

Land Navigation VIII Using GNSS Receivers



Unit 26, Land Navigation VIII:Using GNSS Receivers
Date Last Updated: March 3, 2020

This presentation Copyright © 2020 Paul J. Morris Some Rights Reserved.

This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.
This material may be freely reproduced and used under the terms of the Creative Commons Attribution-ShareAlike License.

This presentation includes images that have been made available under CC-BY and CC-BY-SA licenses, and material from the public domain.

This presentation is not a complete manual for search and rescue response. The materials are not meant to replace field training by competent search and rescue leaders or to replace actual experience. NEWSAR and the authors and contributors do not endorse any specific equipment mentioned or shown in this program. The authors, contributors, and NEWSAR take no responsibility for the use of this guide or the information contained within. The authors, contributors, and NEWSAR take no responsibility and cannot be held liable for statements made by instructors who use this presentation. It is the duty of every community, organization, volunteer group, and agency, to obtain the knowledge, skills, and proficiency to perform and maintain effective search and rescue management and operations. The information presented in this presentation serves as part of a beginning outline and body of knowledge for proper search and rescue response programs at the community level.

A course presented using this material may only be represented as a NEWSAR course, and may only use NEWSAR marks if presented by an authorized NEWSAR instructor under the auspices of NEWSAR. No authorization for the use of NEWSAR marks is given or implied by this document.

Some Key GNSS receiver Settings

- Position format:
 - Latitude/Longitude
 - Decimal Degrees
 - Degrees, Minutes, Seconds
 - **USNG**, UTM/UPS, MGRS
- Datum: NAD27, NAD83, WGS84, etc.
 - Use **WGS84**
 - Unless using a map with a different datum
- Units (elevation, speed): English, Metric
- Bearings: Magnetic, True
- WAAS (on, off)



One set of opportunities for **human error** are the GNSS receiver settings. You must be able to locate and change all these settings on GNSS receivers.

You could be working with a combination such as Latitude/Longitude as the position format, NAD27 as a datum, and magnetic bearings.

Or you could be working with a combination of US National Grid as the position format, WGS84 as a datum, and true bearings.

Working with one set of settings, and communicate with someone else using a different set – certain to cause confusion and navigation errors.

Setting bearings to magnetic may be desirable when working with a lensatic compass. Make sure communications follow the convention (magnetic or true) adopted for the search.

Turn on WAAS (Wide Area Augmentation System) for higher accuracy positions, **but uses batteries faster**.

Datum (geodetic datum)



- The Earth is not a perfect Sphere
- A geodetic datum is a reference model for the shape of the surface of the Earth
- The same coordinate in two different datums may differ in position by hundreds of meters or even kilometers
- (Distinct from vertical datum for elevation)

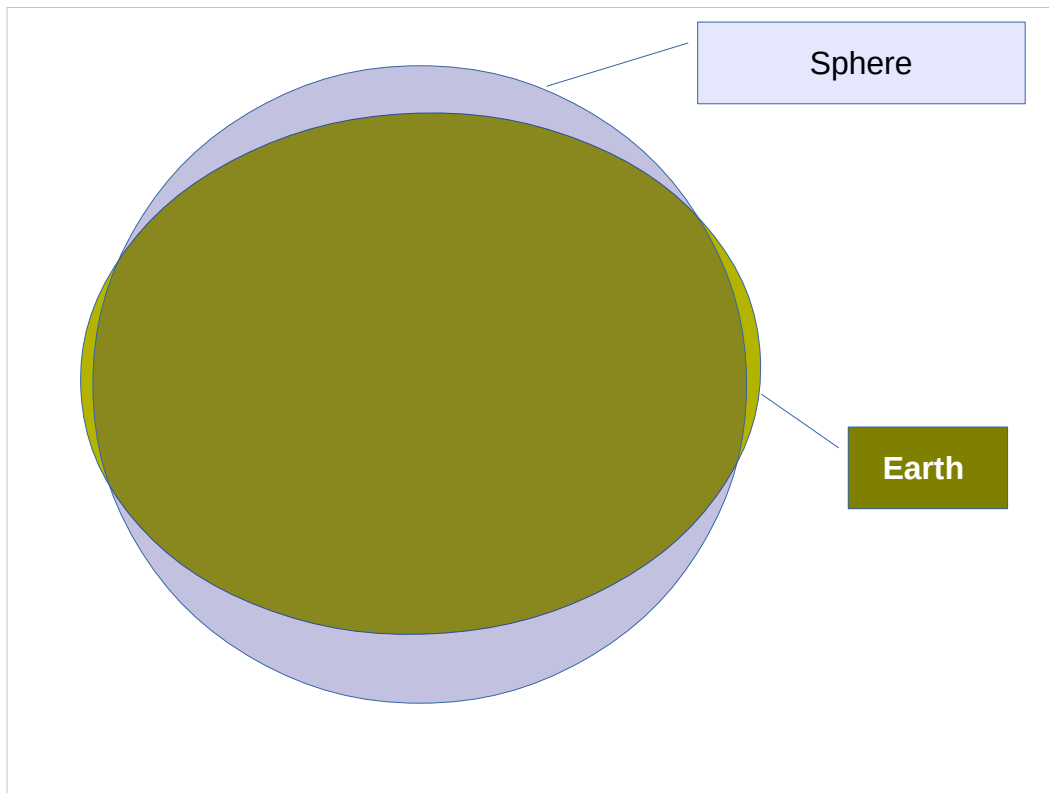


Since the Earth spins, it bulges slightly at the equator – it isn't a perfect sphere. A geodetic datum (like WGS84) is a mathematical model of the shape of the Earth used in producing a map projection.

Some datums were designed to work well in one particular part of the world (and not work well anywhere else). Other datums (like WGS 84, the world geodetic system of 1984) were designed to work anywhere in the world.

If you report a position using one datum to someone else who enters it using another datum, the position might end up as much as 3.6 km off.

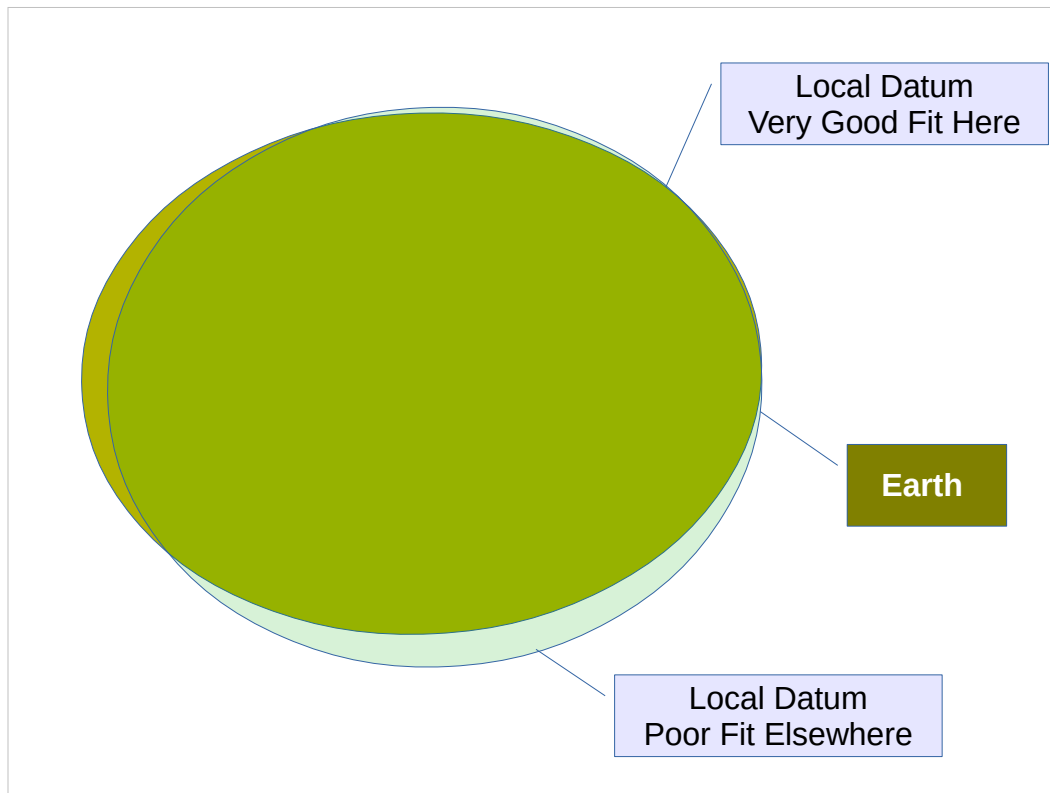
Having your GNSS receiver set to the wrong datum is one source of human error.



The Earth isn't a Sphere.

