Generalising and Symbolising Ordnance Survey Base Scale Data to Create a Prototype 1:50 000 Scale Vector Map

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1. Introduction

1.1 Base scale data

Ordnance Survey are currently implementing significant changes in the way they manage the collection, management and delivery of spatial data in Great Britain. In the past Ordnance Survey have operated as a product-centric organisation, with each product being updated and maintained separately. The product-centric approach is restrictive, since the same spatial information is captured, stored and maintained more than once in independent databases. Inter-product consistency relies largely on good communication between the staff updating the products. Such a strategy presents obstacles when reacting to market demand for new products, or introducing variations on existing products.

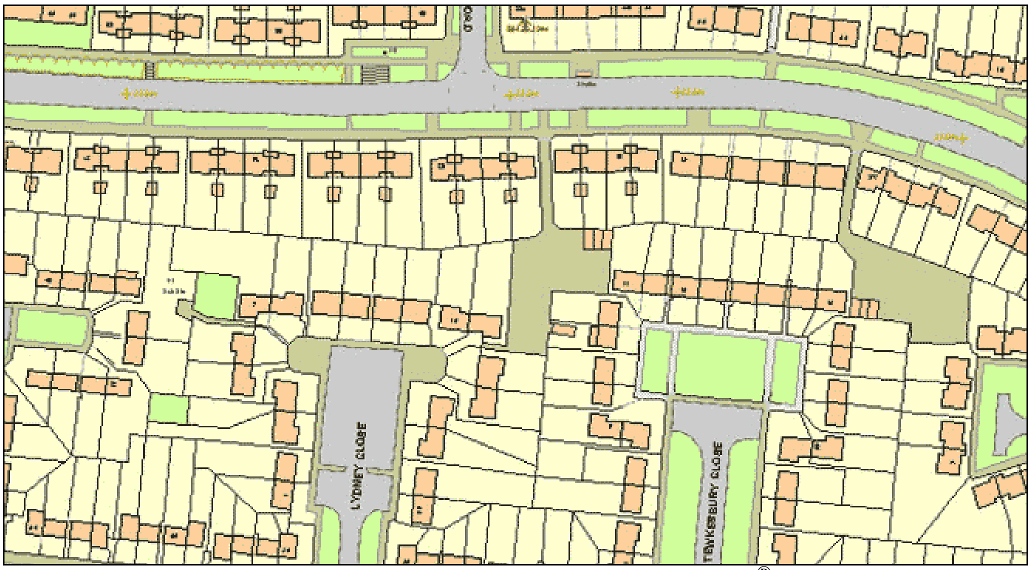

Figure 1. Base scale data represented in the OS MasterMap® Topographic layer.

Ordnance Survey are now moving towards a database-centric approach, where spatial information is captured once, stored in a seamless central database, then used many times for supplying a consistent suite of products. A new central maintenance database is being created, which will act as the single data store for all non-derivable data. A new core data model has been developed which is capable of holding all the information for the current large-scale products, alongside enhanced attribution for supporting derived products. Base scale topographic data is captured at 1:1250 scale in urban areas, 1:2500 scale in rural areas and 1:10 000 scale in mountain and moorland areas. The OS MasterMap representation of this base scale data is shown in Figure 1.

1.2 Deriving products from the base scale

As the maintenance database is updated, earlier versions of the geographic features are date stamped and backed up to an archive database, which also contains the initial versions of all the features. The archive database is the data source for initial creation and update of derived products, with Product Adaptors performing the required geometry and attribute transformations. When the new system goes live, Product Adaptors will supply data to the OS MasterMap and Land-Line® products, but no change should be discernable to external customers of these products.

The creation of the central maintenance and archive databases is a major step forward in the implementation of Ordnance Survey's Derived Data Programme. It is the intention of the Derived Data Programme to create all smaller scale vector and raster products from the archive database. The logical starting point for researching this goal is to develop automated tools for deriving the traditional Ordnance Survey products from the base scale data. Once the traditional products have been derived, the objective is then to extend the tools for generalising to arbitrary scales and specifications. This approach will give great flexibility in supplying a wide range of products and services, tailored to customer's needs, from a single database.

