How to Understand Accuracy and Precision

This brief guide summarises the common levels of accuracy and precision used in GIS and geospatial datasets. It is important to recognise that **Accuracy** (how close a recorded location is to its true location) and **Precision** (how exact are the measurements) are two different but interrelated aspects of geopositioning. A feature's location can be recorded accurately but very imprecisely (eg. it's in the right location but very imprecisely defined), or very precisely but inaccurately (eg. it's in completely the wrong place but specified to 6 decimal places)

Accuracy, Margins of Error and Typical Use Cases

Accuracy (+/- error margin)	Survey/Data Capture Source	Uses	Notes
0.5mm - 1mm	Total Station/Electronic Distance Measurement (EDM). LIDAR Scanning.	Building surveys, construction design, (1:50 – 1:100) Eg. Trimble C5 HP	Typically uses Laser measurements and can be used indoors and outside
10mm	GPS (Base station & roving receiver) Continuous Operation Reference Stations (CORS)	Topo Site Surveys, long term monitoring of topographic variations. (1:100 – 1:500) Eg. Trimble R580	Leaving one receiver stationary increases accuracy of measurements
200mm (20cm)	External GPS antenna connected to tablet or mobile device.	Site surveys, route tracking, feature geolocation. (1:200 – 1:2000 Scale) Eg. Trimble Zephyr 3 GIS	Allows cost-effective site survey without the need for expensive highly accurate equipment and the technical expertise required to set up and use correctly.
1m-1.5m	OS Mastermap digital data	Base mapping for site surveys, feature identification and extraction. (1:500 – 1:5,000 scale) Eg. OS Mastermap Topography Layer	UK wide data source. Structured and attributed mapping data allows easy identification and extraction of features already included on mapping.
2m – 30m	Google Imagery (a global mosaic of images from a variety of providers at a variety of resolutions)	Initial site identification and investigation. Broad scale mapping of site (1:5,000 – 1:25,000 scale)	Positional accuracy is highly variable depending on location as is 'edge matching' between adjacent image 'tiles'.
5m – 10m	Mobile GPS surveying	Quick, cheap surveying using mobile device tools such as Survey123 and Qfield. Eg. Trimble T7	Standard mobile phones and tablets are accurate to +/-5m at most but highly dependent on obstructions to "clear sky" view.
10m	OS 1:10,000 Mapping	Large area site base mapping. Contextual mapping and environmental analysis.	1mm on a 1:10,000 map equals 10m. This scale of mapping also has "feature displacement" and "feature simplification" issues so is unsuitable for detailed site assessments.
10m – 20m	Sentinel Satellite Imagery	Large area habitat/vegetation mapping. Land use change and vegetation health.	Frequently repeated image capture and "open source" (available in 'mosaiced' and 'processed' form via ESRI "Living Atlas"
50m	OS 1:50,000 "Landranger" maps	Site location, route finding, highways navigation	1mm on a 1:50,000 map equals 50m. This scale of mapping is not suitable for site investigation but can be useful for general site location context.

Precision and what this means in the real-world

Decimal Places and Precision of Latitude and Longitude co-ordinates

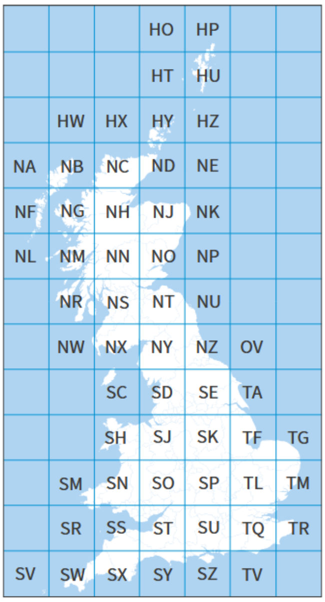
Precision (approx. [1])	Decimal degrees	Degrees, Mins, Seconds	Typical Use
100km	1	1°	National Scale
10km	0.1	0°06′	Regional Scale
1000m (1km)	0.01	0°00′36″	Town Scale
100m	0.001	0°00′03.6"	Neighborhood Scale
10m	0.0001	0°00′00.36″	Site Location
1m	0.00001	0°00′00.04″	Site Survey
0.1m (10cm)	0.000001	0°00′00.004″	Feature Measurements

1. Precision in meters of latitude and longitude is variable depending on position on globe. 1 arc minute along a meridian or along the equator equals 1.852m while precision of longitudes is dependent on latitude (multiply by cosine of the latitude).