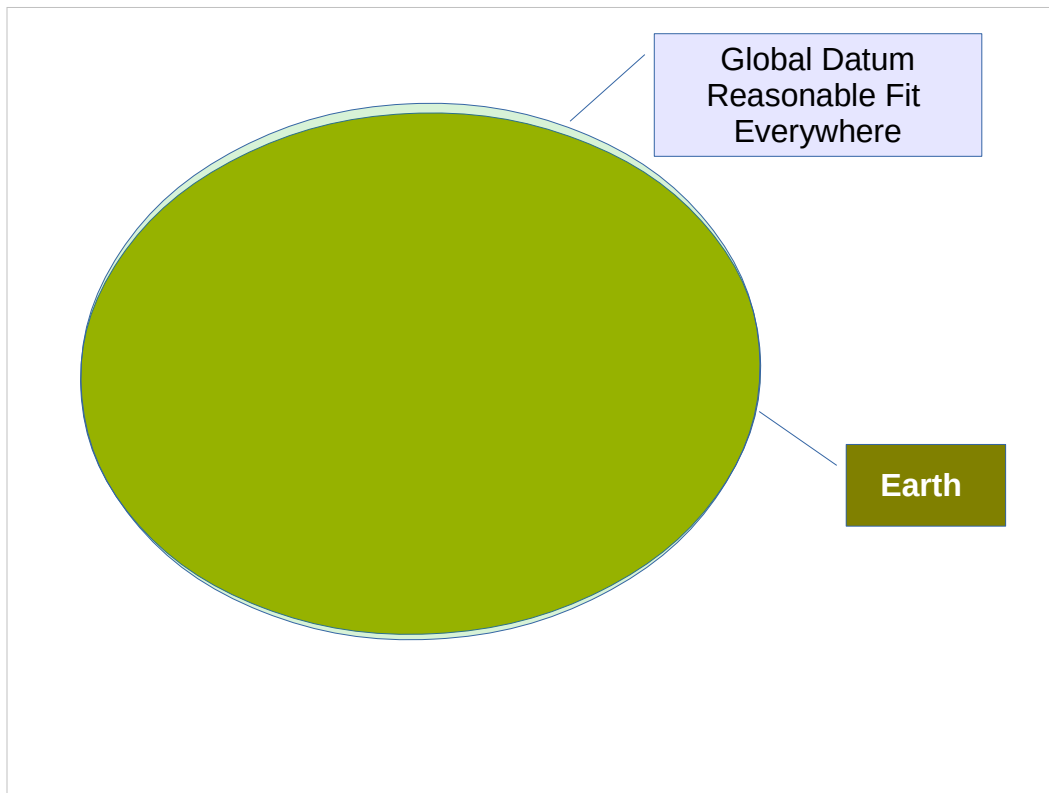
We could model it as one (a simple spherical global datum centered on the center of the Earth), but that would be a poor fit just about everywhere.

So, we need a better Datum, a better model of the actual shape of the Earth.



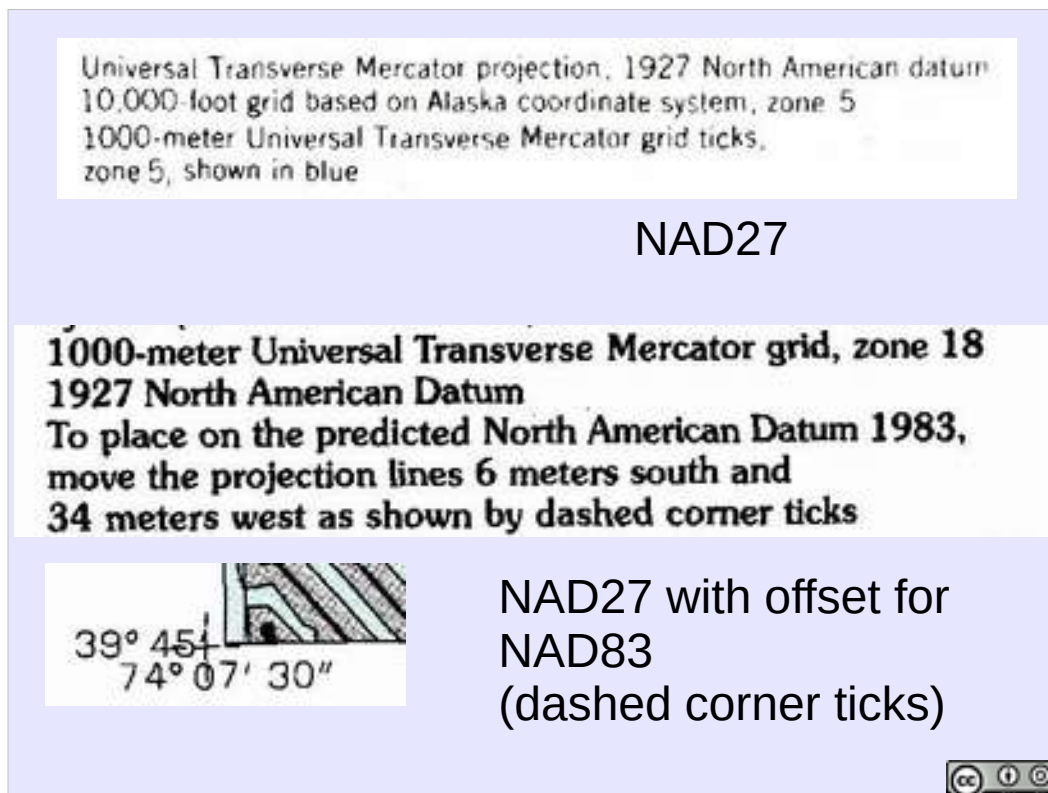
We could model the earth as a spheroid, fitted well to some local part of the Earth.

This is what the datum NAD27 does – it is a model of the shape of the earth, centered on Kansas, that fits well in the US, and poorly elsewhere.



Or we could adjust a spheroid to make a more complex model of the shape of the Earth that is a reasonable fit everywhere.

This is what the datum WGS84 does, it it a reasonable fit to the actual shape of the Earth everywhere on Earth.



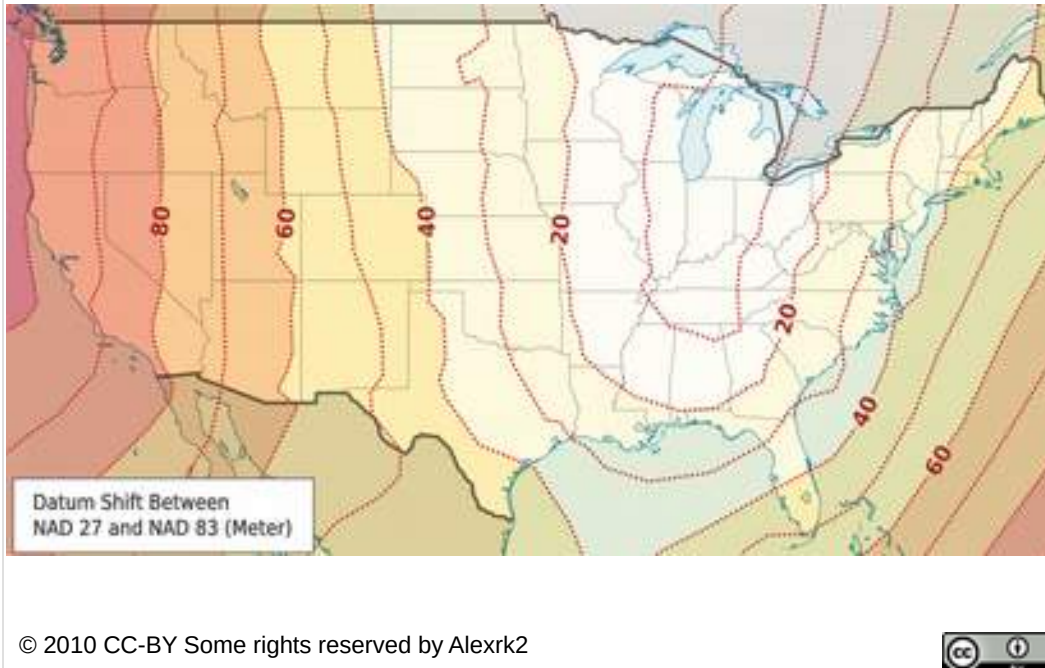
A map is projected using a particular datum. This datum should be included somewhere in the metadata on the border of the map.

At the top is an older USGS topographic quad which used NAD27, the 1927 North American Datum (which is a good fit in the continental United States).