1.3 The 1:50 000 scale generalisation project

The 1:50 000 scale Landranger® map series is perhaps the best known Ordnance Survey paper product and sells nearly two million copies a year. The 204 map sheets in the series provide a complete coverage of Great Britain which includes roads, buildings, footpaths, woodland, water features and contours. The mapping is also available digitally as the 1:50 000 Scale Colour Raster product. The 1:50 000 scale mapping is currently maintained as raster layers which are manually updated by cartographers using Image Mapper raster editing software. Change intelligence information is delivered to the cartographers as paper plots.

Over the past two years the Generalisation Team in the Research & Innovation department at Ordnance Survey have been developing techniques to automatically derive a 1:50 000 scale vector map from base scale data. An area around Glasgow was selected as the study area, since it exhibits a wide range of different landscapes, including dense urban, coastal, moorland, woodland and mountain areas. The generalisation was carried out using Laser-Scan's Clarity software, ArcInfo and ArcGIS from ESRI along with Microsoft Excel. The final map was assembled and symbolised in ArcMap.

Prototype base scale topographic data in the new core data model was used as the primary data source for the generalisation project. At the time of supply some base scale features had yet to be included in the new model, so the data were supplemented with features from the Topographic and Integrated Transport Network (ITN) layers of the OS MasterMap product.

1.4 The 1:50 000 scale data model

During the project a data modelling exercise was conducted, the objective of which was to create some sample 1:50 000 scale Digital Cartographic Model (DCM50k) data, and corresponding data in a medium scale Digital Landscape Model (DLM2). ArcScan was used to convert raster layers from the 1:50 000 scale maintenance system into vector data. These were then separated out into feature classes and the appropriate symbolisation applied to create the sample DCM50k data. For each feature class in the DCM50k a data source was identified and extracted to the DLM2, thus creating sample DLM2 data, albeit in an un-generalised state (Revell 2005b). The data modelling exercise was beneficial for the following reasons:

- Source and target data could be easily compared in a vector environment, making it straightforward to determine which generalisation operators were required for each feature class.
- As generalisation results were obtained it was easy to drop them into the predefined DCM50k and visualise them using the preset symbolisations.

- Data sources necessary for 1:50 000 scale, but not included in the initial implementation of the new core data model, were identified. Therefore, height information had to be obtained from the Land-Form PROFILE® product, data particular to small scales was acquired from the internal Small Scales Mapping Intelligence database and distinctive names were obtained from the 1:50 000 scale gazetteer.
- Data sources necessary for 1:50 000 scale, but not currently held by Ordnance Survey in vector form, were identified.

2. Generalisation of Themes

The following sections discuss the generalisation and symbolisation of the themes included in the final map. The themes were generalised independently, except where specifically noted in the text below.

2.1 Roads

ITN road links and road route information were used as the source data for the road network generalisation algorithms developed in Clarity. This research work concentrated primarily on the DLM2 aspects of generalising the network – reducing the level of detail while still retaining the connectivity and attribution necessary for 1:50 000 scale. The main focus of the research was on pairing up sets of links which comprise both sides of a dual carriageway, then collapsing these links down to a single centreline. The same technique was used to collapse traffic island links at junctions. An overview of how the dual carriageway generalisation algorithms operate is given in (Revell et al 2005) while the details of the algorithms are described in (Thom 2005). A simple algorithm was also developed which deletes short dead ends from the road network.

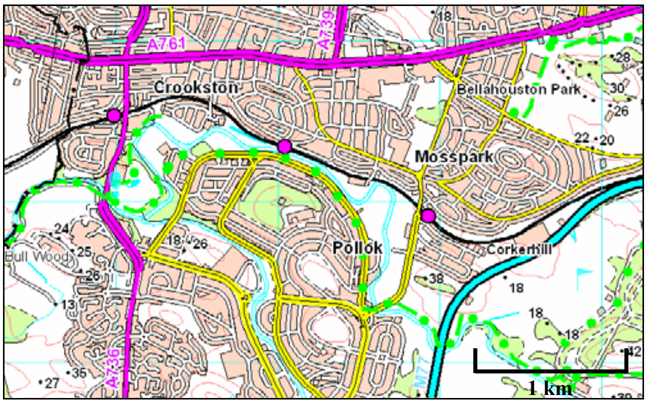

Figure 2. Generalised 1:50 000 scale data showing roads and other communication themes.

