

## **Map Reading and Navigation**

### **1. Topographic Maps**

A topographic map is a graphic representation of features that are on the earth's surface. These features include relief (eg. mountains, valleys), vegetation (eg. wooded and cleared areas), hydrography (eg. rivers, streams, coastal flats) and cultural (eg. roads, geographic feature place names, borders).

See Appendix 1 for further information.

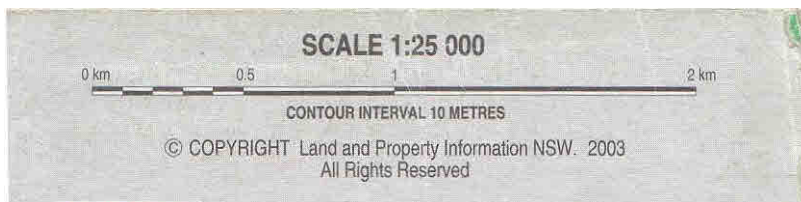
## 2. How to read a topographic map – overview of features

### 2.1. Scale

The map scale tells you the ratio between distance on the map and distance on the ground and the comparative size of features on the map. Some maps may have the scale as part of the map naming:



All maps will have a scale associated with the legend:

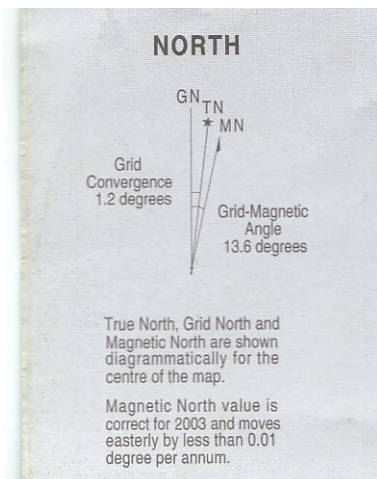


Typical map scales for bushwalking are:

Scale	Distance ratio	Example
1:25000	4cm on map = 1km on ground	Tidbinbilla 8627-2S
1:50000	2cm on map = 1km on ground	
1:100000	1cm on map = 1km on ground	ACT 1:100000 Special (great for overviews from mountain tops)

### 2.2. Direction

The north point diagram shows the direction of:



(From Canberra 8727-3N 1:25000)

True North (TN) – the direction of the earth’s geographic North Pole

Grid North (**GN**) – the direction of the vertical grid lines (eastings) on the map

Magnetic North (**MN**) – the direction from any point to the earth’s north magnetic pole.

Your compass needle points to MN.

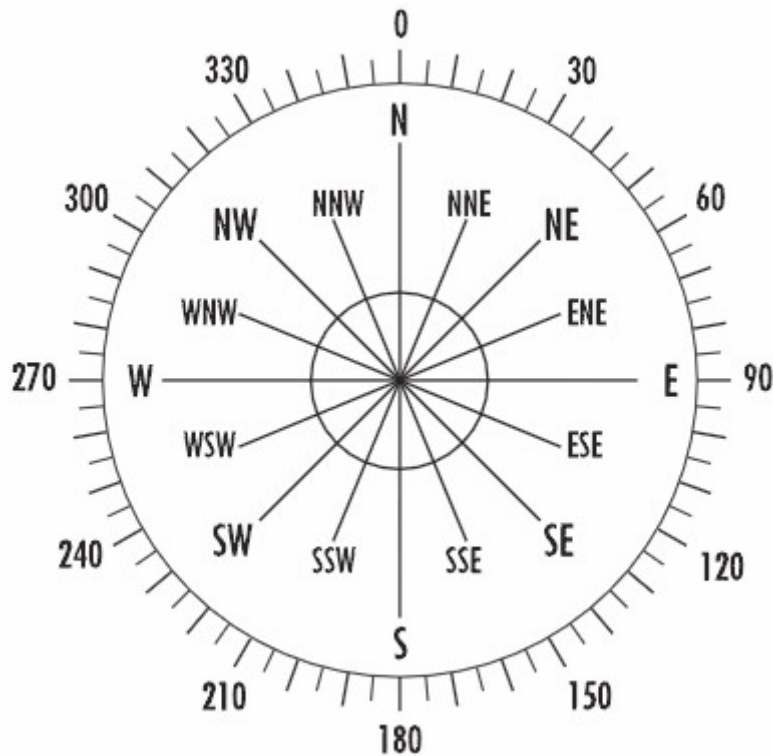
The angle between GN and TN is called grid convergence. The angle between TN and MN is called magnetic declination. Neither of these is used for bushwalking.

For map reading and navigation, the important angle is the **Grid-Magnetic angle**, the angle between GN and MN. It varies across Australia. Use 13.5° in the ACT.

Topographic maps are printed so grid north points to the top of the sheet. This is indicated by the north point diagram.