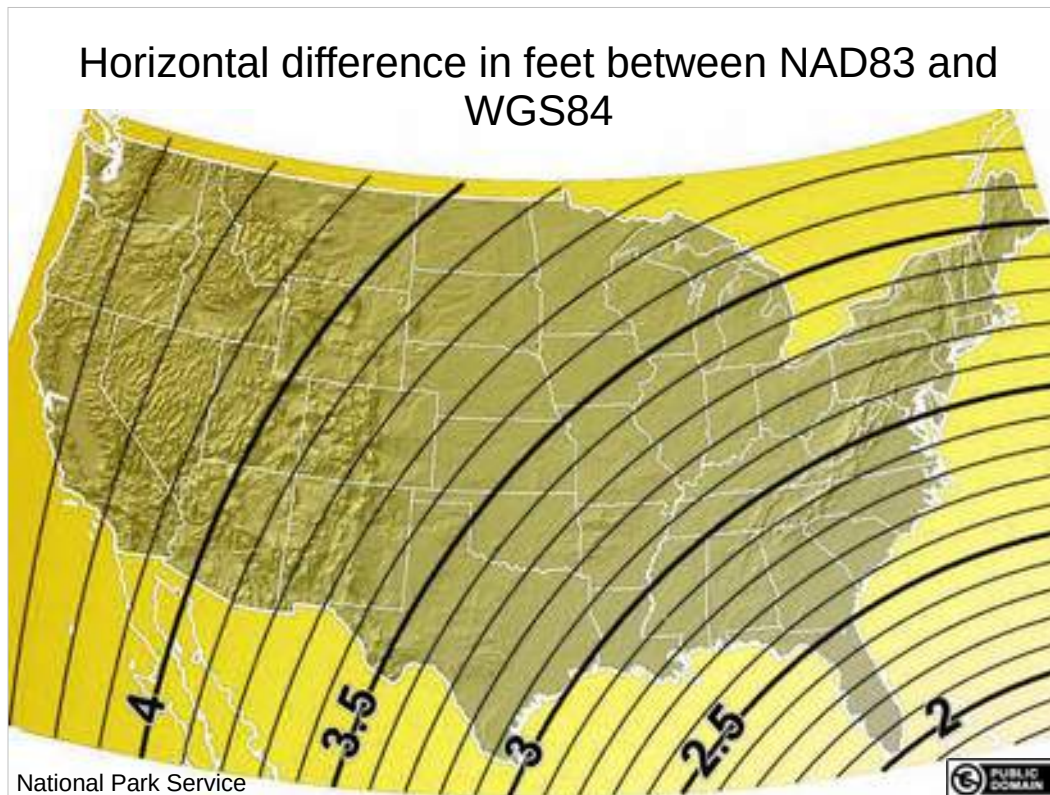
Below is a 1990s USGS topographic map which also used NAD27, but includes markings on the map showing how much positions need to be shifted to between NAD27 and NAD83, the 1983 North American Datum. In this case, the difference is about 36 meters.

Current USGS maps use WGS 84 (and may show the offset between WGS84 and NAD27).

Horizontal difference in meters between NAD27 and NAD83

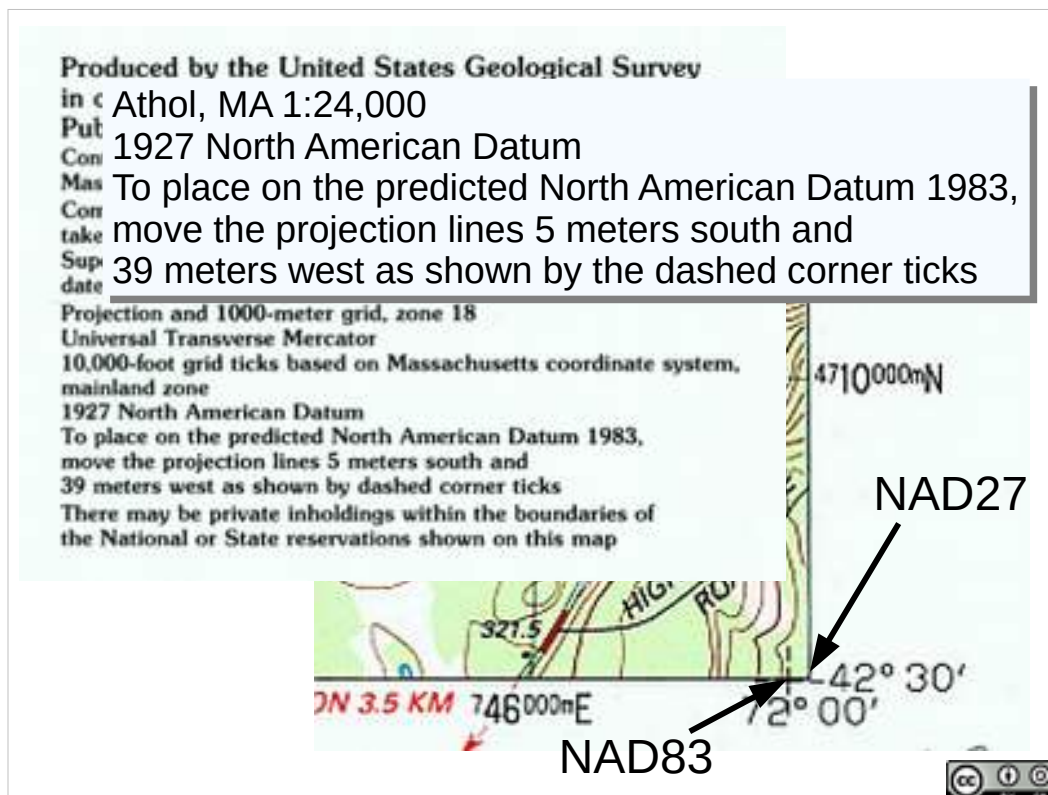


Here's a map showing how much NAD27 and NAD83 differ from each other in the continental US. In New England, these are typically about 40 meters different from one another.



NAD83 and WGS84 are not very different in the continental US. This map shows the difference between them in feet (about 3 feet to a meter).

In New England, NAD83 and WGS84 are on the order of 1 meter different from one another.

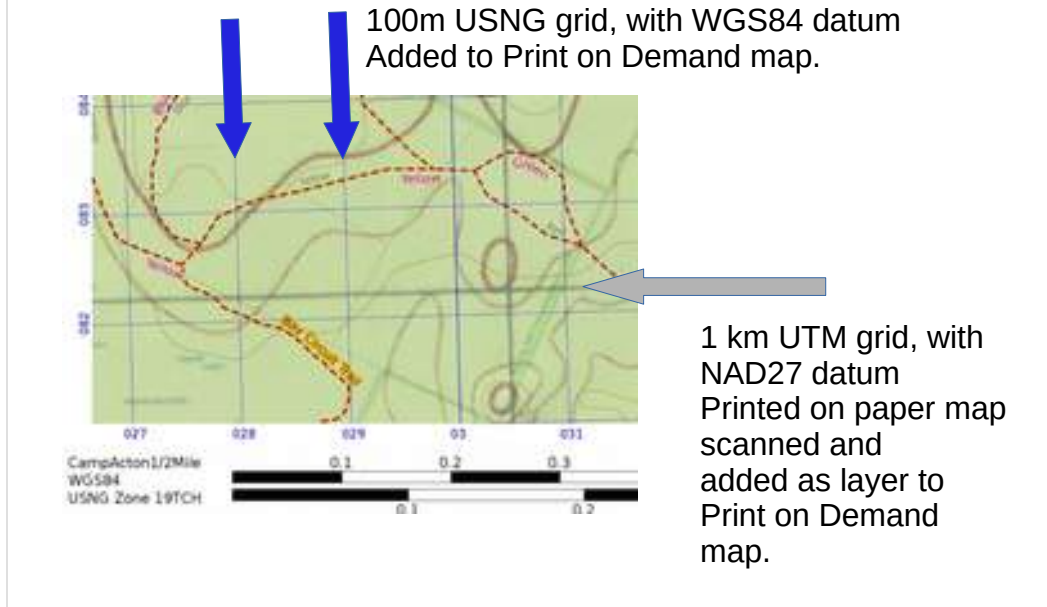


Here is metadata from the border of the Athol, MA 1:25,000 USGS topographic map from 1998. How much difference is there between the grid on the map (NAD27 datum) and WGS84? [39 m west, and 5 m south]

Difference between NAD27 and NAD83 is shown on map (5 m south, 39 m west). Difference between NAD83 and WGS84 in the NE US is just over one meter (previous slide), so for navigating on the ground in New England, NAD83 is effectively the same as WGS84. Difference is just over 40 meters.

So if you have your GNSS receiver set to WGS84, and you are communicating a position in Athol to someone who is plotting it on this map, without realizing the datums differ, they will plot the point about 40 meters east of where it should be. 40 Meters is easy shouting distance, but could be on the wrong side of a stream or other terrain feature if someone tries to navigate to your position using a different datum, and might be too far off from a flagged clue to find the flagging.

