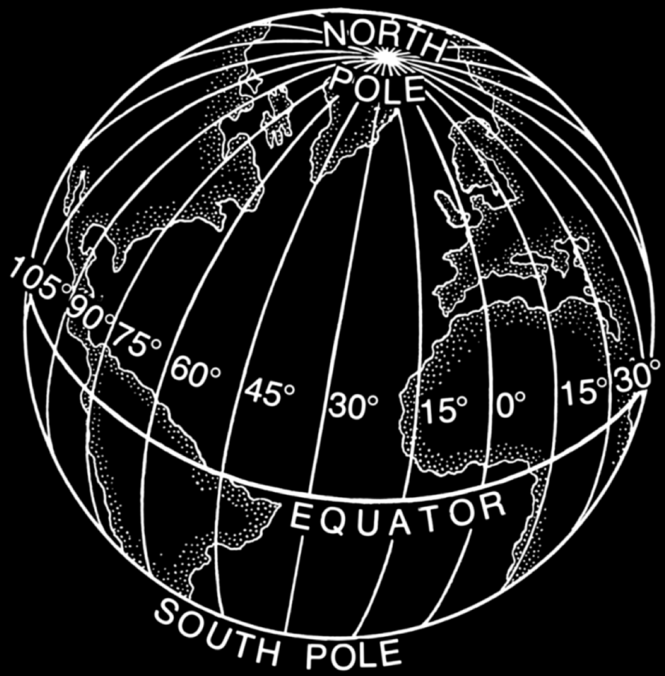


Difference in True North And Magnetic North



Longitude Lines (True North)

Magnetic North is moving approximately 40 miles per year.

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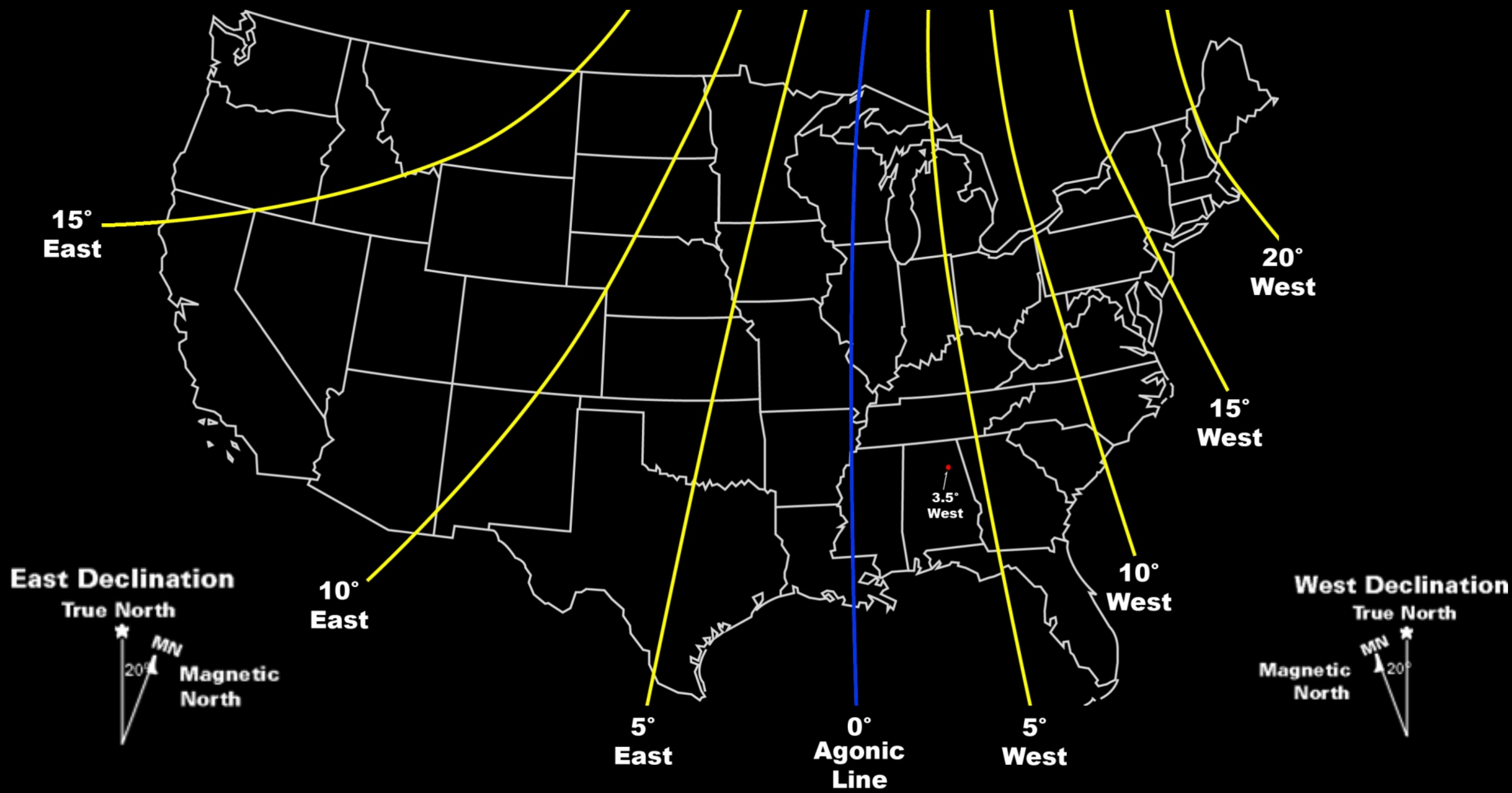
Magnetic Declination



