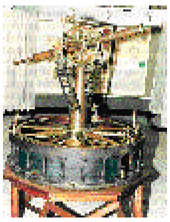
Section 1: Ordnance Survey - Background Information

Concise History of OS Large Scale Maps

The history of Ordnance Survey can be traced back to the middle of the eighteenth century when England was fighting on two fronts - rebellion in Scotland and war with France. In 1746 King George II commissioned a military survey of the Scottish highlands and the task fell to William Roy, a far-sighted young engineer who understood the strategic importance of accurate maps. William Roy is regarded as the father of the modern day Ordnance Survey yet his vision of a national military survey wasn't implemented until after his death in 1790. By then Europe was in turmoil, and there were real fears that the French Revolution might sweep across the English Channel. Realising the danger, the government ordered its defence ministry – the Board of Ordnance – to begin a survey of England's vulnerable southern coasts.



In June 1791, the Board purchased a huge new Ramsden theodolite, and surveyors began mapping southern Britain from a baseline that Roy himself had measured several years earlier. The first one-inch map of Kent was published in 1801, and a similar map of Essex followed – just as Nelson's victory at Trafalgar made invasion less likely! Within twenty years about a third of England & Wales had been mapped at the 1 inch scale.

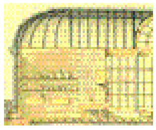
If that seems slow in these days of aerial surveys and global positioning, spare a thought for Major Thomas Colby, later Ordnance Survey's longest serving Director General, who walked 586 miles in 22 days in 1819. In 1824, Parliament ordered Colby and most of his staff to Ireland, to produce a detailed six inch to the mile valuation survey.

Colby designed specialist measuring equipment, established systematic collection of place names, and re-organised the map-making process to produce clear, accurate plans.

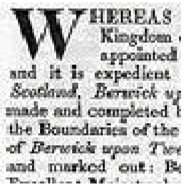
But Colby the perfectionist also travelled with his men, helped to build camps, and arranged mountain-top feasts with huge plum puddings at the end of each surveying season. Soon after the first Irish maps began to appear in the mid-1830s, the demands of the Tithe Commutation Act provoked calls for similar six-inch surveys in England and Wales.

By the late 1830's there was also demand in Scotland for the type of mapping being completed in Ireland where the 1:10560 (6") scale survey was almost complete. In

England work started in Lancashire in the 1840s, but progress was slow due to urban mapping being prioritised. By 1851, only Wigtownshire had been completed in Scotland, but growing need particularly from mining interests, resulted in more effort being directed to the Scottish survey.



As well as mining, there was a new economic power in the land. This was the era of railway mania and if the one-inch map was unsuitable for calculating tithes, it was virtually useless for the new breed of railway engineers. Progress was painfully slow.



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Mapping of England and Scotland remained incomplete and in 1840 the Treasury agreed that *all* areas should be surveyed at the six-inch scale. Because of this, surveyors needed greater access to land than ever before; and so, in 1841, the Ordnance Survey Act gave them a legal right to "enter into and upon any land" for survey purposes.

A few months later Ordnance Survey's cramped Tower of London offices were at the centre of a national catastrophe when fire swept through the Grand Storehouse, threatening to engulf the Crown Jewels in the Martin Tower. Miraculously, the Jewels were saved, and most of Ordnance Survey's records and instruments were also carried to safety.

But the blaze highlighted the Survey's desperate need for more office space, and prompted a move to Southampton. The scene was now set for two decades of wrangling over scales. Throughout this period, Victorian reforming zeal was creating an acute need for accurate mapping. The issue was settled piecemeal until, by 1863, scales of six inches (1:10560) and twenty-five inches (1:2500) to the mile had been approved for mountain and moorland, and rural areas respectively. The one-inch map was retained, and detailed plans at as much as ten feet to the mile were introduced for built-up areas. By now, Major-General Sir Henry James – perhaps Ordnance Survey's most eccentric and egotistical Director General – was midway through his twenty-one year term. James quickly saw how maps could be cheaply and quickly enlarged or reduced using the new science of photography, and he designed an elaborate glass studio at Southampton for processing photographic plates.