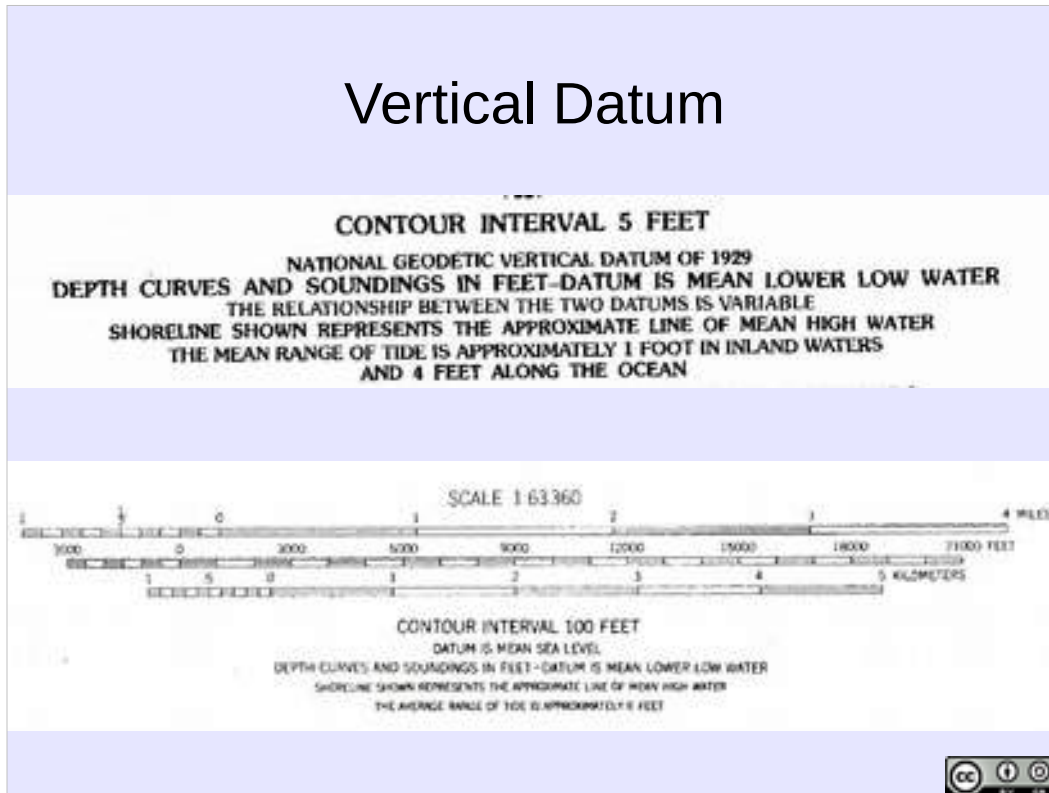
Grids on scanned paper maps as layers in print on demand maps



Don't get confused by grids that were printed on USGS topographic maps when scans of those maps are added as a layer in a GIS application to produce a new print on demand map (with its own grid added).

In the print on demand map (e.g. produced from Terrain Navigator or SARTopo) you may not have access to the metadata that tells you what datum and coordinate system was used for the grid on the underlying scanned map. The print on demand map should include the metadata you need to use the grid it added.

Vertical Datum



Geodetic/horizontal datum is different from the vertical datum (also marked on the edge of maps).

Geodetic datum is a model of the shape of the earth used to project the map.

Horizontal datum is the local zero for elevation, usually mean sea level.

Which horizontal datum is used for the map is usually important to know in coastal areas.



How to get to the settings varies from GNSS receiver to GNSS receiver. Typically there is a main menu with access to units and/or position format settings.

Here, in an older Garmin GPS 60 series GNSS receiver, there's a main menu page with a Setup page with a Units page where you can find the position format, datum, and distance units settings.

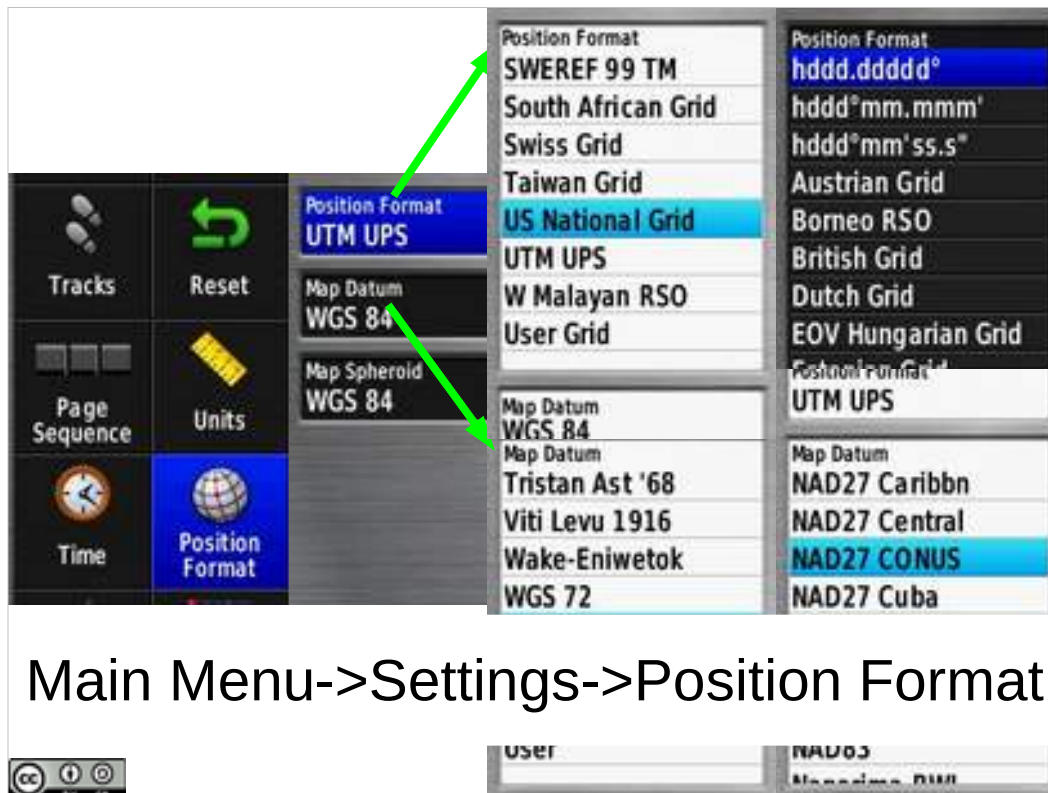
Main Menu->Settings->Units



For Position Format and Datum you will have many choices.

USNG, UTM/UPS, or decimal degrees (here hddd.ddddd) are the likely position formats (at the top and bottom of the very long list).

WGS84 or NAD27 CONUS are the likely Datum choices (again from a very long list).



Here's the menu system for a more recent Garmin GPS 62 series GNSS receiver, with position format and datum accessed from a Position Format section on the main menu.

GNSS receivers vary.

Learn yours. Learn your teammates.

With your GNSS Receiver, Set:

- Position readout to Latitude/Longitude
- Latitude/Longitude Format to Decimal Degrees
- Datum to NAD27
- Units to Feet/Yards/Miles
 - Write down your location

Now change to:

- Position readout to USNG
- Datum to WGS84
- Units to Metric
 - Write down your location



Take out your GNSS receiver.

Practical Evolution: (1) Set datum and coordinate system on a GPS.

Set to: lat/long, decimal degrees, NAD27, units: feet yards/miles.

Then change to: USNG, WGS84, units: metric.

Plot location on a map

- What coordinate system and datum is used by the map?
 - Does it have a UTM grid?
- Change the GPS coordinate system and datum to match the map.
 - View the coordinates (current, in a waypoint)
 - Plot the coordinates on the map.

Given a location, you can plot it on a map.

What do you need to know to plot a location on a map?

May need to set a GNSS/GPS receiver to the same coordinate system (e.g. USNG) and datum (e.g. NAD27) as the grid printed on the map.

Practical Evolution (2) Mark current location on a topographic map

Converting with a GNSS



It is straightforward to use a modern GNSS receiver to convert from one position format to another.

With your GNSS receiver set to one position format, record or enter a position. Then using the menu system, change to a different position format.

Here the location is in UTM in the upper left, working through the menus, the position format is change to latitude/longitude, degrees minutes seconds – and the display changes to show lat/long.