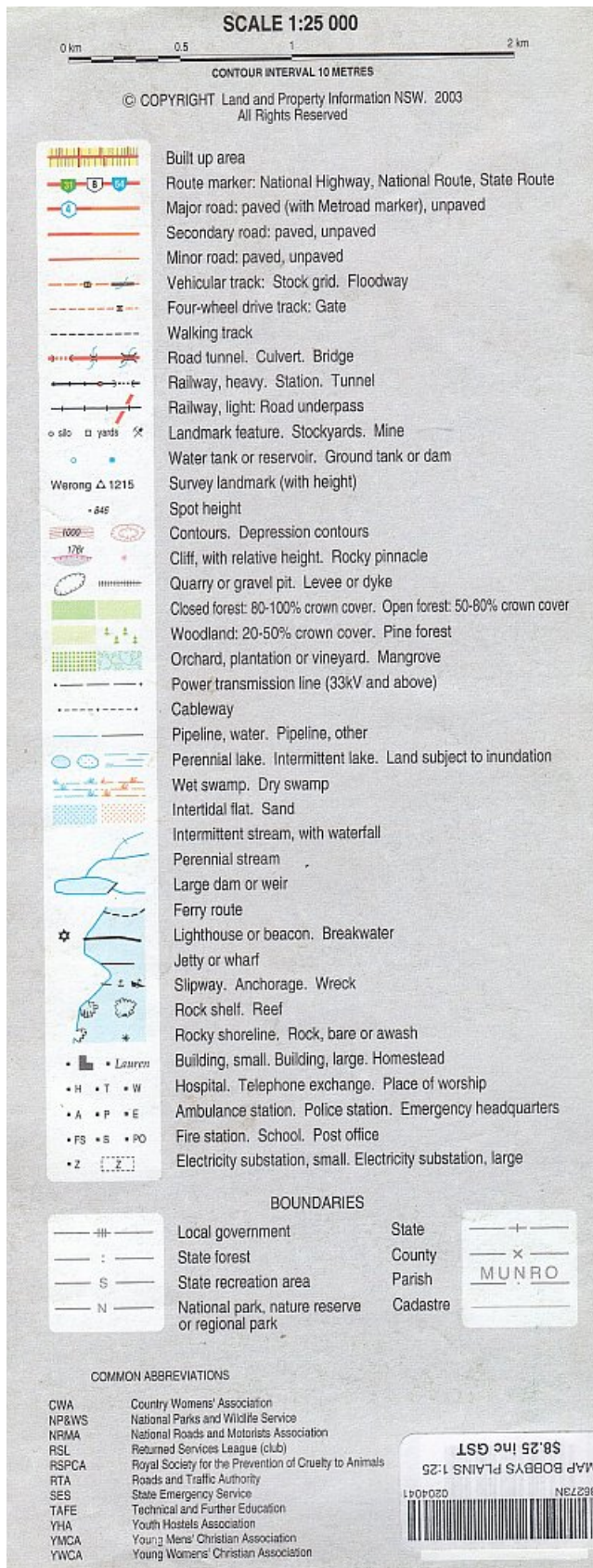
### 2.3. Bearings

A bearing is the clockwise horizontal angle, measured from north to a chosen direction. Bearings are usually shown in degrees and range from 0° (north) to 360° (also north):



### 2.4. Map symbols – legend

Symbols are used to represent features on the ground. Larger scale maps show more detail and a larger number of features:



## 2.5. Map border markings

The map border on GDA based 1:25000 topographic maps presents additional information on the various coordinate systems and datums.

See Appendix 2 for further information.

### 3. Specifying a Location on a map

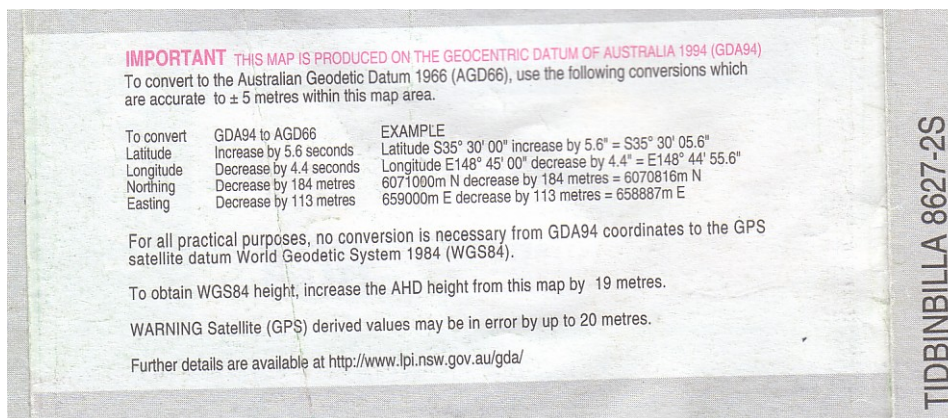
#### 3.1. Datum

Every map is based on a datum, a mathematical surface that best fits the shape of the Earth. Australian maps are based on one of two datums:

Australian Geodetic Datum (**ADG**) – defined in 1966 and best fitted the shape of the Earth in the Australian region only

Geocentric Datum of Australia (**GDA**) – defined in 1994, and is based on a mathematical surface that best fits the shape of the Earth as a whole, with its origin at the Earth's centre of mass. Used by mapping authorities since 2000.

The datum is specified in the margin information on a topographic map:



A location, specified in any coordinate system (see below), will vary by ~200m depending on the map datum. So the datum must be specified when giving a location on a map.

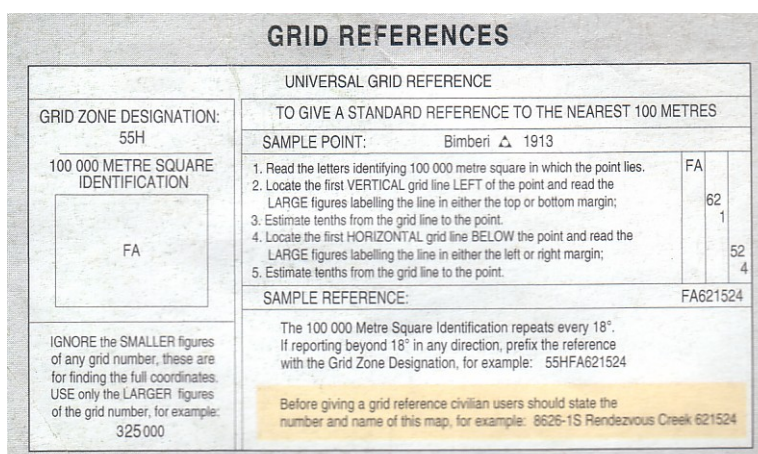
#### 3.2. Coordinates

Location coordinates can be specified as geographical coordinates or grid coordinates.

Geographical coordinates – specified as latitude or longitude, in degrees, minutes and seconds. Not used by bushwalkers.