James planted his name on everything he touched, and later claimed to have invented photo-zincography, a photographic method of producing printing plates. In fact, the process had been developed by two of his staff. There was a drastic acceleration of the slow program in 1880, fuelled by a series of Parliamentary Acts, and a Land Registration scare. This resulted in the 1:2500 series being completed by 1888. The revision policy in the 1890's was that no 1:10560 would be more than 15 years out of date, and no 1:2500 would be more than 20 years out of date.

By 1895 the twenty-five inch survey was complete. The twentieth century brought cyclists and motorists swarming onto the roads, and the new Director General, Colonel Charles Close, prepared to exploit this expanding leisure market. But by now, the tide of history was sweeping Ordnance Survey back to its military roots.

As Britain entered the First World War, surveyors, draughtsmen and printers from Ordnance Survey were posted overseas. Working in appalling conditions alongside the troops, surveyors plotted the lines of trenches and, for the first time, aerial photography was used to capture survey information.

The demands on manpower during the First World War, and the financial constraints in the post war years, resulted in limited if any revision between 1914 and 1935, at which time the 20 year revision cycle was formally abandoned. Many 1:2500 plans were in effect not revised for over 70 years.

In an uncanny echo of the mid-nineteenth century, a whole raft of new legislation brought demands for accurate, up-to-date mapping. Matters came to a head in 1935, and the Davidson Committee was established to review Ordnance Survey's future. That same year, a far-sighted new Director General, Major-Gen Malcolm MacLeod, launched the re-triangulation of GB.

The Davidson Committee

The recommendations of the Davidson Committee were to set Ordnance Survey policy for the following 50 years:

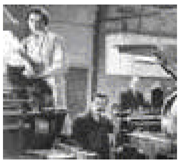
- 1:2500 series should be retained;
- 1:2500 County Series should be recast to National Grid sheet lines;
- General Overhaul of 1:2500 County Series to revise and eliminate errors;
- Metric measure to be introduced;
- Large Scale maps should be 1 Km square (25") and 5 Km square (6");
- 6" Series to be retained;
- Review of 1:2500 Urban areas for re-survey at 1:1250 scale;
- Additional contours should be introduced;
- Continuous Revision should be adopted.

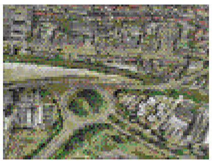
The Davidson Committee's far-sighted final report set Ordnance Survey on course for the 21st century. The National Grid reference system was introduced, using the metre as its measurement. An experimental new 1:25,000 scale map was launched, leaving only the one-inch unscathed. It was almost forty years before this popular map was superseded by the 1:50,000 scale series, first proposed by William Roy more than two centuries earlier. It was not until the late 60's that many of the other recommendations were finally introduced; it was only in the 1980's that the last 1:2500 maps were overhauled, and 6" maps converted to 1:10000.

After the war, Sir Charles, as he now was, returned to his marketing strategy and appointed a professional artist to produce eye-catching covers for the one-inch maps. Ellis Martin's classic designs boosted sales to record levels, but the war had taken its toll; behind their bright new covers, the maps were increasingly out of date. Surveyors began an Olympian task, building the now familiar concrete triangulation pillars on remote hilltops throughout Britain. Deep foundations were dug by hand, and staff dragged heavy loads of materials over isolated terrain by lorry, packhorse and sheer brute force.

In 1939, war intervened once again. The Royal Artillery was now responsible for its own field surveys, but over a third of OS's civilian staff were called up, and its printing presses were kept busy with war production. It wasn't a soft option. Enemy bombing devastated Southampton in November 1940 and destroyed most of OS's city centre offices.

Staff were dispersed to other buildings, and some were sent to temporary accommodation at Chessington. But the Ordnance Survey staff were kept very busy; the demand for mapping from the military remained insatiable - the Normandy landings alone devoured 120 million maps!





After the war, OS returned to Davidson's agenda; the re-triangulation was completed, and metric maps began to appear along National Grid sheet lines. Aerial survey helped speed up the new continuous revision strategy, and up-to-date drawing and printing techniques were introduced.

But the organisation was still fragmented, scattered across southern England in a battered collection of worn-out buildings. All that changed in 1969, when Ordnance Survey moved to its present, purpose-built headquarters on the outskirts of Southampton. Four years later, the first computerised large-scale maps appeared; the digital age had begun.