Startup: Practice Good Habits

- Before you start:
 - Check/Change your batteries.
 - Check Datum, Coordinate System, distance units
- When you get out at the drop off point
 - Make sure your GPS has an accurate position.
 - Mark a waypoint with your GPS.
 - Save and clear the current track (dog's too).
 - Make sure that your GPS is recording the track.
 - Calibrate the compass.
- When you start your assignment
 - Mark a waypoint
- When you complete your assignment
 - Save the track for the assignment with clear name.

Reminder: Practice good Habits.

Create Waypoints By:

- Mark Current Position
- Create a waypoint and enter the coordinates.
- Select a position on the map.
- Project a waypoint.

You can create waypoints in several ways.

You can mark your current location as a waypoint (often a Mark button).

You can create a waypoint, then edit the coordinates to move the waypoint somewhere else.

You can select a position on the map and turn it into a waypoint.

You can project a waypoint some distance on some bearing from the current location or another waypoint.

Let's walk through these.

Navigating with GPS

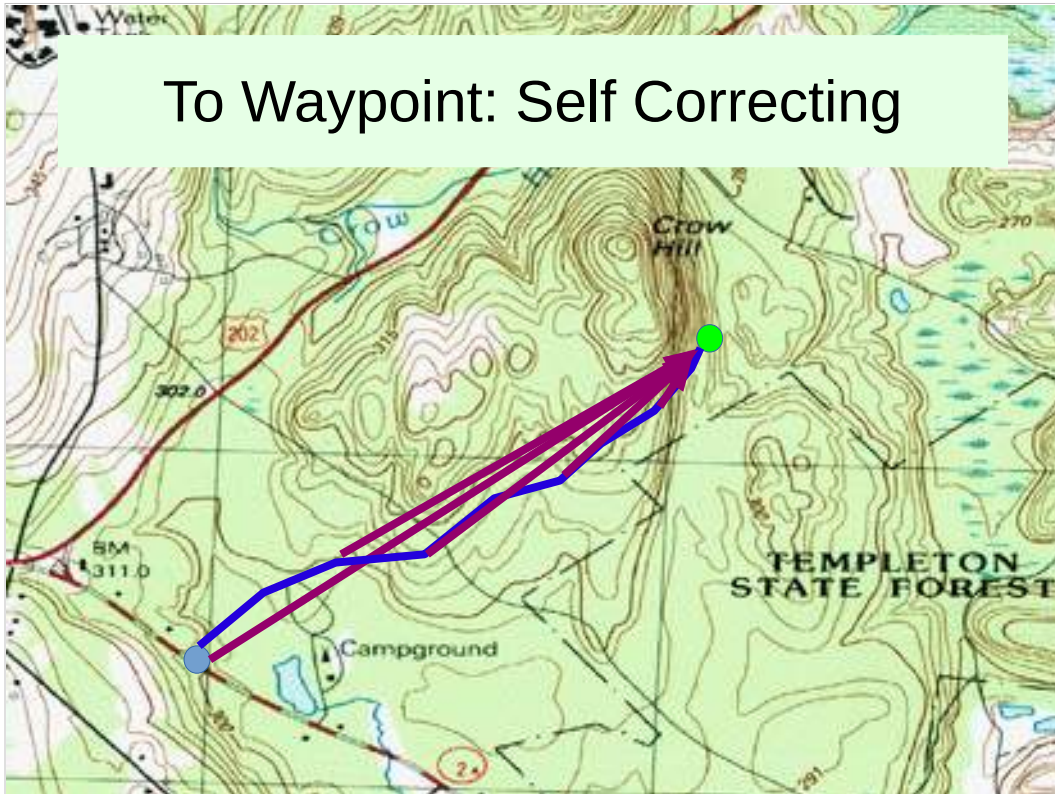
- Enter a waypoint, go to waypoint.
 - Self correcting navigation.
 - (Enter a route, follow route).
- Project a waypoint a distance on a bearing.
 - Self correcting navigation
- Backtrack
- Navigate with the GNSS compass on a bearing
 - Errors accumulate.

First, lets think about two fundamentally different ways you can use your GNSS/GPS receiver to navigate.

One is navigating to a waypoint.

The other is navigating on a bearing using the GNSS receiver's compass.

To Waypoint: Self Correcting



Purple is where the GNSS receiver is telling you to go as you check it along the way. If you are navigating to a waypoint, it will always point you at the waypoint.

On Bearing: Errors Accumulate

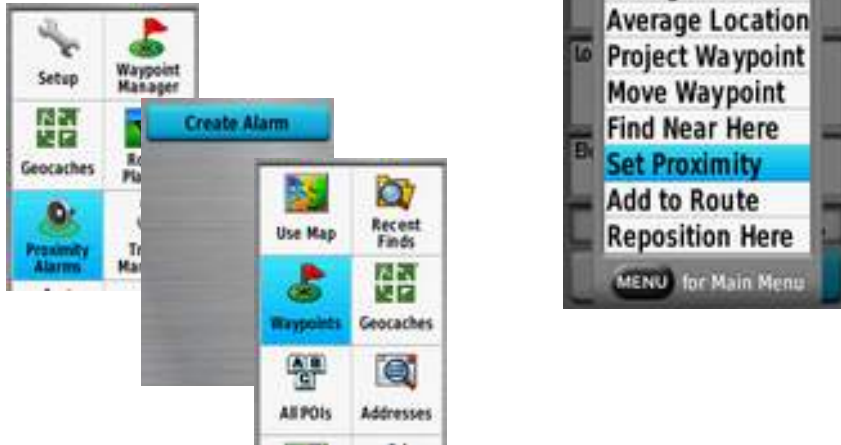


If, however, you are using the GNSS receiver to travel on a bearing, then errors accumulate.

The purple arrows show the bearing the GNSS receiver is pointing you on as you check it along the way.

Are we there yet?

- Proximity alerts.

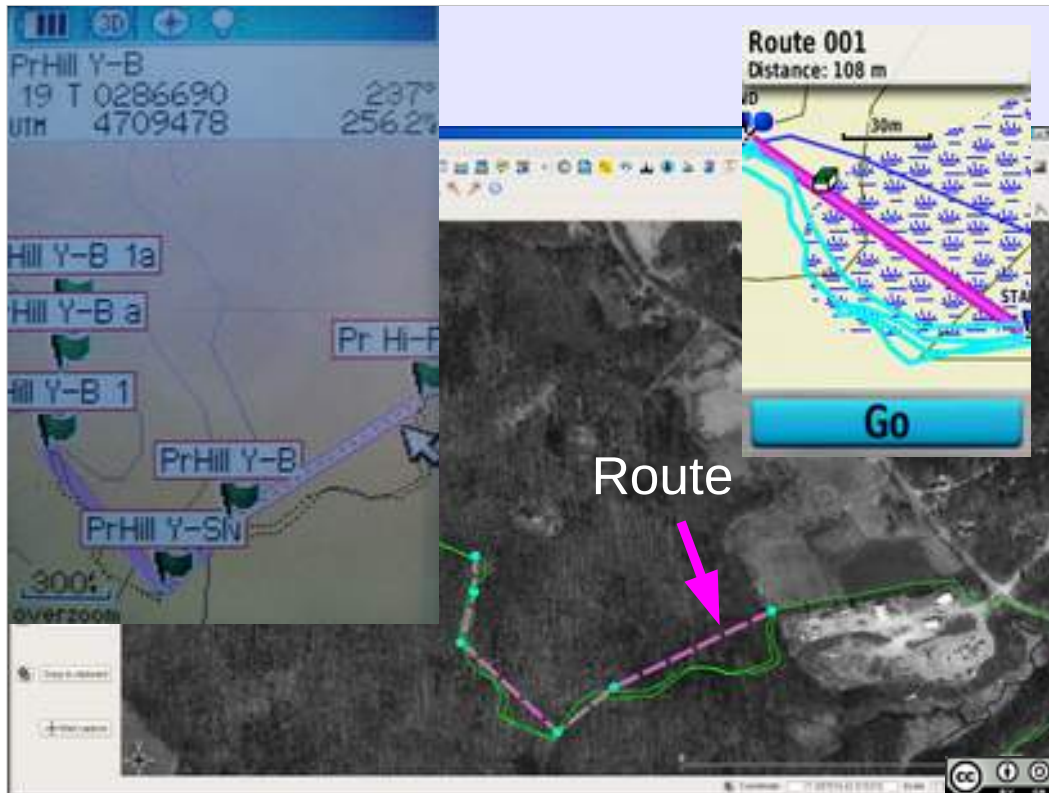


You can set your GNSS/GPS receiver to beep or otherwise notify you when you get within some distance of a waypoint that you are traveling to.



Your GNSS may allow you to build a route out of a set of waypoints.

You may also be able to do this in an external application on a computer, and upload the waypoints and route into your GNSS.