If you do not have a compass that adjusts for declination remember to add or subtract declination to your azimuth.

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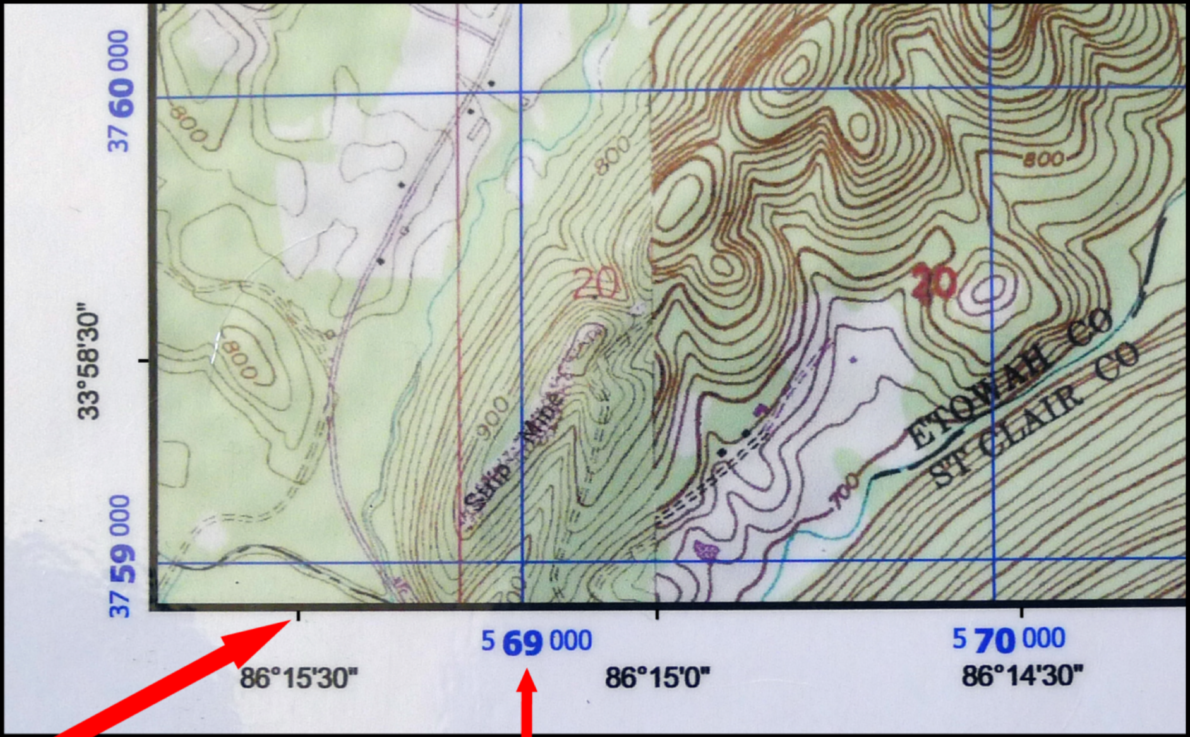
Exaggerated example
Of magnetic declination

SEARCH AND RESCUE LAND NAVIGATION

Depending on your map, it may printed with True North Reference lines or Grid North Reference lines



True North (Longitude)

Grid North (UTM Or Other Grid)