Today, the basic scales of 1:1250, 1:2500 and 1:10000 provide national coverage of Great Britain. Revision is currently completed by both continuous update based on change criteria, and cyclic programmes. Ordnance Survey digitised the last of some 230,000 maps in 1995, making Britain the first country in the world to complete a programme of large-scale electronic mapping. Computers have transformed the map-making process, over 400 million geographic objects of electronic data are stored in the main national database, with over 5,000 of these updated daily and routinely available to customers within 24 hours of being surveyed.

Some more detail – 1:2500 mapping

In order to understand Ordnance Survey maps well, for those using the data for land registration purposes, it is useful to have an understanding of three particular issues that have been important milestones in the development of the current national dataset. The three basic scales that cover GB are designed to be appropriate for urban areas (1:1250), rural areas (1:2500), and mountain/moorland areas (1:10,000). By far the biggest area covered (almost 70% GB large scale mapping) is rural mapping at 1:2500 and it is in these areas that users find most anomalies and problems. This is because

i) the other scales are either much more accurately defined (e.g. in the case of in 1:1250 urban areas with the use of instrument survey) or in areas where high survey accuracies are less necessary (e.g. in the case of 1:10,000 moorland areas),

ii) the transformation of old mapping from individual county series projections to a modern national grid, over decades, has caused inaccuracies that are only just being resolved at the current time.

In particular three related issues can be considered as crucial in the formation of the current 1:2500 rural mapping data. These are:

- the conversion of 1:2500 scale maps from the county series to the national grid (1945-1985);
- the digitisation of basic scale data (1972-1995);
- the positional accuracy improvements (PAI) (2001-2006).

The first two of these are discussed below; PAI is discussed in a later section of this reference booklet, under "Ordnance Survey - current issues".

Background to 1:2500 National Grid Plans.

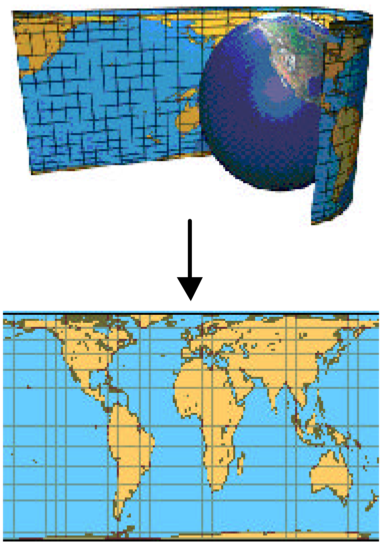
The 'County Series'

Initial national mapping at large scales in Great Britain was very much dictated by the experiences of the 1840 survey of Ireland. A start was made in the late 1840s on the survey of England, Wales and Scotland at a scale of 1:10560 (6 inches to the mile). Only Lancashire, Yorkshire and a few Scottish counties had been completed however when a change of policy meant that this survey was stopped and a 1:2500 survey commenced. This survey was based on the Cassini projection and used 39 separate County meridians. It was completed in 1896. A first revision was begun in

1886, a second revision in 1904, and some isolated plans were revised a third time prior to 1935. In order to understand the significance of the use of the Cassini projection on individual county meridians, and the impact this was to have on today's data, it is necessary to understand a little about the nature of map projections.

Introduction to map projections

Mapping involves representing the features on the curved surface of the Earth onto a plane (flat) surface, so distortions of distances, angles or both are inevitable. To complicate matters further the Earth is not an exactly regular sphere, it is an irregular geoid. To be able to mathematically map this it has to be represented as a sphere, and this spheroidal representation, or geodetic datum, can take many different forms depending on the area of the globe being mapped - OSGB36 and WGS84 are ones commonly referred to. OSGB36 is a datum used to match the fairly localized area of Great Britain whereas WGS84 is a global datum. Converting points from a sphere to a plane originally meant using the plane surface of a paper map sheet; now it can also be the plane coordinate system of GIS software. A map projection is the means of converting the co-ordinates of a spherical shape, usually in the form of latitude and longitude, to plane coordinates, usually in the form of eastings and northings.