Decimal Places and Precision of Ordnance Survey Coordinates

Precision	Easting/Northing notation[1]	Grid Reference Notation[2]	Typical Use
100km	100000,100000	SW	National Scale
10km	120000,120000	SW22	Regional Scale
1000m (1km)	123000,123000	SW2323	Town Scale
100m	123400,123400	SW234234	Neighborhood Scale
10m	123450,123450	SW23452345	Site Location
1m	123456,123456	SW2345623456	Site Survey
0.1m (10cm)	123456.1,123456.1	SW23456.123456.1	Feature Measurements
0.000001m[3]	*123456.123456, 123456.123456*	*N/A*	***Do Not Use for Geospatial Use***

1. For use in GIS, Grid coordinates must be in two columns for the X and Y (Easting and Northing) or Latitude and Longitude (Lat, Lon) Co-ordinates.
2. The two-letter prefix in Grid Reference notation refers to the relevant 100km square as shown in the figure (from the OS "Using the National Grid" Factsheet).
3. Grid references to 6 decimal places (micrometers) are usually a result of inappropriate data type formatting to a default 6 decimal places. They have no place in normal geospatial/GIS applications unless involved in precision engineering or highly scientific physical measurement of micro-processes.



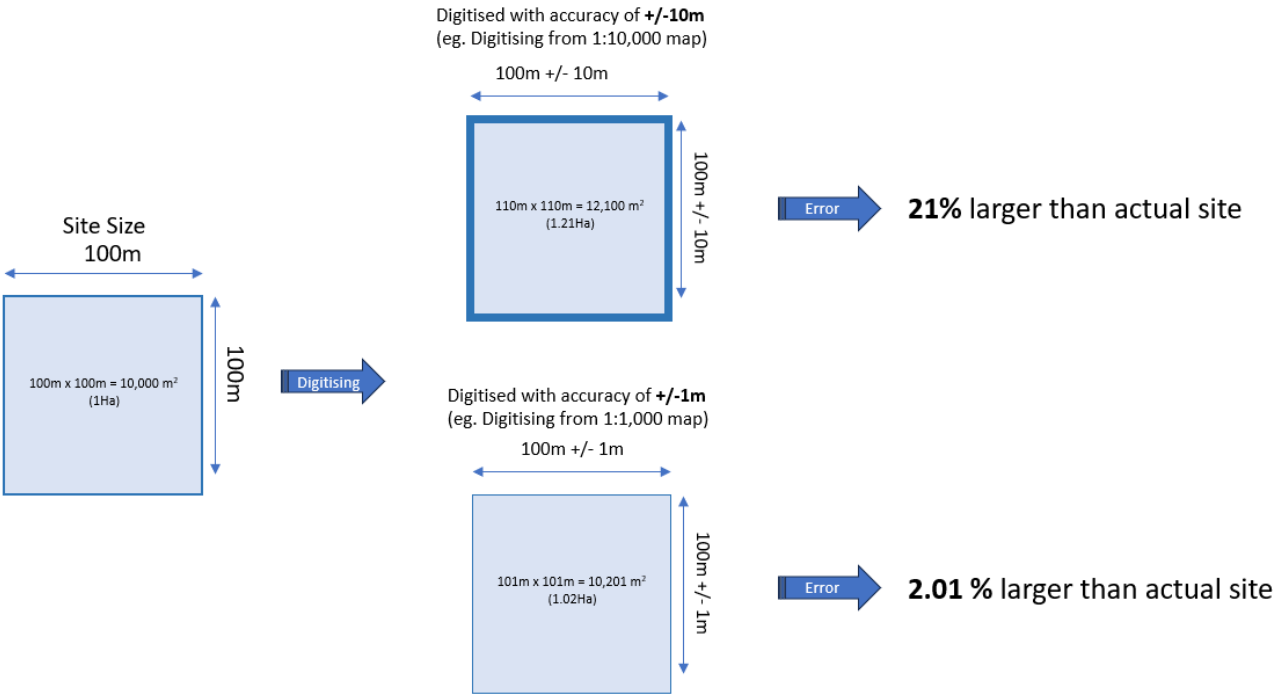
Accuracy and Precision when digitising polygons (eg. Site boundary and habitat areas)

So what does all this mean in practice if you are digitising a site boundary and its contained habitats?.

Let's take a simple example of a site that is a 100m x 100m square and work through the maths of error. It is important the correct scale of map is used in the first instance - too large a map scale and it will need several map sheets to mark the entirety of the site boundary and take longer to digitise, too small a map scale and its not going to be so easy to identify exactly where the site boundary is and any mark-up will be less precisely placed.