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LAND NAVIGATION

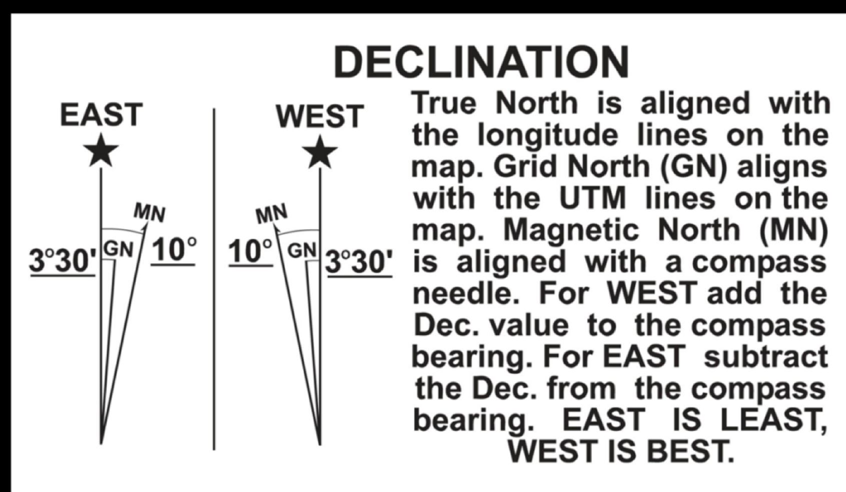
Adjusting For Declination For Map Use

Declination is the difference between true north and magnetic north when using the longitude lines as north reference.

Declination is the difference or spread between grid north and magnetic north when using the UTM grid lines as north reference.

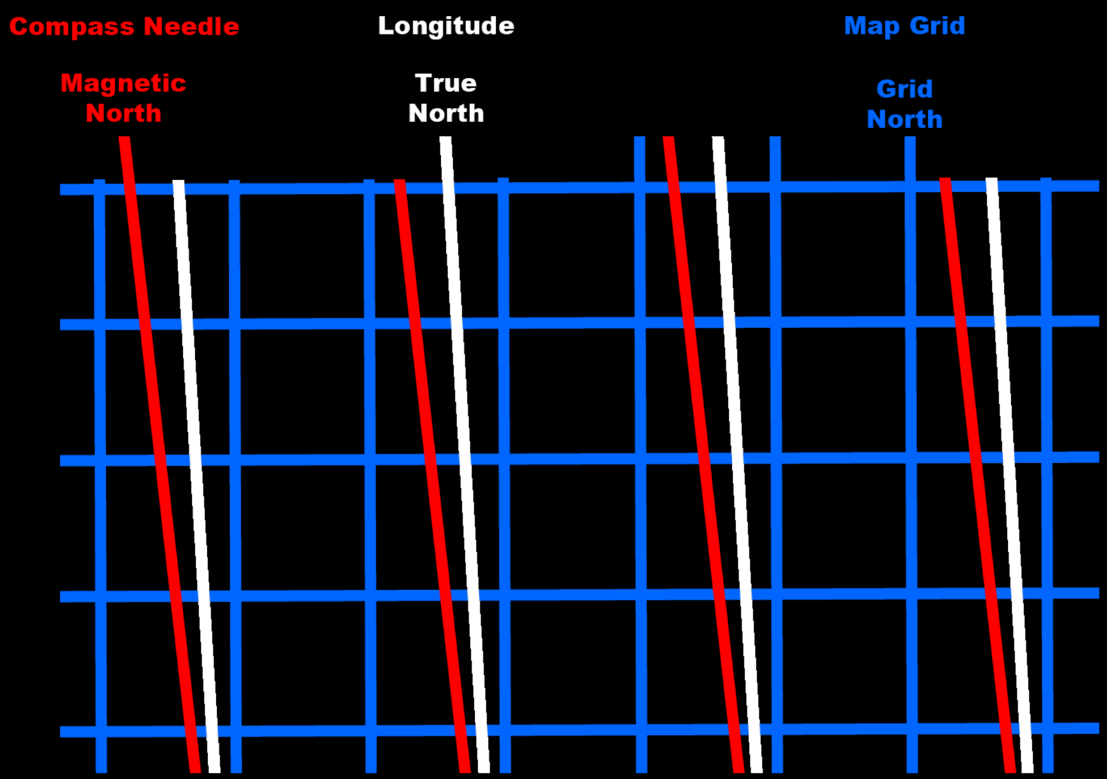
If the MN line is left of the Reference Line you are using to measure your azimuth, then it will always be West Declination. If the MN line is right of the Reference Line it will always be East Declination

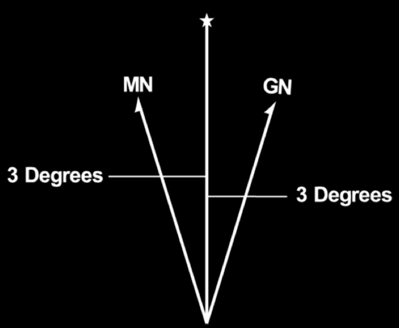
If you are using a compass that is not adjusted for declination, add the amount for west declination when going from map to real world, subtract the amount for east declination (when going from map to real world). If your compass is adjustable for declination, set it for the north reference declination value you are using. No further addition or subtraction is required.