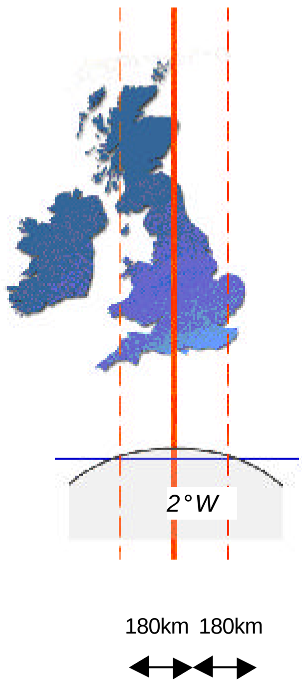


Cylinder projection *- The diagram left shows a Lambert equal area cylindrical projection. This is known as an equal area or tangent cylinder projection, in this case with a tangent along the equator, referred to as the "standard parallel". For this type of projection the resulting map can be visualized by imagining a sheet of paper wrapped around the globe with each point then projected horizontally onto it.*
In other words, light rays can be imagined shooting from the cylinder's axis towards its surface. It is then cut along the equator and unrolled. Like nearly all cylindrical projections, it is quite acceptable for the tropics, but becomes less and less practical as you move towards the polar regions, which become compressed, resulting in a map much broader than tall.

A particular map projection is chosen for the area of the globe in question – some map projections are better suited to equatorial regions than polar areas for example. Ordnance Survey has always used a cylindrical projection, either the Cassini or Mercator. These types of projection have the benefit of preserving angular integrity, although there will be some distortion in distances.

Since the 1930s Ordnance Survey maps use a type of projection known as the Transverse Modified Mercator (TMM). This single national projection is a cylinder type, like the one shown in the diagram above, but to minimize the distance distortion it runs north – south (transverse) following the main GB alignment, and "touches" the surface on two parallels 180Kms east and west of the central meridian which runs at 2°W (modified). The same type of projection used in worldwide mapping is known as Universal Transverse Mercator (UTM). In the case of Great Britain the TMM projection can be thought of as a sheet of paper carrying the mapping grid (of eastings and northings), which is curved so as to touch the ellipsoid along a north-south central meridian. Points on the ellipsoid are projected onto the curved sheet, giving easting and northing coordinates for each point. The effect is to distort the distance between projected points, except on the central meridian where the ellipsoid touches the mapping grid. This scale distortion effect increases east and west of the central meridian. The scale distortion can be measured by a local scale factor which is 1 on the central meridian and greater than 1 everywhere else. To reduce the worst scale distortion effect in the extreme eastern and western regions of the mapping area, a scale reduction factor is introduced over the whole mapping area. This makes projected distances on the central meridian slightly too small, but lessens the scale distortion for points far to the east or west of the central meridian.

With the overall scale reduction applied, there are now two lines (each side of the central meridian) on which the local scale factor is 1. Inside these lines, the local scale factor is less than 1 (with a minimum on the central meridian), and outside these lines it is more than 1. On the central meridian, the local scale factor is now equal to the scale reduction factor that was introduced. The TMM projection used for all OS maps has a central meridian at longitude 2°W and a central meridian scale factor of 0.9996. The two lines of true scale are about 180 km to the east and west of the central meridian. The stated scale of an OS map is only exactly true on these lines of true scale, but the scale error elsewhere is quite small. For instance, the true scale of OS 1:50k scale map sheets is actually between 1:49980 and 1:50025 depending on easting.



County Series Survey Method

Triangulation produced a network of control points approximately 1.5 to 3 Kms apart. These were used as the basis of a chain survey, breaking down the triangulation by chain lines and fixing map detail by offsets from those lines. This survey information was then plotted on paper. Yorkshire, Lancashire and the Scottish counties mentioned above, were not resurveyed at 1:2500. Instead, the original 1:10 560 survey was replotted at the larger scale. After detail survey, the completed survey was traced onto paper for fair drawing and then traced onto the printing plate using Lithographic transfer paper.

Subsequent Revision of County Series mapping

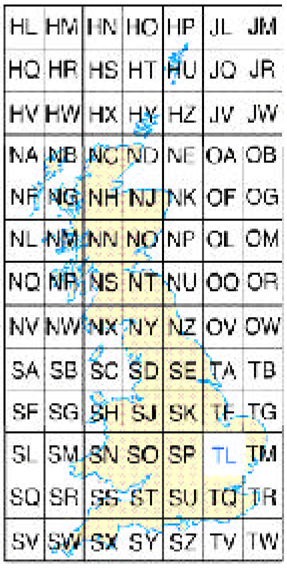
The first revision was done on thick card but the difficulties of working over edges coupled with the two subsequent tracings necessary to produce a printed map increased the chance of random errors. In the later stages of the revision, improved reproduction processes reduced the amount of tracing needed. The second revision gave rise to further problems in that no record had been kept of the original survey work. New detail was often surveyed using second generation detail as control. It can be seen that there were a number of ways in which this 1:2500 County Series mapping could have generated errors:

- Errors due to separate County Meridians and Triangulations:
    - differences in scale at the boundaries between areas surveyed on different projection meridians;
    - discrepancies between unadjusted tertiary triangulations.
- Errors due to surveying and drawing:
    - distortions in the materials used for documents;
    - the replotting of county boundary sheets;
    - the replotting of 1:10 560 surveys at 1:2500 scale;
    - the numerous tracing and transfer processes;
    - accumulated survey errors and revisions.

Conversion to National Grid

To re-cap – at the end of the 19th century all of Great Britain had been mapped at 1:2500 scale (County Series), but this mapping was based on 39 different county projections and there were many errors, especially at the boundaries between counties at the edges of each projection.

In 1935 the Davidson Committee recommended that the County Series maps should be recast onto a National Grid based on the Transverse Mercator Projection with 1Km square sheet lines. At the same time "there should be a general overhaul of the plans in order to remove the discrepancies along the county boundaries (due to individual Cassini Projections) and to eliminate the errors which have crept into the original survey in the course of revision". The term 'overhaul' has its origins in this recommendation. Also in 1935 the re-triangulation of Great Britain was started.



Of the new triangulation stations only those which were part of the old network were shown on the County Series maps. It was therefore necessary to survey the remainder of the new triangulation stations onto the county series plans in their correct positions in relation to the surrounding detail.

Recasting the plans to the National Grid involved adjustment. The grid was constructed on the new plans so that all the triangulation stations fell in their correct National Grid positions. In theory the adjustment was gradual and systematic. In practice, the paper distortion and random errors in the old plans resulted in a grid, which was not necessarily straight or square.

The final grid on the field revision document had to be truly square. This was achieved by actually ***cutting up the plan*** to physically fit a master grid!

The first maps in the new national grid series were published in 1948 and over the next 35 years over 170 000 maps were converted. The task was enormous and a great expansion within Ordnance Survey took place to meet the programme. In the 4 years between 1966 and 1970 nearly 6000 sheets were revised. Much of the field work was completed with the aid of photography using fit and trace methods, followed by a ground check before being sent for scribing by draughtsmen in OSHQ.

The transparent documents with the Grid superimposed were sent to the field in batches along with the relevant rectified photo enlargements. The surveyor was faced with what looked like a jigsaw, where the maps had been cut up to fit the control points, leaving lines which did not join across the cuts. These anomalies were resolved by joining the junctions and checking that the measurements were within tolerance. Problems arose where long linear features such as power lines crossed many plans. The results were not always straight, but did fit relative to the local detail. It was normal that a line taped on the ground would have to be equated to agree within the framework on the survey document. The cut up of the old maps obviously resolved more errors than it introduced, but the residual errors became more random, and therefore more difficult to resolve in subsequent survey. The tendency was to make the built up areas correct and equate the errors into the surrounding countryside. This has resulted in new developments on the edge of the residential areas sitting uncomfortably within the framework of old local detail.

The revision created some interesting challenges. As many sheets had not been revised since 1900, there were no hardtop roads or curbing. Railways that had never appeared on the County Series were being shown as dismantled, and previously classified airports and wartime airfields were not on the map and were by then disused. There were no power lines and of course there was major residential change. With 70 years of change to survey and problems of equating measurements to resolve, coupled with a largely inexperienced workforce and a seemingly endless programme continually looking for economies, it is not surprising that the overhaul programme introduced its own problems that are manifest in current mapping. The rule at the time was that "the old detail of the County Series will be accepted as correct unless it is obviously wrong or unless discrepancies are found when the new detail is supplied". Indeed this is still the rule today, as in recent years the first major revisions have been completed on these rural maps. Little attempt has been made to resolve errors unless these are outside the tolerance limits. The limitations in the conversion process have resulted in ± 2.8 metres RMSE[1] absolute accuracy in rural areas. However, the relative accuracy of features (distances between features close to each other) has been very good, in the order of ± 1.2 metres RMSE. To bring this discussion even more up to date one should read the discussion of Positional Accuracy Improvement (PAI) later in this reference booklet.