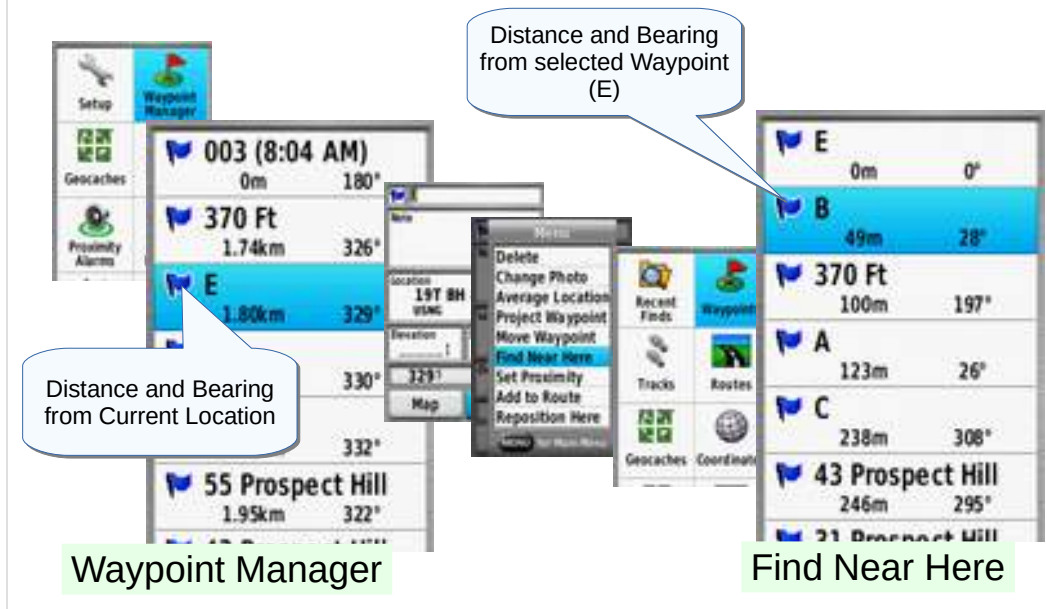
Route connects waypoints with straight lines.

GPS screen and mapping application show a route and the actual track followed while following a trail.

(On the map, trail is in green, waypoints are in blue, and the route is in pink).

In this particular case, the pink route happens to lead through a swamp, the green track around it.

Determine Distance and Bearing between two waypoints

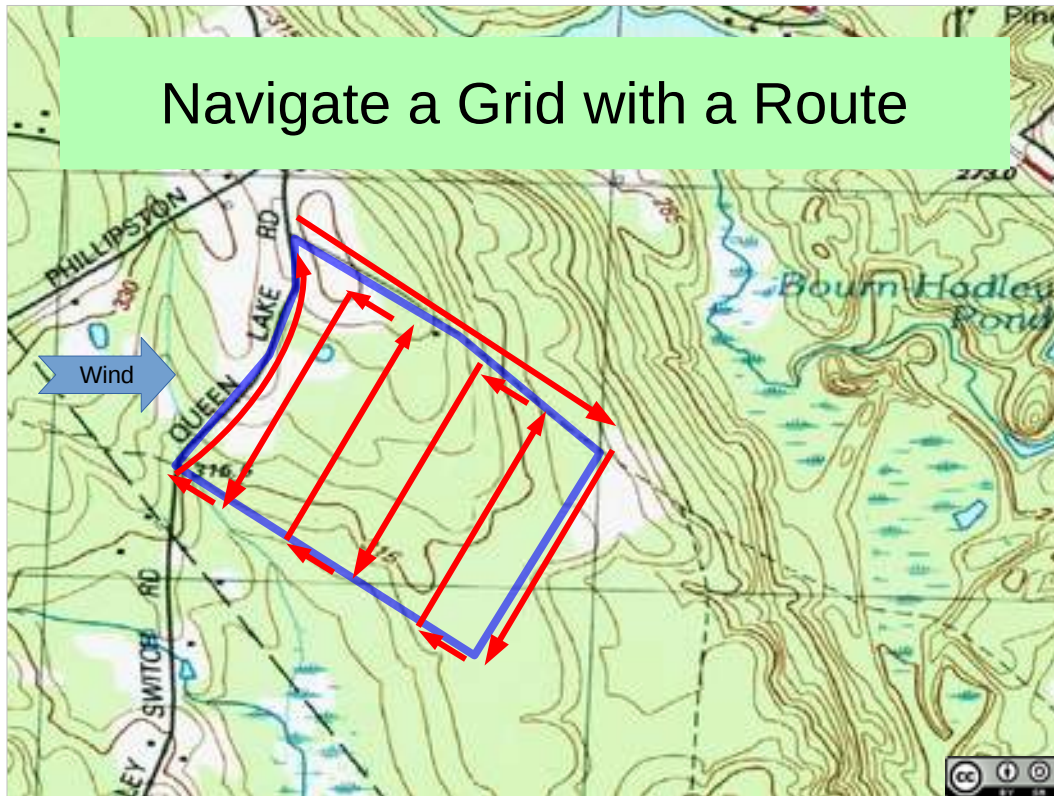


Your GNSS/GPS receiver may allow you to find the distance and bearing between two arbitrary waypoints.

In recent Garmin receivers, the waypoint manager lists waypoints with distance and bearing from the current location.

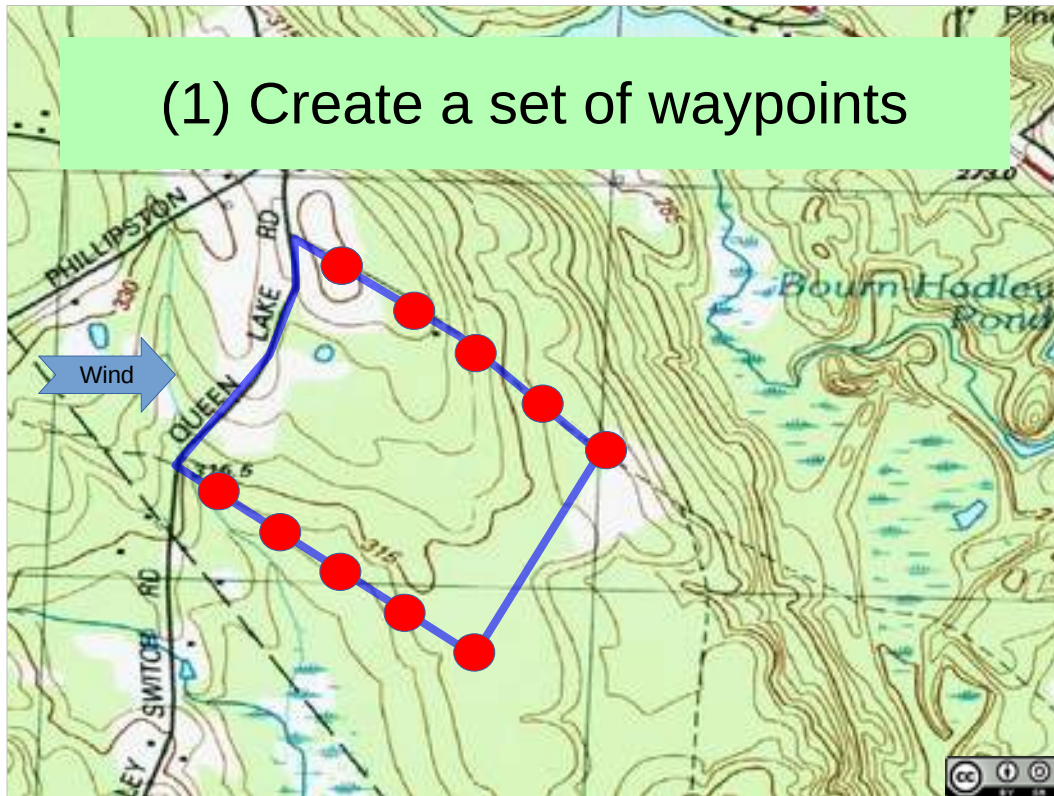
Select a waypoint then: Menu -> Find near here -> Waypoints brings up a list of waypoints with distance and bearing from the selected waypoint (bearings and distances from E). How far at what bearing from E to B?

Practical evolution: (3) Determine the distance and bearing between two waypoints.