SEARCH AND RESCUE LAND NAVIGATION

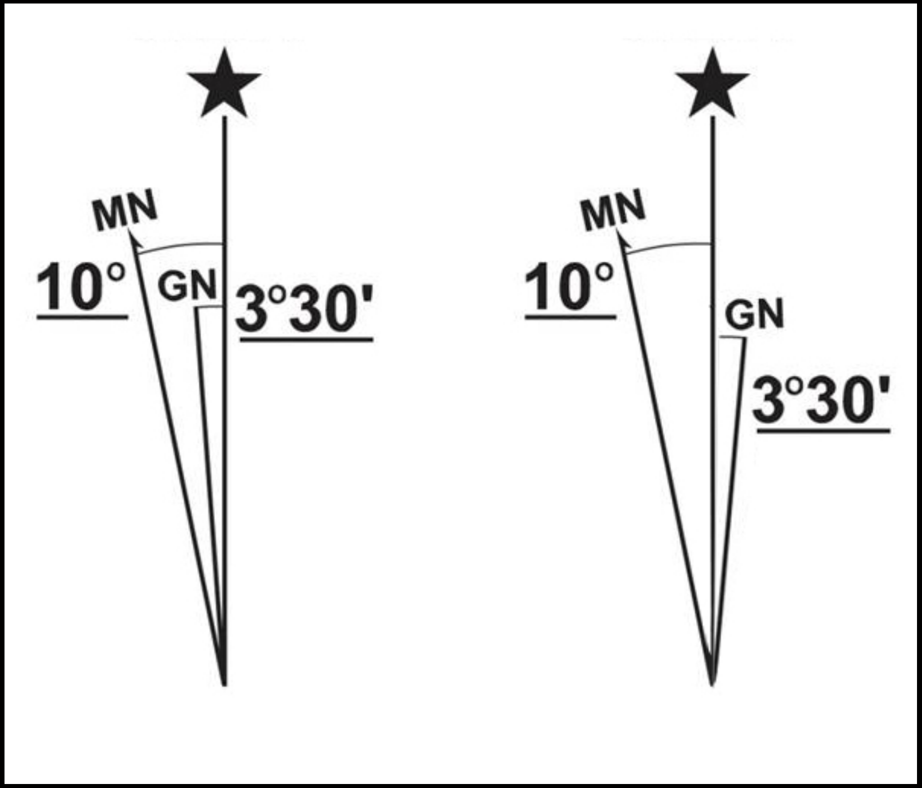
True North / Magnetic North / Grid North





If using Grid North as Reference then declination would be set to 6 degrees West
If using True North as Reference then declination would be set to 3 degrees West

SEARCH AND RESCUE LAND NAVIGATION



What is our declination value for each of the diagrams using Grid North Reference?

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5-POINT LAND NAV CHECKLIST

1. Verify Coordinates
2. Pace / Distance
3. Azimuth / Declination
4. Checkpoint / Terrain Association
5. Backstops, Handrails, etc.

SEARCH AND RESCUE LAND NAVIGATION

ADDITIONAL INFO

- Determining Unknown Distance
- Determining Height

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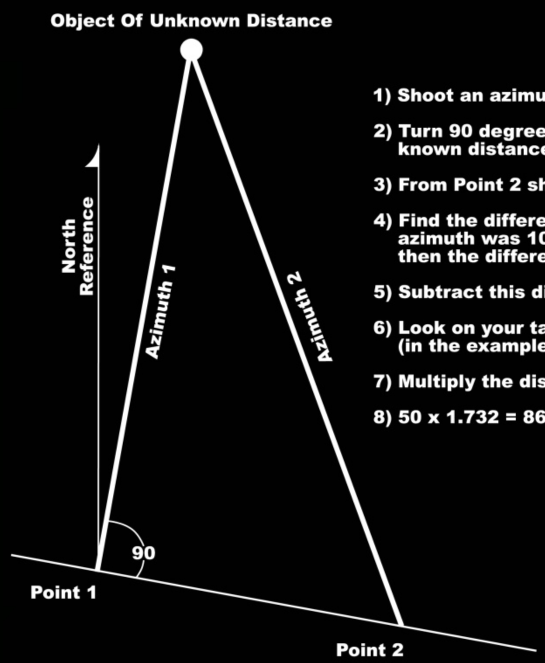
LAND NAVIGATION