For the DCM50k, an algorithm was developed which creates and stores the symbolisation of the road network (Revell et al 2005). The coloured fill of the roads is represented using polygons classified as Motorway, A Road, B Road, Minor Road and Other Road, while the black road casings are modelled using lines, attributed as being thick lines for Motorways and thin for other roads. Implementation of a strategy to displace roads is an ongoing piece of research, so the symbolisation algorithm was designed to give reasonable results in places where the road symbols overlap. Dual carriageways are represented using a triple line symbol. Road numbers are placed automatically using the road number attribute from the ITN road links. The results are illustrated in Figure 2.

2.2 Other communications

Transport networks other than the road network are not represented as networks in the new core data model. Railways are captured as pairs of tracks which are broken when they pass under other features such as bridges. It is possible that a rail network could be deduced from this detailed data, but there was not time to develop such an algorithm during the project. Fortunately a rail network was present in the Small Scales Mapping Intelligence data, along with point features for the railway stations. It was not necessary to generalise this data for the final map. Cycle and ferry routes were also obtained from Small Scales Mapping Intelligence data, and no generalisation was required before including them in the final map. The representation of railways and cycle paths can be seen in Figure 2.

Tracks and paths are represented in new core data model using topographic areas and lines depending upon their width on the ground. There was not time during the project to develop an algorithm which constructs a track and path network from this data and connects it up to ITN. Hence tracks and paths are not included in the final map. Ordnance Survey do not currently maintain Rights of Way data in vector form, and eventually it will be necessary to digitise this information from the current raster mapping.

2.3 Hydrology

In the new core data model, tidal water and inland water are modelled using topographic lines and areas. Some of the topographic lines represent the edge or limit of water areas; these were ignored since they are synonymous with the water polygon boundaries. The remaining topographic lines represent bodies of water too narrow to capture as polygons. Similarly to the railway data, the water is broken when it passes under other features such as roads. In order to generalise this data in a consistent manner, it was necessary to first construct hydrology networks from the disjoint water. An algorithm was implemented in Clarity which builds upon previous research on this topic (Regnauld & Mackaness 2006).

The algorithm starts by collapsing all water polygons to centrelines. Gaps in the network are deduced and reconnected, with a confidence factor being attached to each deduced link to facilitate manual checking. The network is then classified into four categories: (a) rivers represented by lines in the source data; (b) polygon rivers less than 4 metres wide; (c) polygon rivers between 4 and 8 metres wide and (d) polygon rivers over 8 metres wide.

The network is then analysed to contract a hierarchy of rivers, using an technique based on the Horton Ordering (Horton 1945). This allows the main streams to be distinguished from the tributaries. The ordering allows the network to be pruned, following the principles described in (Thomson and Brooks 2000). Only rivers in category (a) are affected by the pruning. On the final map only rivers in category (d) are represented by polygons. Where short sections of such polygons fall below the minimum width, they are widened by buffering the centreline and merging it with the polygon. The first three categories are represented by linear features with proportional widths and were all were all lightly smoothed. The results of this processing are shown in Figure 3.

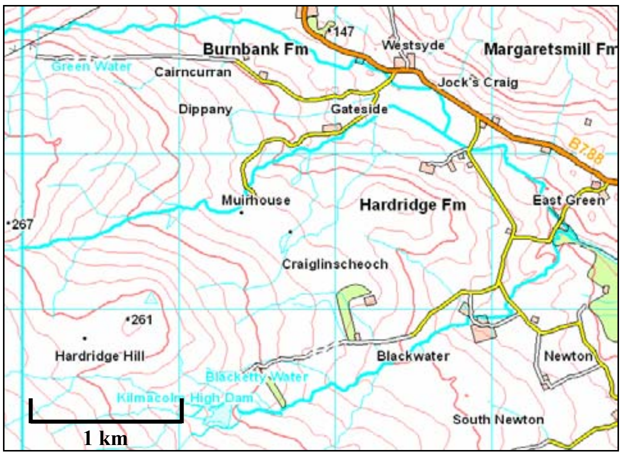

Figure 3. Generalised 1:50 000 scale data showing the representation of rivers.