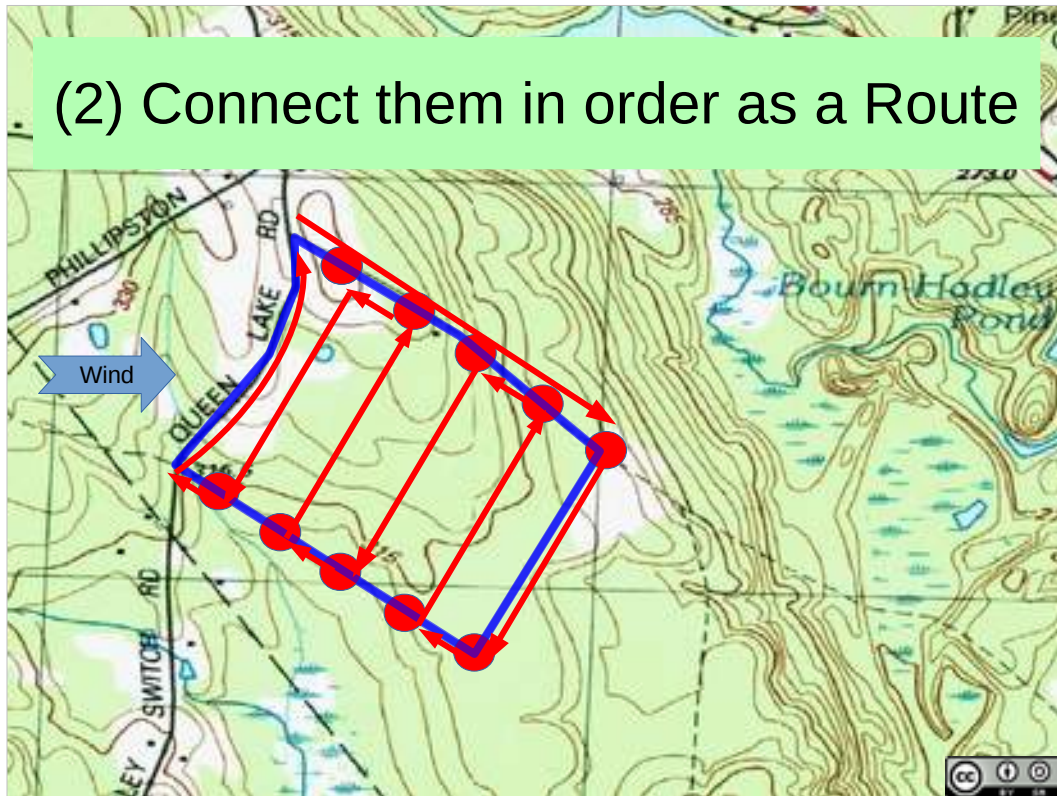


You can create a set of waypoints, then connect those waypoints into a route to navigate a grid of a segment.

(1) Create a set of waypoints



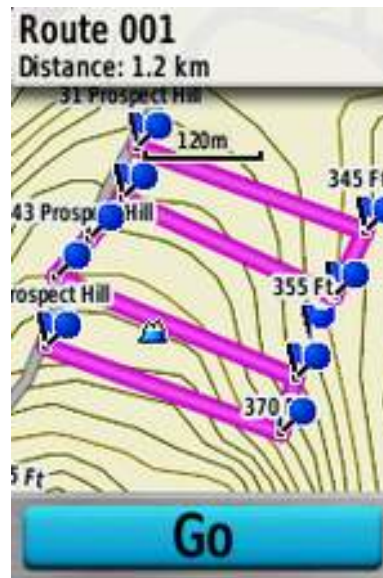
First, create them as waypoints.



Then assemble them into a route.

(or add them to the route as you create them).

Select the route and navigate it



Then select the route and tell your GNSS receiver to navigate it.

Hint: it is easier to connect them if you give them sequential names as you create them (A, B, C...)

Hint: it is a lot easier to do this in a GIS application and upload into the GNSS/GPS receiver than to create the waypoints for the grid of a segment using the GNSS/GPS receiver.

Backtrack

- Manually
 - Use GPS map and pointer to work out bearings to points along track.
- Automatically (some GPS units)
- You need to be recording the track....



You've been following some route through some complex system of trails and you want to find your way back to your starting point.

If you recorded your track with your GPS, that can help.

Some GNSS units have a backtrack function that will treat your track as a route that you can navigate in reverse.

Navigation Errors....



“The prudent mariner will not rely solely on any single aid to navigation”

How many ways can navigation go wrong with a GNSS receiver?

Discuss potential ways navigation errors can happen with GNSS receivers.

Include: Human Error, Wrong Datum, compass not calibrated, magnetic/true north setting, batteries ran out, forgot to record waypoint to navigate back to, entered coordinate incorrectly, particularly near zone boundaries, solar storms, canopy, multipath, forgetting to record track, connecting wrong waypoint sequence into a route, projecting a waypoint too far or in the wrong direction....

Failure to sanity check, sole reliance on GNSS receiver...

Download Tracks, Waypoints, or Routes from GPS to Computer



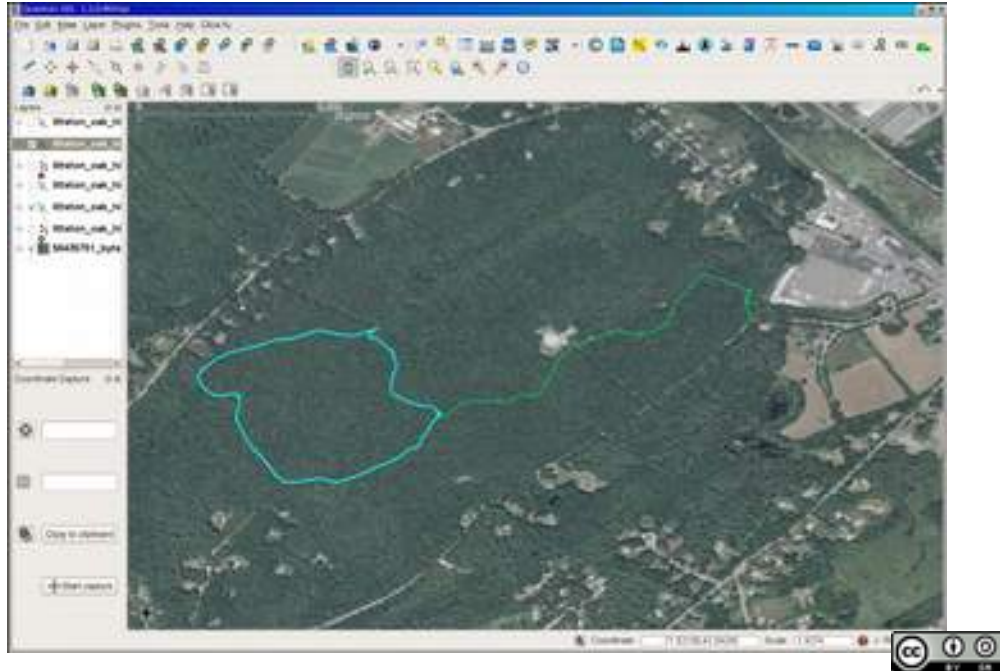
You can download stored data (waypoints, routes, tracks) from a GNSS to a computer.

Older models – serial protocols, require software that can talk specifically to the GPS.

Recent models often simply mount the GNSS as a USB storage device and generate GPX files that you can copy directly off of that storage when you plug them in, no special software needed to move data off the GNSS.

You can also upload waypoints and routes from a computer to a GNSS. For example, segment corners as waypoints.

Add as Layers in a GIS Application



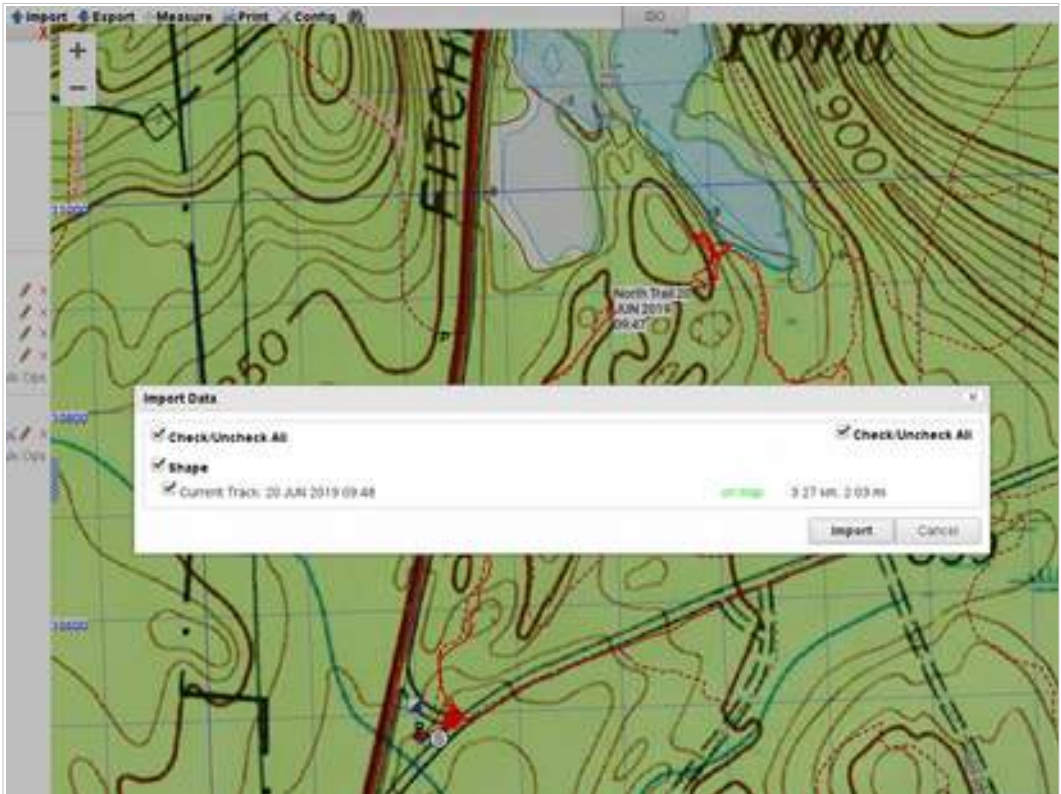
Once you've got data off the GNSS, you can add the data as layers to a geographic information system application.