DETERMINING UNKNOWN DISTANCE WITH COMPASS

Angle	tan(a)	Angle	tan(a)	Angle	tan(a)	Angle	tan(a)
0.0	0.00	25.0	.4663	46.0	1.0355	71.0	2.9042
1.0	.0175	26.0	.4877	47.0	1.0724	72.0	3.0777
2.0	.0349	27.0	.5095	48.0	1.1106	73.0	3.2709
3.0	.0524	28.0	.5317	49.0	1.1504	74.0	3.4874
4.0	.0699	29.0	.5543	50.0	1.1918	75.0	3.7321
5.0	.0875	30.0	.5773	51.0	1.2349	76.0	4.0108
6.0	.1051	31.0	.6009	52.0	1.2799	77.0	4.3315
7.0	.1228	32.0	.6249	53.0	1.3270	78.0	4.7046
8.0	.1405	33.0	.6494	54.0	1.3764	79.0	5.1446
9.0	.1584	34.0	.6745	55.0	1.4281	80.0	5.6713
10.0	.1763	35.0	.7002	56.0	1.4826	81.0	6.3138
11.0	.1944	36.0	.7265	57.0	1.5399	82.0	7.1154
12.0	.2126	37.0	.7535	58.0	1.6003	83.0	8.1443
13.0	.2309	38.0	.7813	59.0	1.6643	84.0	9.5144
14.0	.2493	39.0	.8098	60.0	1.7321	85.0	11.430
15.0	.2679	40.0	.8391	61.0	1.8040	86.0	14.301
16.0	.2867	41.0	.8693	62.0	1.8907	87.0	19.081
17.0	.3057	42.0	.9004	63.0	1.9626	88.0	28.636
18.0	.3249	43.0	.9325	64.0	2.0503	89.0	57.290
19.0	.3443	44.0	.9657	65.0	2.1445	90.0	infinite
20.0	.3640	45.0	1.000	66.0	2.2460		
21.0	.3839			67.0	2.3559		
22.0	.4040			68.0	2.4751		
23.0	.4245			69.0	2.6051		
24.0	.4452			70.0	2.7475		



1) Shoot an azimuth from Point 1 to the object of unknown distance.

2) Turn 90 degrees from this azimuth and move to a second location (Point 2) that is a known distance from your first point (pace count 50 meters for example).

3) From Point 2 shoot another azimuth to the object of unknown distance.

4) Find the difference in degrees from these two azimuths (For example if your first azimuth was 10 degrees and your second azimuth was 340 degrees, then the difference is 30 degrees).

5) Subtract this difference from 90 (in the example above you would come up with 90-30=60)

6) Look on your tangent tables and find the tangent for the value (in the example, the value from the tangent tables for 60 is 1.732)

7) Multiply the distance you moved from Point 1 to Point 2 (50 meters) by the tangent of 1.732.

8) 50 x 1.732 = 86.6 meters (distance from Point 1 to the object of unknown distance).

EQUATION:

$d = (\tan(90 - (A - B))) \times Ref$

d = Distance (to be calculated)
Tan = Tangent value of the resultant angle
A = Greater value of the two measured bearing angles
B = Lower value of the two measured bearing angles
Ref = Measured reference distance between Point 1 & Point 2

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Using Basic Trigonometry To Determine Approximate Distance Across A River:

1) Mark a starting point along a straight stretch of the river as Point A.