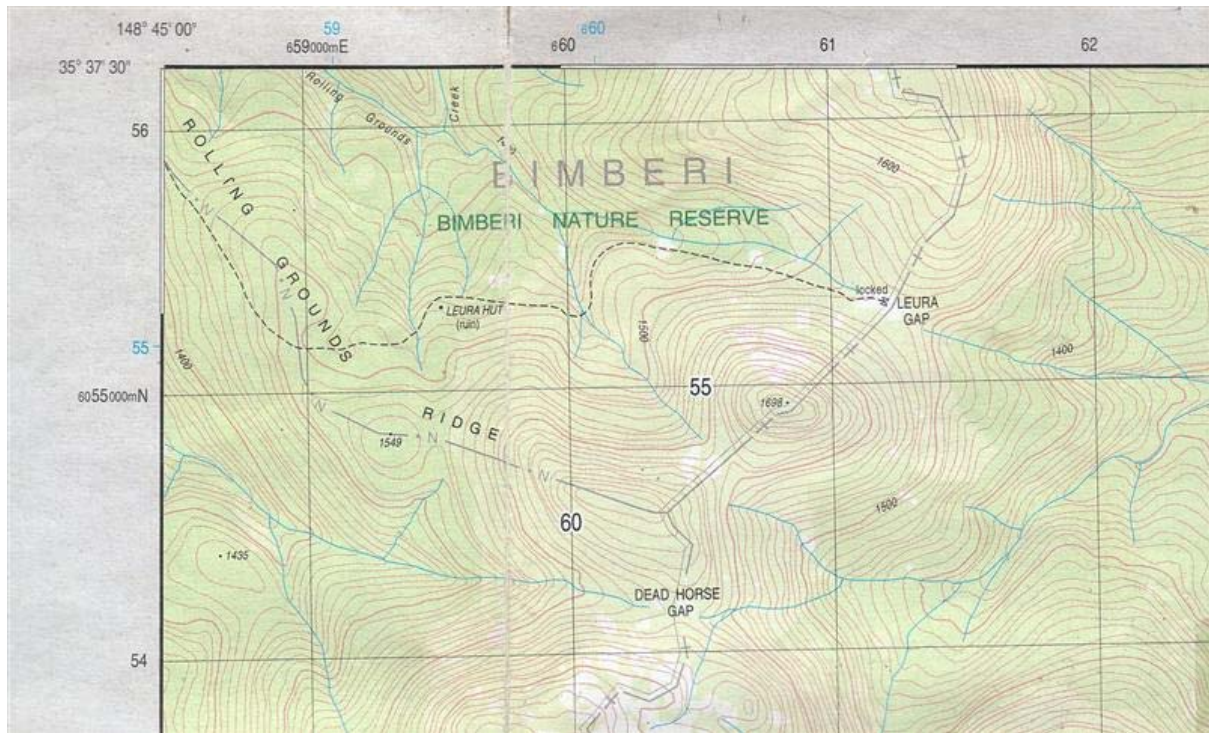
Grid coordinates – specified as easting and northing values, in metres.

The usual grid coordinate system used by bushwalkers is the Military Grid Reference System (MGRS), or **GR**. An example of specifying a location using grid coordinates is given in the margin information on a topographic map:



### 3.3. How to quote a Grid Reference

As an example, we want to quote the grid reference for the locked gate at Leura Gap:



- 3.3.1. Locate the vertical grid line (easting) to the left of the point of interest - 61
- 3.3.2. Estimate (or use the relevant map scale measuring edge on your compass) the tenths from the easting to the point of interest – 2
- 3.3.3. This gives an easting of 612
- 3.3.4. Locate the horizontal grid line (northing) below the point of interest - 55
- 3.3.5. Estimate (or use the relevant map scale measuring edge on your compass) the tenths from the northing to the point of interest - 3
- 3.3.6. This gives a northing of 553
- 3.3.7. So the gate is at GR612533. **However, this GR is only unique for this map and if it is to be communicated to others, it must be suitably qualified to ensure absolute uniqueness.**
- 3.3.8. Qualifications – include the map datum (MGA/MGA94), so that someone using the same named map, but based on AMG, will not plot the location ~200m away; include the 100 000 metre square identification (and/or the map name), so that the location is not confused with the same GR 100km away; include the Grid Zone Designation, so that the location is not confused with the same GR 18° of separation away.
- 3.3.9. So the unambiguous location is:  
**GR 55H FA 612553 (MGA94) Rendezvous Creek 8626-1S 1:25000.**
- 3.3.10. You'd better be able to do this to call in the rescue helicopter when you don't have a PLB!
- 3.3.11. Accuracy – note that a 6-figure GR (3-figure easting + 3-figure northing) places the location somewhere within a 100m square. If you are able to estimate 4-figure eastings and northings to produce an 8-figure GR, the location would be somewhere within a 10m square. Using a GPS which shows 5-figure eastings and northings, a 10-figure GR can be quoted which, in theory, is accurate to the metre. However, due to various factors, your GPS accuracy may only be 15m!

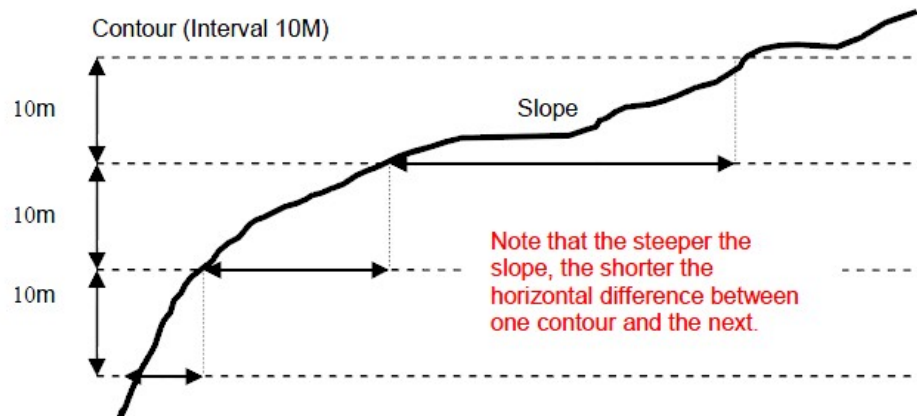
See Appendix 3 for further information.

#### 4. Landform Features on a Topographic Map

As bushwalkers, we need to be skilled at relating map to ground and ground to map. We need to be able to visualise the going to be expected from an examination of map features.

##### 4.1. Contour lines

Contour lines join points of equal height above sea level/elevation and represent the relief of the terrain. For example, if there are many contour lines close together, the terrain is steep. Contour lines that are far apart indicate land with gentle slopes. Contour values read uphill, so as you read the contour numbers with the numbers up the right way, you would be looking up hill.



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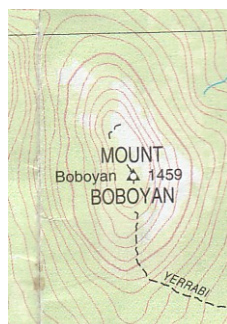
The contour interval is printed in the map information:



or can be deduced from counting the contour lines between numbered 100m contour lines.