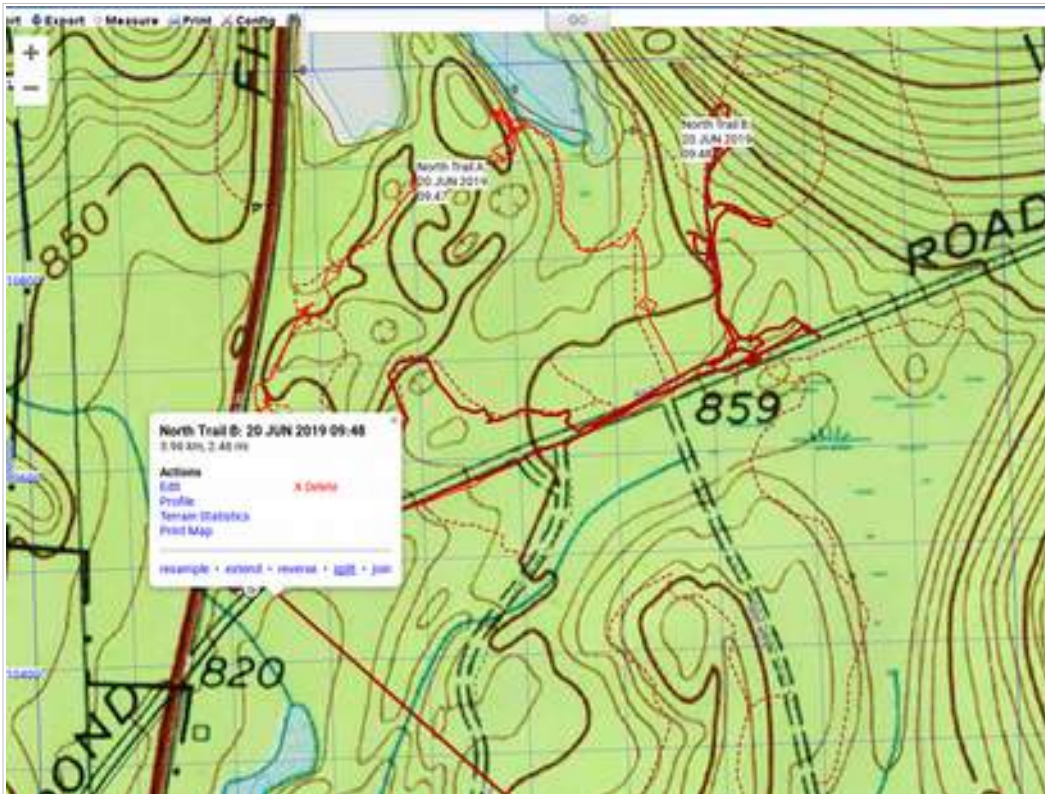
One online GIS application designed for SAR is SARTopo – it can allow you to upload tracks from a GNSS receiver, and edit tracks (split, and delete to remove extraneous before start or after end information (like the track of your drive from home to the search staging area).



SARTopo, like other GIS applications, allows you to upload tracks, waypoints, and trails from GNSS/GPS receivers. A frequent means for this is by uploading .gpx files.



From which tracks, waypoints, and routes present can be selected for import.



SARTopo allows for the editing of tracks.

A case is if you didn't remember to clear your track before starting a problem, such that the track contains your drive from the last place you had the GNSS/GPS receiver on.

A way to handle this is to select the track, split it, then delete the unwanted portion.

Best to avoid having the GIS specialist from having to clean up your tracks, so:

Saving Tracks

- Save a separate track for each assignment (documenting your search effort for that assignment).
 - Reduce clutter and work for the Planning Section.
 - Some GNSS Receivers limit the number of points in a track. Saving very large tracks can reduce precision of fit between the track and your route.
- Establish a routine – use on every training.
- Make sure tracking is on, start new/save with each assignment.

Get into good habits of recording and saving clean tracks of your assignments

Save the current track just before you start.

Clear the current track.

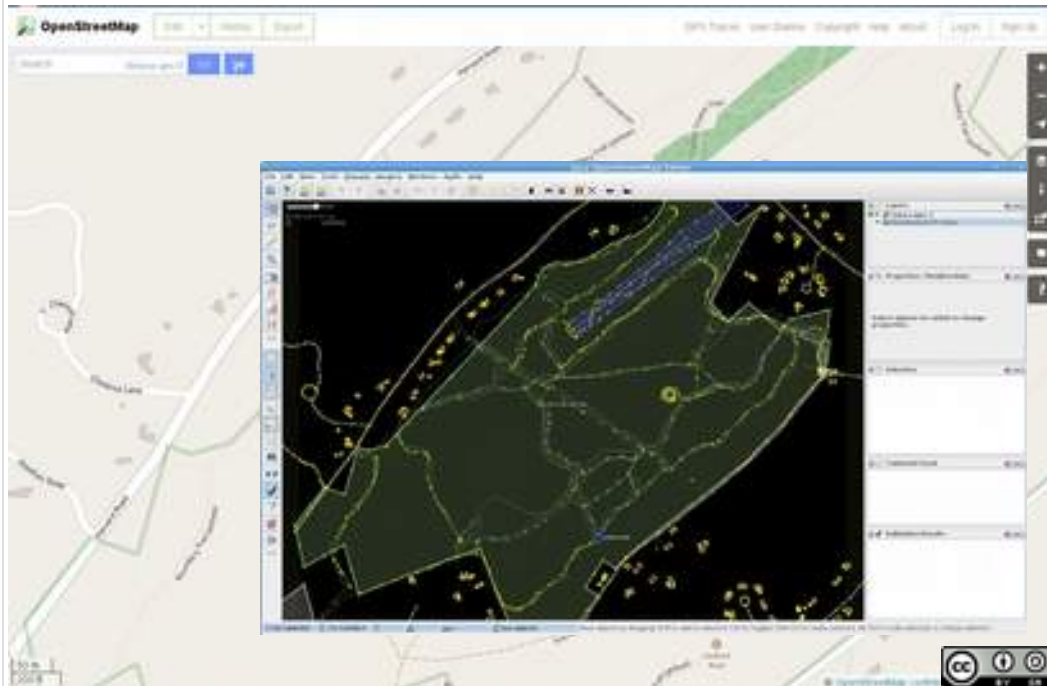
Make sure your track is being recorded.

Carry out your assignment.

Save your track.

You will make the GIS specialist very happy.

Contribute to Open Street Map



You can also contribute to OpenStreetMap

Improve the world's knowledge of trails and other map features in areas where you train. Travel somewhere that hasn't been mapped, upload the tracks from your GNSS/GPS receiver, then add and edit the map features.

Load Maps into your GNSS receiver

- Options may include (see your user manual)
 - Maps on a micro SD card.
 - Maps uploaded from a computer.
 - Maps loaded over a wireless connection.

Depending on your GNSS/GPS receivers, you may be able to add maps from external sources to display on your receiver.

With some GNSS receivers you can upload maps and air photos of an area from a computer, with others, you can obtain maps and air photos live with a wireless connection. See your receiver's manual.



This presentation Copyright © 2020 Paul J. Morris Some Rights Reserved.

This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. This material may be freely reproduced and used under the terms of the Creative Commons Attribution-ShareAlike License.

This presentation includes images that have been made available under CC-BY and CC-BY-SA licenses, and material from the public domain. Attributions are noted on individual slides. These contributions to the commons are very gratefully acknowledged.

Practical Evolution: (4) Plot the location of a task, direct them to another location.