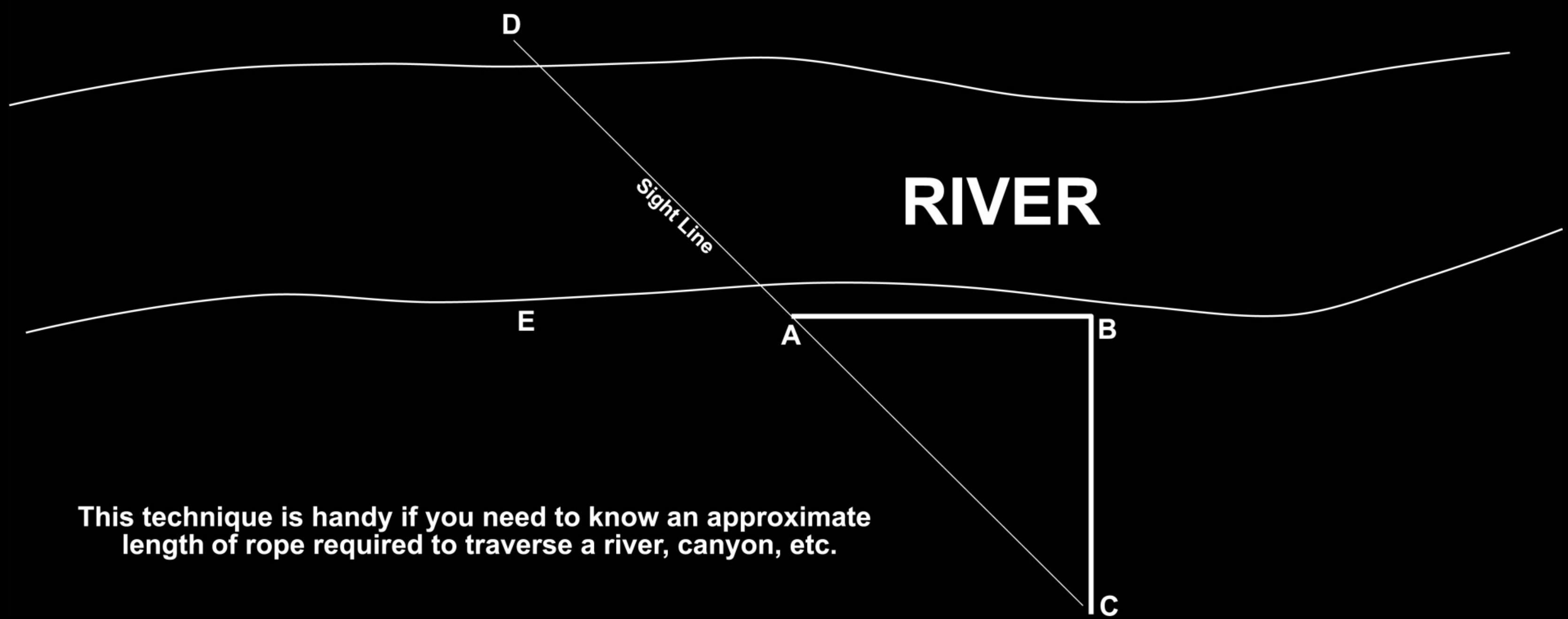
2) Start at Point A and walk 5 paces (can be another number) along the side of the river to point B.

3) Turn 90 degrees and walk the same amount of paces to Point C.

4) Sight from Point C to Point A and find a distant point (D) on the other side of the river.

5) Return to Point A and count your paces until you are directly across from the point you sighted as D (this will be Point E).

6) The river is approximately the same distance in width as the distance you counted between Point A and E



This technique is handy if you need to know an approximate length of rope required to traverse a river, canyon, etc.

SEARCH AND RESCUE LAND NAVIGATION

Height Measurement Using An Inclinometer

If angle is less than 45 degrees:

- Convert angle to percent of grade (see below).
- Multiply distance from object by percent of grade, then divide this by 100.
- Add eye (compass) level height to this value.

Converting to percent of grade:
When an angle is less than 45 degrees you must covert angle to percent of grade. To do this multiply the angle tan value by 100. Example: if the angle is 35 degrees then the tan value is .7002, so .7002 x 100 = **70.02 (or rounded off to 70)** percent grade.

Once you have percent of grade, to find height use this equation: Multiply the distance to the object by the percent of grade, and then divide this number by 100. For example: you are standing 30 feet away from a tree and your eye level is 5 ½ feet. You measure an angle to the top of the tree as being 35 degrees. You convert this angle to percent of grade (70). So, 30 x 70 / 100 = 21. Add your eye level height back to this and the tree is 26.5 feet tall.

If an angle is more than 45 degrees you can skip converting to percent of grade and use the tan value direct.

- Find Tan Value of angle.
- Multiply Tan value by distance away from object being measured.
- Add eye (compass) level height to this value.

For example if you are standing 30 feet away from a tree and your eye level is 5 ½ feet. You measure an angle to the top of the tree as being 52 degrees. The tan value of 52 is 1.2799. So, (30 x 1.2799) + 5.5 = 43.9 feet tall.