2.4 Buildings

At 1:50 000 scale buildings are generalised differently depending upon their density. In rural areas buildings tend to be generalised as small amalgams comprised of straight segments and right angles. In urban areas there is usually no space to retain the individual buildings characteristics, so as an alternative, solid fill is employed to represent the general distribution of buildings. An algorithm was developed in Clarity for detecting urban areas and rural building clusters. The buildings are buffered by 25m, the buffers are then dissolved and simplified, with the areas above 200,000m^2 being classified as urban. Similarly to the woodland, this process fails if there are too many buildings, so a new approach was found which plots the buildings 25m larger than reality, exports this to a monochrome map then converts the raster back to polygons.

The next step in the data enhancement was to use the generalised road network for partitioning the urban areas and rural building clusters. The partitioning algorithm in Clarity was used to slice up the regions inside and outside of the clusters of buildings. This approach fails for large datasets, so a new method was developed which slices up the building clusters one at a time, thus creating partitions only where they are required for building generalisation - inside the clusters of buildings. Each partition can then be generalised as an autonomous unit. Buildings inside each of these partitions were generalised in Clarity using the Agent system.

The first step in the rural building generalisation is to group the buildings together using a proximity graph computed from a triangulation (Regnauld 2005). Very small building groups are deleted, while other groups below the minimum size are enlarged to squares and rectangles representing the original building positions. For larger, more complicated groups, the buildings were initially enclosed by the smallest amalgam aligned to the general orientation of the group which is comprised of straight segments and right angles. This was simplified by removing concave corners, enlarging juts and widening narrow parts. If the amalgam is obscured by the road representation, or is too close to the road, it is widened or displaced (Revell 2004a; 2004b).

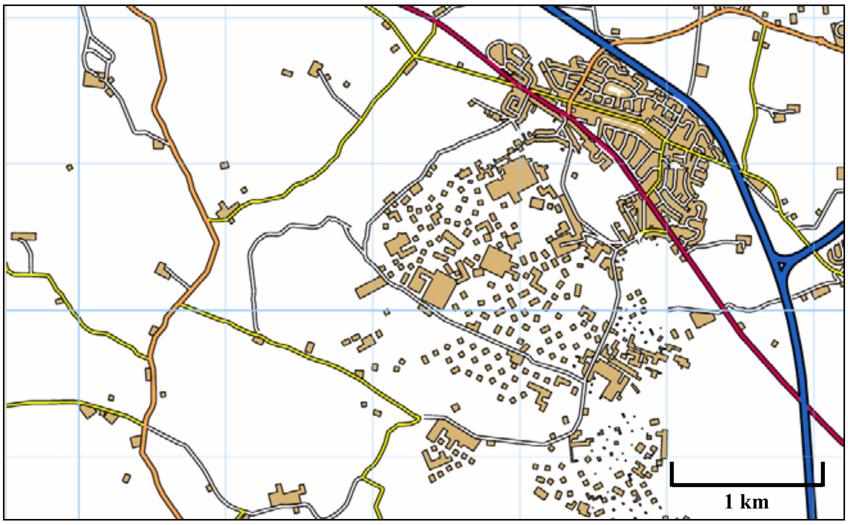

Figure 4. Rural and urban building generalisation, at the periphery of an urban area.

For the urban building generalisation a growing tide algorithm was implemented (Regnauld 2003). Buildings inside an urban partition are split into groups using a proximity graph computed from a triangulation. This approach allows restrictions to be applied which prevent buildings from being grouped together across railways, hydrology features and dead end roads. The shadow of each building group on the surrounding roads is computed and buffered by the minimum building width. Any buildings outside these initial buffers are included using the rural building amalgamation and simplification algorithms. The last step is to delete any small holes. (Revell et al 2005)(Regnauld 2006). Results of the building generalisation can be seen in Figure 4.