The foregoing description is quite lengthy and complicated. The important point to understand however is that the old County Series mapping, itself prone to a number of fundamental errors, was re-aligned to the national grid, on new sheet lines in new documents, in a fairly crude manner at times. In areas of disagreement, particularly at county boundaries, sometimes quite large errors were "lost" in woods or open countryside. Over the years these open areas have gradually become developed and it is then that the underlying problems have come to light.

The problems have often been resolved locally and relative accuracies have been maintained but in recent years, in the GPS era, users have begun to integrate their own GPS co-ordinated data to the existing OS rural data, and the problems inherent from the County Series and overhaul have come back into focus.

To solve the problem once and for all Ordnance Survey embarked upon the Positional Accuracy Improvement project which is explained in more detail in a later section of this reference booklet, under "Ordnance Survey - current issues".

[1] Root Mean Square Error – a statistical method of defining "average" error

Digital Conversion

By the time digital mapping became a reality in the early 1970's, detail surveyed in the mid 1800s had been plotted, fair drawn by draughtsmen on unstable material, copied many times, transferred to National Grid, shifted to meet the new control and was now to be digitised in many cases by contractors. The original point fixed by the surveyor in all probability was unlikely to represent the exact and intended position in the digital data. In deed with all this copying there is a possibility that it may be represented by the wrong feature code entirely, and may even be wrongly described. Subsequent survey is now based on some of these points which form the framework of the new survey.

Of course most of the data is fit for purpose, but as Ordnance Survey stated in the 1930's, "any single error on a plan is enough to shake the faith in the whole of the rest of the plan, irrespective of the care that has been invested in it".

Digital data has many benefits in that detail can be viewed at invariable scale, has no artificial internal (sheet) edges, and is easy to reproduce to consistently high standards. It can also be revised directly in the field, without the need for redrawing or copying, hence eliminating sources of error.

However, the standard of the data is only as good as that detail it was created from, and the control on which the survey was based. If you view a 1:2500 survey at 1:500, the measurements do not improve, and indeed the discrepancies introduced during digitising only become more evident. <u>There is a temptation to use computer tools to 'improve' the visual impact or aesthetics by using parallels and squaring routines. These tools may make the survey look better, but do nothing to improve its accuracy.</u> Digital data is very good at producing consistent high quality prints. There are also a range of tools that make it easier to measure from exact points without the need to rely on the human eye to judge a reading, or the hand to transfer and plot the result.

The precision available in these computer generated measurements however should not mislead the user into thinking the reading is achievable. The 2m thick junction of a hedge given to the nearest centimetre on the computer display, is at best measurable physically to 0.2m, and was probably plotted to nearer 0.3m during the 1:2500 field survey. Add redrawing, conversion and copying and 0.5m might seem reasonable. As the feature is 2m wide this still would seem fairly acceptable. Solid features on the map may not be quite so clear or identifiable in the field.

When viewed at scale as intended, the 1:1250 and 1:10000 map quickly becomes cluttered, particularly in urban areas, and some features and aspects therefore needs to be generalised to make the map usable. This is evident with parallel features, for example, where one feature is shown where two exist – e.g. the road verge not shown parallel to a wall or fence, a fence not shown next to the stream. Similarly, buildings close to a property boundary may be shown joining the feature where there is clearly access between them. On 1:10,000 data, even more generalisation is used to exaggerate certain features, and thereby make the detail clearer to the user.

It is well known that anything copied from an original is likely to introduce some error. Most of the error is acceptable, but in some cases there will be gross error introduced. In the course of time many of these will be identified and eliminated, but it is worth remembering that the data shown on a current OS 1:2500 map may be derived from mapping captured decades ago – which may have had a number of errors, been re-positioned during overhaul, re-positioned during digitisation, and which may be generalised to represent a more complex situation on the ground – plenty of possibilities for discrepancy between the map and the deed plan!

Key Points from this section

- Ordnance Survey is a very old institution – some of its current day maps display the results of that long legacy, having been derived from surveys going back decades, and then subsequent digitisation;
- The 1:2500 scale mapping in particular should be treated with caution – especially around county boundaries and in the fringes and infill areas of rural towns;
- Modern day data capture methods, particularly GPS, highlight areas of weakness for absolute accuracy – but relative accuracy is usually good;
- Ordnance Survey is using a programme of PAI - positional accuracy improvement to improve the overall quality of rural mapping and bring it to a homogeneous high standard.