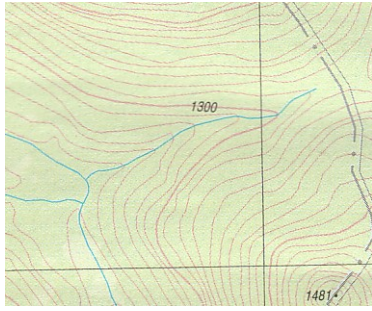
##### 4.1.1. Hill

A hill is represented by one or more concentric closed contour lines:



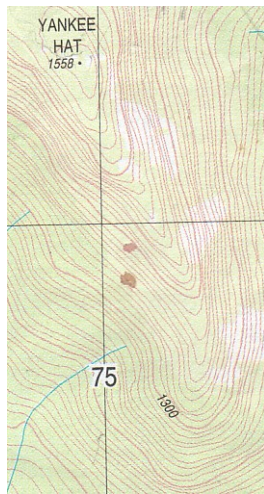
##### 4.1.2. Gully

A gully is a U or V shaped series of contours with the bottom of the shape at a higher elevation. On the ground, gullies are found between spurs or drop away from saddles and provide the means for creeks to form:



#### 4.1.3. Spur

A spur is a U or V shaped series of contours with the bottom of the shape at a lower elevation. On the ground, spurs lead up to hills/mountains:



#### 4.1.4. Ridge

A ridge is indicated by two contours of equal elevation running generally parallel for some distance:



#### 4.1.5. Cliff

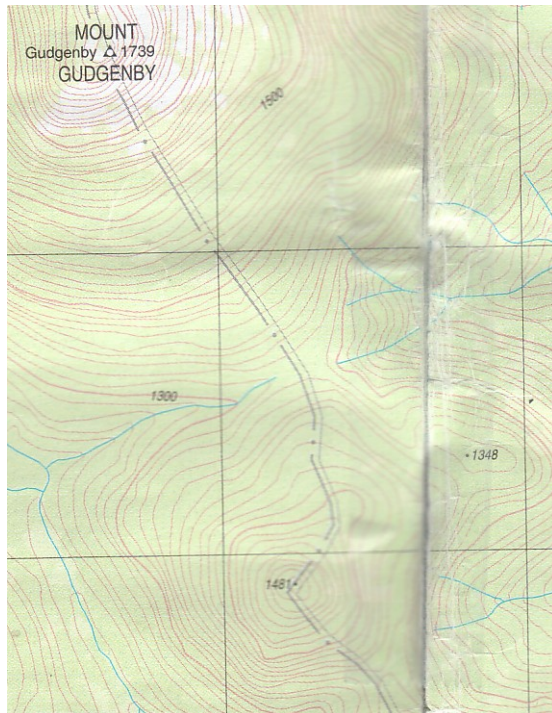
Cliffs are marked by their specific map symbol:



Cliffs may be in other areas and unmarked, particularly where contours come close together.

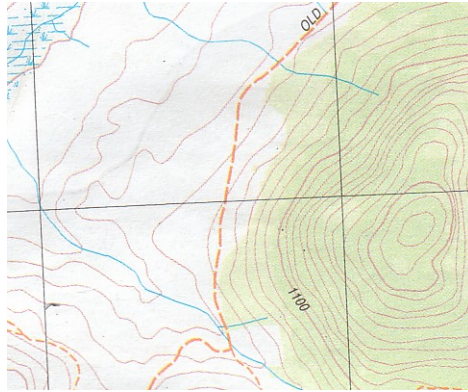
#### 4.1.6. Saddle

A saddle is an area on a ridge from where the elevation increases in both directions along the ridge. The contours along the ridge will converge to the saddle and there will possibly be two spurs facing each other. Gullies may form from each side of the saddle:



#### 4.1.7. Steep Slope/Gentle Slope

The closer the contour lines, the steeper the slope. Conversely, gentle slopes have contour lines spaced far apart:



#### 4.1.8. Subtle Contour Features

These features are less obvious and require detailed examination of the map:

	<p>This is a knoll or bump along a ridge that is too small to generate its own closed loop contour. Where the ridge contours diverge and then converge again is a sign that there is a small hill less than one contour interval in height above the surrounding ground. The top of the hill or bump can be assumed to be near where the contours are furthest apart.</p>
	<p>This is a saddle which is not deep enough to cause two parallel contours of the same elevation to cross the ridge and connect. Instead, parallel ridge contours come closer together, as if pinched, but without actually joining. The lowest point in the saddle may be assumed to be near where the contours are closest together.</p>
	<p>This is a dent in the side of a ridge or slope. It may be the beginnings of a gully that is too high in the headwaters to form a channel or watercourse.</p>
	<p>This is a bump on the side of a ridge or slope. It may be an outcrop of land on a slope causing localized flattening or the slope, or it may be the top of a small spur blending into the slope.</p>

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#### 4.1.9. Visualising relief features

To increase our ease and confidence in the bush, we must be able to visualise landform features from a map. Begin at home by plotting the profile of a feature, then check it on the ground. Another technique is to examine an area of a map and visualise the relief, then check it via Google Earth. See Appendix 4 for details.

### 4.2. Waterways

#### 4.2.1. Intermittent Stream

#### 4.2.2. Perennial Stream

#### 4.2.3. Waterfalls and Cascades

### 4.3. Roads, Vehicular Tracks, Four-wheel drive Tracks, Walking Tracks

4.3.1.... more to come

### 4.4. Vegetation

4.5.... more to come

## 5. Test Your Map Reading and Navigational Knowledge - Questions

- 5.1. A datum is a mathematical surface that best fits the shape of the earth. All maps are based on a datum. In Australia, maps such as those used for bushwalking (eg. 1:25000 topographic maps), can be based on one of two datums, depending on the age of the map. What are the names of these two datums? If you have a topographic map, find where the map datum is specified.
- 5.2. A different datum is used for the global positioning system of satellites and may need to be set in your GPS. What is this datum called?
- 5.3. For all intents and purposes the GPS datum is equivalent to one of the map datums used in Australia. Which Australian map datum is equivalent to the GPS datum?
- 5.4. A handrail is a linear, natural or man-made, feature which assists in navigation. Name three such features.
- 5.5. You take a bearing of 72°Magnetic to your next destination 1.3km away. It's a hut right beside a fire trail. You arrive at the fire trail but do not see the hut. Which way do you turn to get to the hut – left or right? To prevent this sort of problem, you could deliberately walk on a bearing of 62°Magnetic and, when the fire trail is reached, know for sure that turning right along the fire trail will get you to the hut. What is this technique called?
- 5.6. You are walking with a 'living legend', a walk leader who has been walking for many years. A halt is called south of Tidbinbilla Peak (on the way SW then NE to The Pimple) to check the current location of the party. It's a sunny day and you can see your objective. He uses his old map and compass to determine the location, but asks you to confirm the location from your GPS. You read off GR 70715E 76736S. He scratches his head, because he has determined the location to be GR706765. What's going on here?
- 5.7. A GPS 'cold start' is when the unit is turned on for the first time after a long period of no use and/or is turned on many, many kilometres away from the last time it was used. Under these conditions it may take several minutes before the GPS is registering an accurate location and the unit may need recalibrating. What do you think a 'warm start' might be?
- 5.8. To convert a magnetic bearing from your compass to a grid bearing to use on your map, do you add or subtract the grid-magnetic angle when walking around Canberra?
- 5.9. What is the value of the grid-magnetic angle around Canberra?
- 5.10. Generally speaking, in the southern hemisphere, would you expect north and west facing slopes to be hotter and dryer than south and east facing slopes?
- 5.11. Do you think it would be generally easier to navigate up a flowing creek system, or down? What about spurs?
- 5.12. What is an attack point?
- 5.13. A location on a map is defined in map coordinates. For example, latitude and longitude are geographical coordinates, but not often used by bushwalkers. What grid coordinate system do you prefer to use when using a map? When using a GPS?