2.5 Woodland

In the new core data model woodland polygons are attributed as being "Coniferous Trees", "Non-Coniferous Trees", "Scattered Coniferous Trees" or "Scattered Non-Coniferous Trees". Combinations of vegetation types are expressed using the + operator, so "Coniferous Trees + Non-Coniferous Trees" represents mixed woodland. Non-wooded vegetation types can also be included, such as "Coniferous Trees + Rough Grassland". Canopy cover always takes precedence over other types of vegetation during generalisation, so all polygons with "Trees" in the attribute value are taken as candidates for woodland. Initial thoughts on how to generalise this data to 1:50 000 are given in (Revell 2005a).

At 1:50 000 scale woodland is represented as being either coniferous, non-coniferous or mixed. Any polygons which had both "Coniferous" and "Non-Coniferous" in the attribute value were treated as mixed. It was then straightforward to divide the remaining polygons between coniferous and non-coniferous. A generalisation process was developed in ArcGIS, but at the time the final map was created this did not distinguish between types of woodland. The woodland polygons were amalgamated by buffering them outwards by 25m, dissolving, then buffering back in by 25m. The boundaries of the resulting polygons displayed some unnatural artefacts from the buffering, so a further simplification and smoothing process was applied to make the perimeter appear more natural. Lastly, small areas of woodland were deleted.

After the final map was completed, another dataset was processed, for which the buffering and dissolving approach failed due to the volume of data. An alternative method was developed which plotted the woodland 12.5m wider than reality, exported this as a monochrome map, then converted the result back to polygons. This allowed the woodland extents to be identified, with the process being repeated to determine the extents of the coniferous, non-coniferous and mixed woodland. Small holes and small areas of woodland were then deleted, while maintaining consistency between the woodland extents and the different types of woodland (Revell 2006). The final step was to apply tree symbols to the different types of woodland. For this Java algorithms were developed which optimised the positions of the symbols (Harrie and Revell 2006). Polygons representing the non-wooded areas of the map were deduced and used to mask symbols protruding beyond the boundaries of the woodland. The results of the automated tree symbol placement are shown in Figure 5.

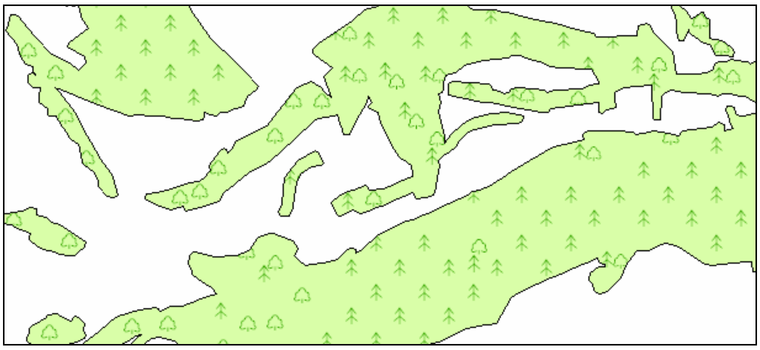

Figure 5. Generalised woodland at 1:50 000 scale, including automated tree symbol placement.

2.6 Obstructing features

In the new core data model, topographic lines represent obstructing features such as fences, hedges and walls. At 1:50 000 scale such features are heavily generalised and are only shown if they form the boundary of roads or woodland. In such cases the boundary is plotted as a continuous black line, and the remaining non-obstructed boundaries are plotted with a pecked black line. Generalisation was carried out in ArcGIS, and the first step was to select all of the obstructing features in close proximity to the roads and the woodland perimeter lines. This helped reduce the data volume significantly.

The next step was to buffer the obstructing features, then use these buffer polygons to erase against the road casing and woodland perimeter lines. There were some short line segments in the result, which were deleted. The remaining lines could then be plotted as non-obstructed boundaries. The converse of this result was computed which gave the sections of road and woodland bounded by obstructing features.