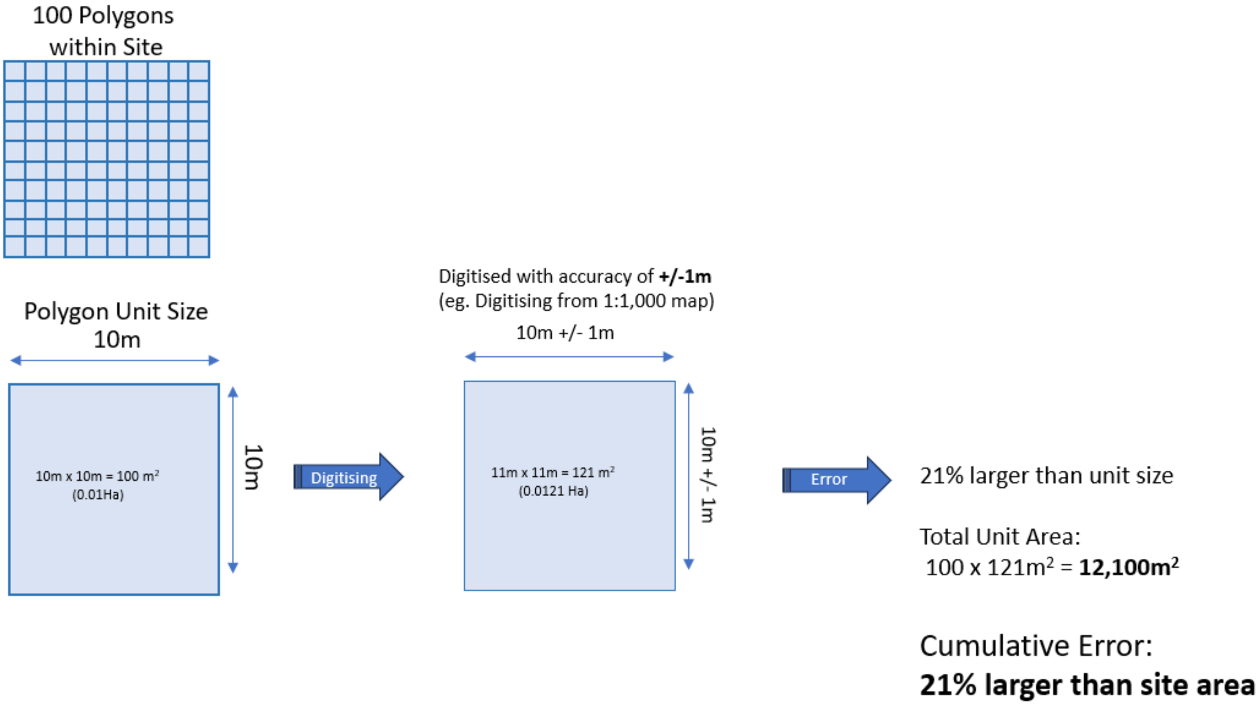
The line width and accuracy of drawing will also impact on errors. A 1mm thick line drawn on a 1:10,000 scale map is equivalent to 10m in real life, a 1mm thick line drawn on a 1:1,000 scale map is equivalent to 1m in real life. Any deviations and 'wiggles' from the lines true location will also have similar issues, so trying to draw a straight line but deviating by 1mm on a 1:10,000 map will represent a 10m deviation from the lines true position while the same amount of deviation on a 1:1,000 map will be just 1m from true position.

So if we digitise our 100mx100m site on a 1:10,000 map with a notional level of accuracy of +/-10m, then the actual digitised area could be as much as **12,100 m^2** even though the actual area is only 10,000 m^2 (an error of **21%**). If we digitise the same site from a 1:1,000 map with a notional level of accuracy of +/-1m, then the actual digitised area could be **10,121 m^2** (an error of just **2.01%**).



If we then come to digitise the individual habitat polygons within the same 100mx100m site, if it's a complex varied site, there may be 100 different habitat units (I know this is unlikely on a site of this size, but it makes the maths work a bit easier). If each habitat unit is 10m x 10m and we digitise at a scale of 1:1,000 assuming a accuracy of +/- 1m we could get an area of **121 m^2** rather than **100 m^2** (an error of **21%**). Totaled up over all 100 habitat units, then the possible digitised area could be **12,100 m^2** which, when compared to the total site area is yet again an error of **21%** - even though we have been digitizing from a 1:1,000 map.

This is a key issue to consider, the 'cumulative error' on a map is dependent on the number as well as the size of the polygons being digitised – the more polygons to digitise, the more the cumulative error is likely to be.



In reality of course, there are GIS techniques that can help avoid or reduce errors to acceptable levels;

- **Snapping to vertices** – ensures feature digitisation is coincident with existing feature vertices
- **Tracing boundaries** – using the 'trace' function ensures entire 'shared' boundaries of polygons are copied exactly avoiding gaps and slithers, even when the markup may not be entirely co-incident.
- **Splitting polygons** – repeatedly splitting existing site polygons rather than digitizing new polygons within a site will ensure that the existing overall site boundary is consistent with the habitat polygons that are contained within it.
- **Use high precision field survey** – instead of manually marking up a map by drawing lines, capture the true location of features using GPS field survey equipment.
- **Use existing data to retain consistency of location** – Use of existing feature boundaries as defined in existing digital mapping (eg. OS Mastermap) ensures representation to a known level of accuracy and maintains consistency where site and features are shown on existing mapping.
- **Cross check site area with cumulative habitat area** – if the total area of all polygons within a site is substantially larger or smaller than the total site area, then it's obvious there are a few problems.

In practice, all digitised features and feature representation will have some level of inaccuracy and lack of precision but for successful pragmatic and cost-effective project delivery, it is important to ascertain what an "appropriate" level of accuracy and precision is and work to that.