5.14. You are heading towards lunch on The Pimple. You stop your party at SH1555 and, although you know that there is a spur to act as a handrail leading to the saddle before the final climb to The Pimple, as an extra precaution, you measure the direction of your objective from your current position. Using your compass and map, the bearing is  $308^{\circ}$ Grid. What bearing would you set on your compass to follow on the ground?

See Appendix 5 for answers.

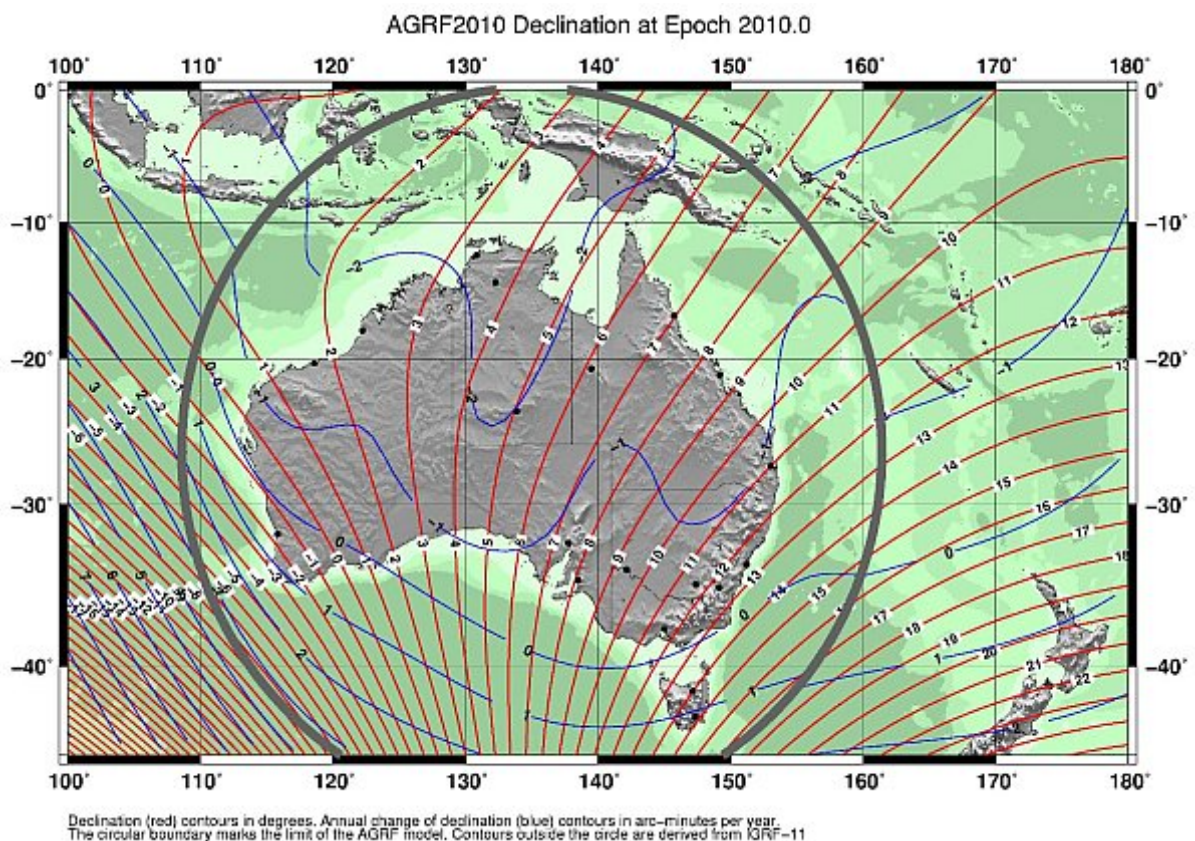
**6. ... more to come**

## **Appendix 1 - Topographic Maps**

1. Topographic maps at the 1:10000, 1:25000 and 1:50000 scales are produced by State Government agencies. 1:25000 and 1:50000 scale maps are most suitable for bushwalkers. The larger the scale of the map, the more area is covered on one map sheet, but less detail is available
2. The Department of Defence also produces topographic maps at the 1:50000 scale, primarily of Northern Australia
3. GeoScience Australia produces topographic maps at the 1:100000, 1:250000, 1:1 million, 1:2.5 million and 1:5 million scales

## Appendix 2 - How to read a topographic map – overview of features

1. Grid convergence, the angle between GN and TN, varies across Australia, its magnitude and direction east or west of TN being usually less than 2°.
2. Magnetic declination is the angle between TN and MN. Hence Grid-Magnetic angle = Grid convergence + Magnetic declination. The following diagram is taken from GeoScience Australia at [http://www.ga.gov.au/image\\_cache/GA16056.jpg](http://www.ga.gov.au/image_cache/GA16056.jpg).



The red lines are isogonals, lines joining places with equal magnetic variation. They do not, as is sometimes supposed, themselves point in the direction of Magnetic North. It might be expected that isogonals would follow a regular pattern but the earth's magnetic field at any point is affected by the land and mountain masses and the presence of metallic ores. Therefore, the isogonals are pulled out of shape and follow no regular pattern.