2.7 Coastal

In the new core data model, inter-tidal topographic areas have such attributes as "Inter Tidal + Mud", "Inter Tidal + Sand" and "Inter Tidal + Shingle". Like the woodland, combinations of landcover types are permitted, such as "Inter Tidal + Mud + Sand". Any polygons with "Inter Tidal" in the attribution were extracted. On the seaward side these are bounded by topographic lines representing the Mean Low Water (MLW), while on the landward side the boundary is usually the Mean High Water (MHW) line, but this does not form a continuous coastline.

There was no polygon data available for the sea, so this was calculated in ArcGIS. This was achieved by selecting all topographic area polygons in proximity to the MLW and dissolving them together. The dissolved polygons were used to erase against a rectangular area defining the data extents. Those resulting polygons covering inland areas were easily selected and deleted, while the sea polygons remained. A continuous coastline (MHW) was derived in ArcGIS by first dissolving together the inter tidal, tidal water and sea polygons, then extracting the boundary of the result. The resulting coastline was added to the final map, although it requires further simplification.

On 1:50 000 scale maps Ordnance Survey portray inter-tidal areas as mud, sand, shingle, along with the combinations mud & shingle and sand & shingle. No other combinations are valid, although salt-marsh and rock may be additionally shown. For the final map, shingle was not represented and the inter tidal polygons were reclassified as being either sand or mud. More research is required into how the detailed inter tidal classification in the new core data model can be reclassified into the simpler 1:50 000 scale representation. This will probably involve contextual merging of polygons with their most appropriate neighbours, so as to maintain a continuous inter-tidal classification containing no blank regions. The representation of inter-tidal and tidal areas used on the final map is shown in Figure 6.

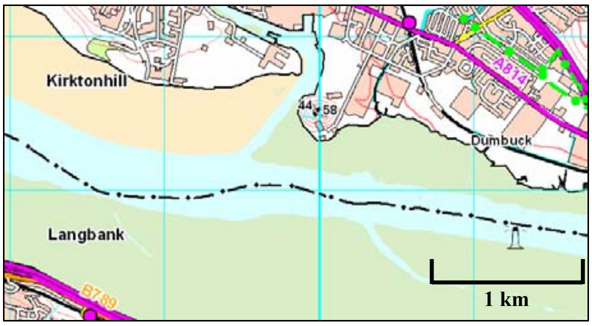

Figure 6. Generalised 1:50 000 scale data illustrating the representation of coastal areas.

2.8 Height

Land-Form PROFILE data, surveyed at 1:10 000 scale, was used as the data source for the contours. This data is too detailed for 1:50 000 scale, so the DTM was smoothed using a algorithm developed by (Rana 2003). The terrain smoothing algorithm first characterises the terrain by detecting the ridges and channels at the required level of detail. The ridge and channel lines are then used to constrain the smoothing, so that the important landscape features are preserved. This processing was carried out in

ArcInfo. From the smoothed terrain, 50m index contours and 10m intermediate contours were extracted in ArcGIS.

No further generalisation was required for the index contours. However in steep areas the intermediate contours become closer than the minimum separation distance, necessitating the removal of contour segments. The areas of conflict were detected in ArcGIS by computing slope from the generalised terrain, then reclassifying this into ranges of steepness motivating the number of intermediate contours to remove. An algorithm was developed in Java for removing contour segments (Steven and Mackaness 2006).

Spot heights were taken from Land-Form PROFILE, removing any values in proximity to buildings and roads. The results show places where many spot heights are grouped together, which require typification. They also appear in places which do not require a spot height, while other places which need a spot height are lacking one. It would be better to characterise the generalised DTM as peak, pass, pit, plane, channel and ridge (Fisher et. al. 2003), then place spot heights on significant landscape features (Revell 2005c). The contours before and after they were generalised are shown in Figure 7. Figure 3 is an example of the contours at the correct scale and their relationship with the hydrology.