**The whole point of this diagram is to demonstrate that the Grid-Magnetic angle varies across Australia!**

3. Thus the Grid-Magnetic angle ranges from about 5° west of true north in Western Australia to about 15° east of true north in eastern Australia.
4. As an example near/in the ACT region, the west to east series of Second Edition 1:25000 topographic maps Bobbys Plains, Cotter Dam and Canberra have Grid-Magnetic angles of 13.2°, 13.4° and 13.6°.
5. Additional Information on map borders:



The latitude and longitude of the map corner: 35°30'00" 149°00'00", in black for the datum of the map

The full easting and northing of the first grid lines from the corner, in black for the datum of the map: 682000mE (MGA) and 607000mN (MGA)

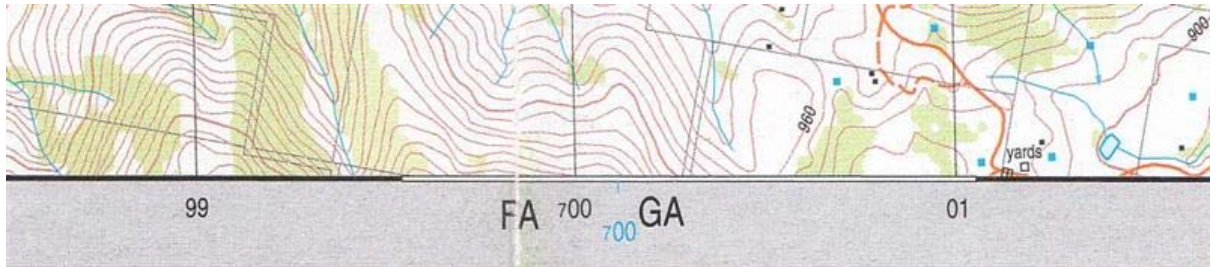
Blue tic marks with the full easting and northing of the first grid lines from the corner, in blue for the AMG datum: 682000mE (MGA) and 607000mN (MGA)

Eastings for the datum of the map are marked in black at 1000m intervals across the border: 83, 84, 85, .... Eastings for the AMG datum are marked with blue tic marks in 1000m intervals across the border: 85, .... 5' increments of longitude are marked across the border

Northings for the datum of the map are marked in black at 1000m intervals up the border.

Northings for the AMG datum are marked with blue tic marks in 1000m intervals up the border. 5' increments of latitude are marked up the border.

If the 100000 metre square identification changes on the map, it is noted on the map border:

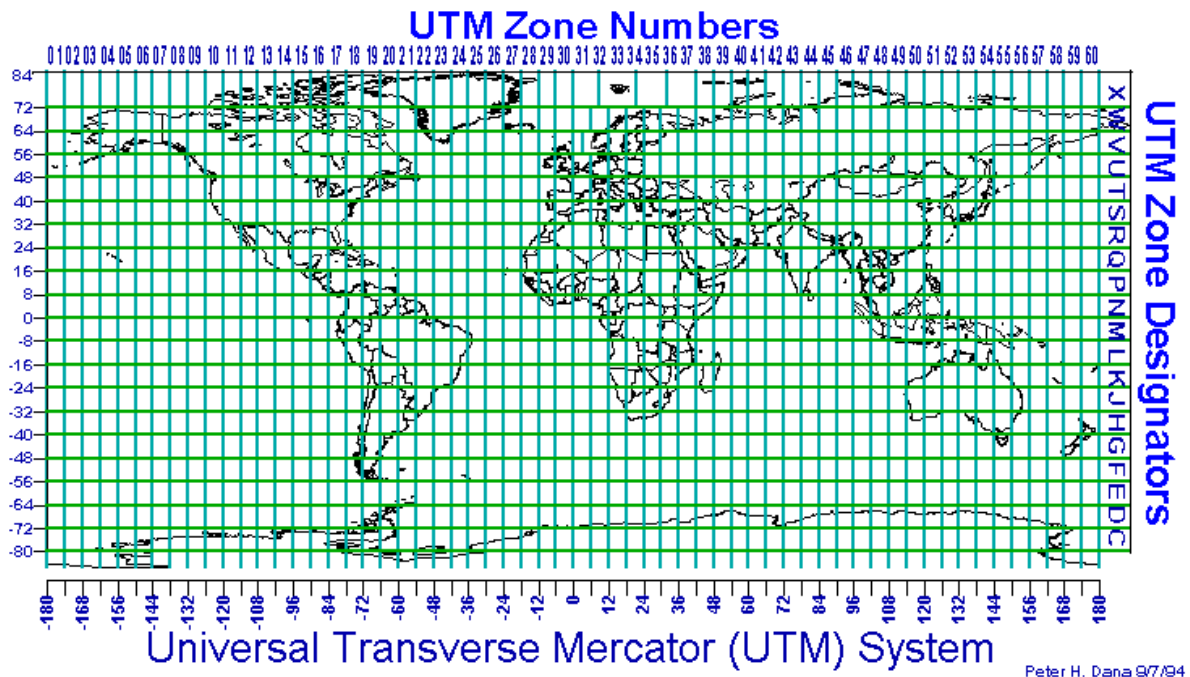


### Appendix 3 - Specifying a Location on a map

1. An updated version of the AGD datum, known as AGD84, was adopted by some Australian States in 1984. AGD84 coordinates are based on the same datum as AGD66 and for map reading and navigation purposes can be regarded as being the same.
2. The primary reason for the introduction of GDA is the widespread use of satellite-based navigation systems such as the Global Positioning System (GPS), which is based on a geocentric datum known as the World Geocentric System 1984 (WGS84). For most practical purposes, WGS84 and GDA coordinates are the same.
3. AGD/AMG, GDA/MGA? Strictly speaking, ADG66 is used for geographical coordinates based on the ADG; AMG66 is used for grid coordinates based on the ADG; GDA94 for geographical coordinates based on GDA; MGA94 for grid coordinates based on GDA.
4. Map Coordinates - **Latitude and Longitude**: Any point on the earth can be uniquely identified by its geographical coordinates, given as latitude and longitude. Latitude is the angular expression of the distance north or south from the equator (0° latitude). The South Pole is at 90°S and the North Pole at 90°N. Longitude is the angular expression of the distance east or west from the imaginary line known as the Prime Meridian - 0° longitude on all maps. Latitude and longitude are measured in degrees (°), minutes (') and seconds ("). Each degree is divided into 60 minutes and each minute is divided into 60 seconds.

Thus, Mount Tennent, near Tharwa in the ACT, could be described as being located at 35°33'00"S, 149°2'40"E (GDA94). Quite a mouthful.

5. Map Coordinates - **UTM Grid**: To simplify the use of maps and avoid the use of curved reference lines, a rectangular grid consisting of two sets of straight, parallel lines, equally spaced and set perpendicular to each other is superimposed on a map. Such grids are usually identified by the name of the projection used to represent the curved earth's surface on a plane. A popular projection is the Transverse Mercator projection which is the basis of the Universal Transverse Mercator grid. An excellent treatment is at [Locations in Tasmania: The UTM System](#). To prevent area distortion, the world is divided into 60 north-south zones, each covering a strip 6° of longitude wide. The zones are numbered consecutively beginning with Zone 1 between 180° and 174°W longitude and progressing eastwards to Zone 60 between 174° and 180°E longitude. This gives a Zone Number:



In the middle of each of the 60 Zones is a pole-to-pole line called the Central Meridian. This Central Meridian is allocated an Easting value of 500,000 metres (this is done so that there will be no negative easting values).

The Northing value is measured, in a northerly direction, from the equator. Again, so that there will be no negative northing values, the equator is allocated a Northing value of 10,000,000 metres.

Thus, Mount Tennent, near Tharwa in the ACT, could be described as being located in Zone 55 at 685,314E (Easting), 6,064,038N (Northing) (MGA94).

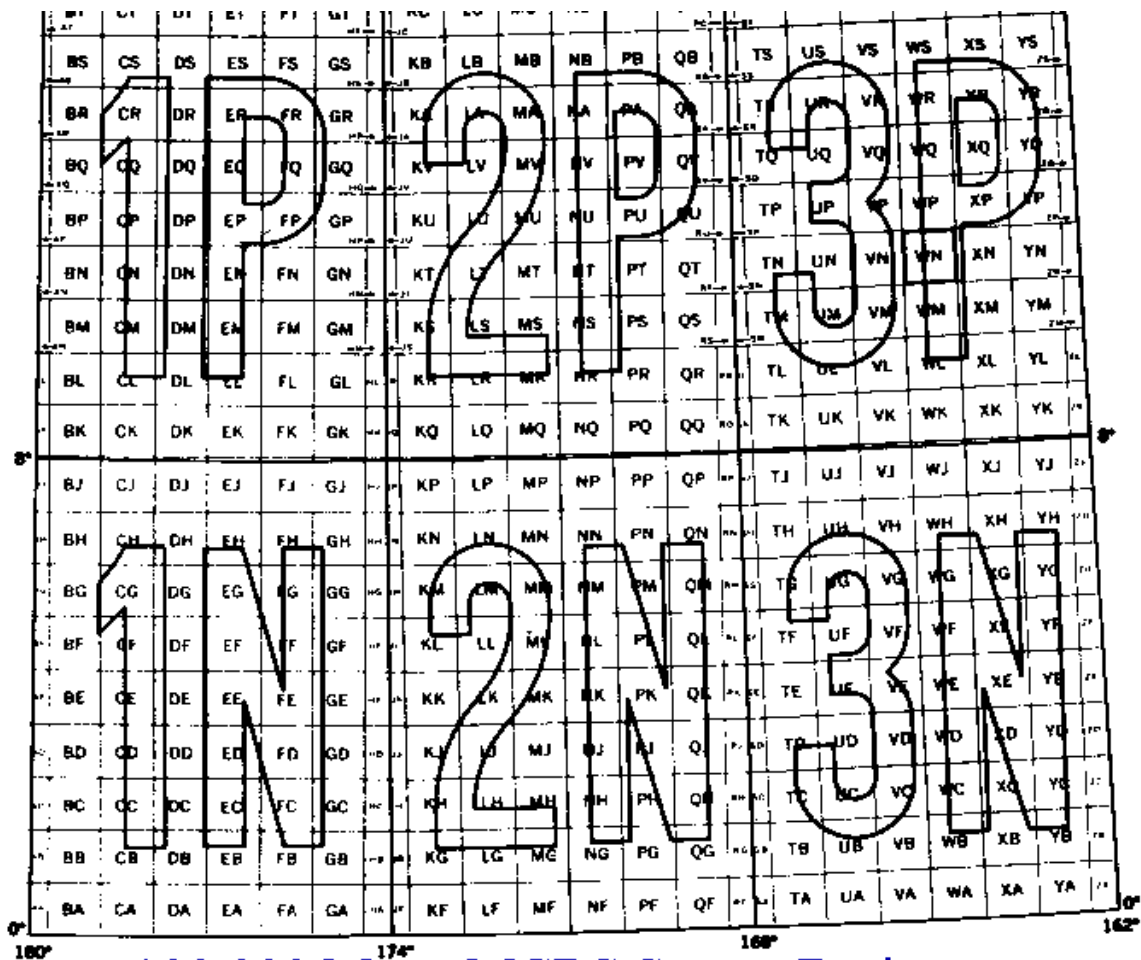
In addition, each of the 60 zones is divided into 8° blocks of latitude. Block C covers 80°S to 72°S and so on northward, omitting the letters I and O. The final Block X covers 12° of latitude. This gives the Zone Letter.

The combination of Zone Number and Zone Letter provides a Grid Zone Designator.

The central slice of NSW, including all the ACT, is in Zone 55H. Now Mount Tennent, near Tharwa in the ACT, could be described as being located in Zone 55H at 85314E, 64038N (MGA94). Once the zone block is specified, the leading hundred thousand can be dropped from the Easting and leading million dropped from the Northing.

6. Map Coordinates - **MGRS Grid**: The Military Grid Reference System is an extension of the UTM system. The UTM zone number and zone letter are used to identify an area 6 degrees in east-west extent and 8 degrees in north-south extent. The UTM grid zone designator is followed by 100 km square easting and northing identifiers. The system uses a set of alphabetic characters for the 100 km grid squares. Starting at the 180 degree meridian the characters A to Z (omitting I and O) are used for 18 degrees before starting over. From the equator north the characters A to V (omitting I and O) are used for 100 km squares, repeating every 2,000 km. Northing designators normally begin with 'A' at the equator for odd numbered UTM easting zones. For even numbered easting zones the northing designators are offset by five characters, starting at the equator with 'F'. South of the equator, the characters continue the pattern set north of the equator. (Complicating the system, ellipsoid junctions (spheroid junctions in the terminology of MGRS) require a shift of 10 characters in the northing 100 km grid square designators. Different

geodetic datums using different reference ellipsoids use different starting row offset numbers to accomplish this.):



## 100,000 Meter MGRS Square Designators

The UTM zone designator and the two 100 km square characters are followed by an even number of digits representing easting and northing values. If 10 digits are used, a precision of 1 metre is assumed. 2 digits imply a precision of 10km. From 2 to 10 digits the precision changes from 10km, 1km, 100m, 10m, to 1m.

Thus, Mount Tennent, near Tharwa in the ACT, could be described as being located at 55H FA 8531464038 (MGA94). Normally, this is shortened to GR853640 (MGA94) (giving 100m accuracy and with the nearest same GR being 100km away - hence a 100km square two character identification would be needed and, if reporting beyond 18°, the Grid Zone Designator).

7. To convert from geographic to grid coordinates, use the calculator at [http://www.ga.gov.au/geodesy/datums/redfearn\\_geo\\_to\\_grid.jsp](http://www.ga.gov.au/geodesy/datums/redfearn_geo_to_grid.jsp).
8. To convert from grid to geographic coordinates, use the calculator at [http://www.ga.gov.au/geodesy/datums/redfearn\\_grid\\_to\\_geo.jsp](http://www.ga.gov.au/geodesy/datums/redfearn_grid_to_geo.jsp).
9. GR accuracy – note that a 6-figure GR (3-figure easting + 3-figure northing) places the location somewhere within a 100m square. If you are able to estimate 4-figure eastings and northings to produce an 8-figure GR, the location would be somewhere within a 10m square. Using a GPS which shows 5-figure eastings and northings, a 10-figure GR can be quoted which, in theory, is

accurate to the metre. However, due to various factors, your GPS accuracy may only be 15m!  
And to top it off, the map might not be that accurate:

RELIABILITY Horizontal: 90% of well defined detail is within 12.5 metres of true position.

## Appendix 4 – Visualising relief features

### 1. Plotting a feature from a map

Step 1 – Draw a pencil line on the map covering the profile to be plotted

Step 2 – Place the edge of a piece of paper along the line and mark where major contour lines cross. Write down the heights. 100m contour lines may be sufficient; marking additional lines will give more detail to the profile. Include specific heights such as Spot Heights

Step 3 – make a rough graph of the heights and join the dots.

The example below is a profile of the Gudgenby saddle area, as seen from the east. Note that the edge of the paper has been raised slightly off the profile line, just to show what's going on:



*Plotting a relief feature*

How does it compare with actuality?



*Photograph of Gudgenby saddle and Mt Gudgenby*

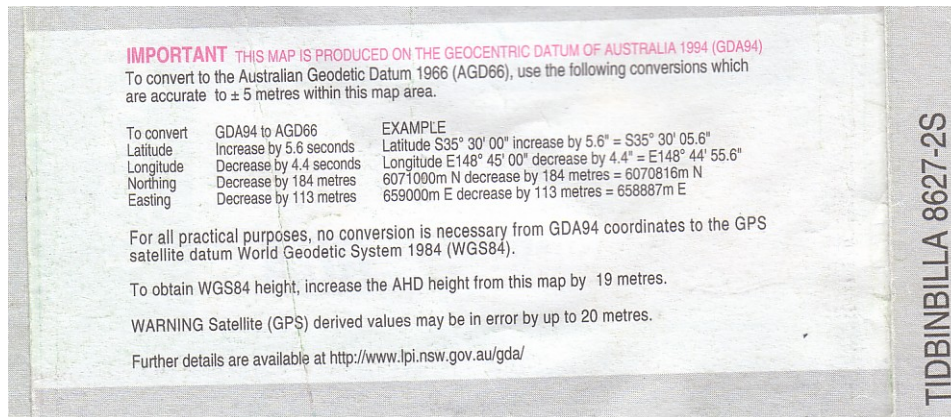
## **2. Google Earth view**



*Gudgenby saddle and Mt Gudgenby from Google Earth*

## 7. Appendix 5 – Test Your Map Reading and Navigational Knowledge - Answers

### 7.1. Australian Geodetic Datum 1966 (ADG66) Geocentric Datum of Australia 1994 (GDA94)



### 7.2. World Geocentric System 1984 (WGS84)

### 7.3. GDA94 = WGS84

### 7.4. Handrails include ridges and spurs, creeks, cliffs, management trails, fence lines.

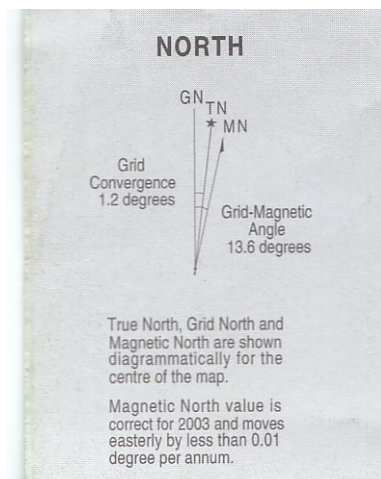
### 7.5. Aiming-off

### 7.6. Your walk leader is using a map based on ADG66 datum. Your GPS is set on WGS84 or GDA94 datum. A 6-figure grid reference is usually of sufficient accuracy for a map check under ideal conditions; your GPS will always show a location down to the 1 metre (although will not be accurate to this level). You are both in the same location, at SH1556.

### 7.7. A warm start is an update on a recent position fix. For example, turning on your GPS within 30 minutes of its last use.

### 7.8. MGA. Magnetic to Grid, Add the grid-magnetic angle.

### 7.9. Around $13.5^{\circ}$



- 7.10. Generally yes, north and west facing slopes are hotter and dryer; south and east facing slopes are cooler and damper.
- 7.11. It is generally easier to navigate down a creek system because, whenever you come to a junction, you follow the water flow down. If navigating up a creek system and a junction is reached, there is a choice of arms to be taken. It is generally easier to navigate up a spur as, when a branch point is reached, you continue up. If navigating down a spur system, when a branch is reached, a bearing may be required to decide which branched spur to continue down.
- 7.12. An attack point is a feature that is relatively close to your target, but is more significant and easier to find. First navigate the easier leg to your attack point, then the short leg to your objective. When moving on a compass bearing a similar technique can be used if a more distant object (eg. a prominent hill or saddle) is in the same direction. Look up and move towards the object, occasionally checking your direction using your compass.
- 7.13. The most commonly used grid coordinate system is Military Grid Reference System (MGRS, or GR). Make sure that your GPS is set to the same grid coordinate system and not something else (such as UTM). In addition, ensure that your GPS is set to the same datum (ADG or GDA = WGS) as the map you are using.
- 7.14. GMS. Grid to Magnetic, Subtract the grid-magnetic angle.  $294.5^{\circ}\text{M}$ .

## References:

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2. *Locations in Tasmania – A guide to map grid references, latitude/longitude, datums, GPS use and other basics of spatial data* <http://www.geol.utas.edu.au/censis/locations/index.html>.
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<http://members.ozemail.com.au/~aburke/Navigation/NavigationCourseHandout.pdf>.

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