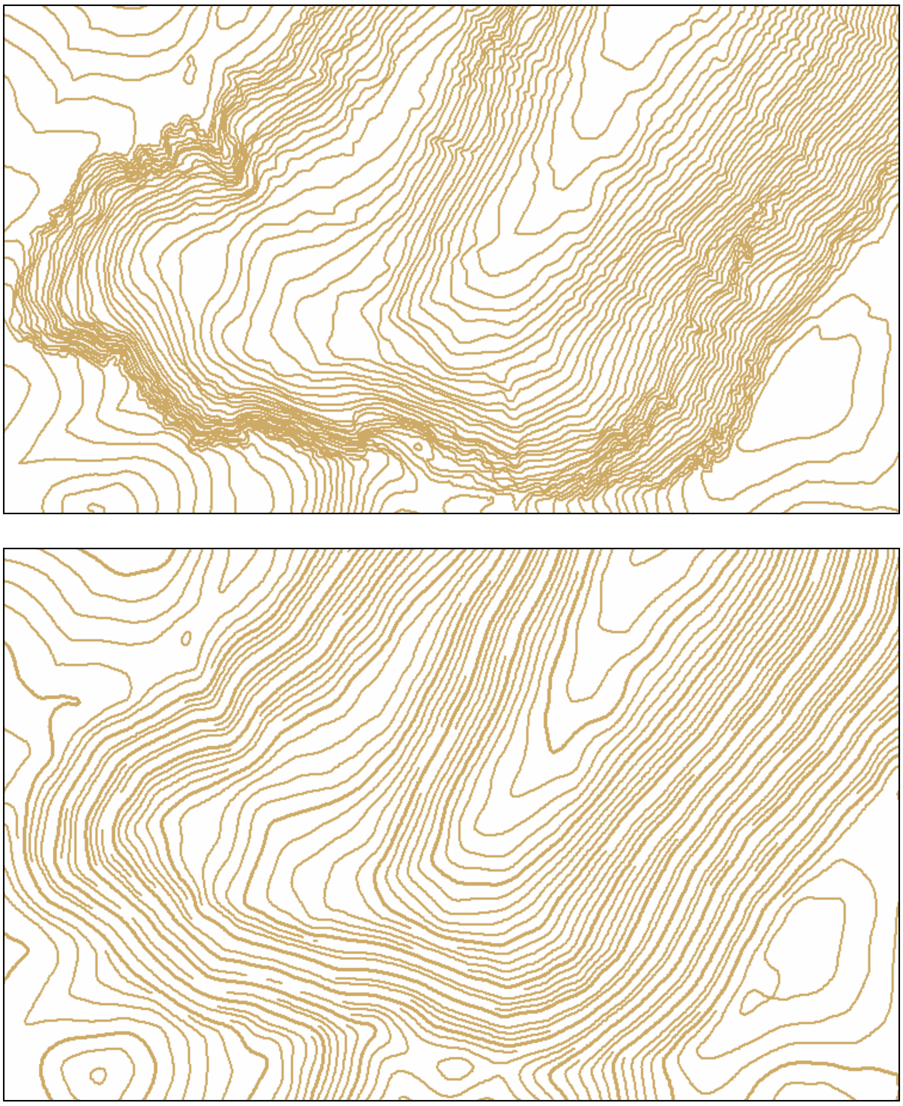

Figure 7. Land-Form PROFILE contours (above) and generalised contours (below)

2.9 Boundaries

County boundaries were extracted from OS MasterMap topographic lines and no generalisation was necessary. National park boundaries were extracted from Small Scales Mapping Intelligence data and the five band vignette symbol was created using a multiple ring buffer in ArcGIS. Polygons for National Trust and Forestry Commission land were also taken from Small Scales Mapping Intelligence data. These are both represented as a lilac band buffered inwards, denoting access land on 1:50 000 scale mapping.

2.10 Tourist information and landmarks

The Small Scales Mapping Intelligence data was used as a data source for the following tourist information symbols: public convenience, post office, public house, telephone, youth hostel, walks or trails, visitor centre, picnic site, park and ride, parking, nature reserve, information points, golf course, garden, caravan site, and camp site.

Landmarks such as places of worship, lighthouses and beacons were also taken from Small Scales Mapping Intelligence data. True type font symbols were created so that all these features could be plotted on the final map. Electricity transmission lines were included in their un-generalised form using OS MasterMap topographic lines. Topographic areas for piers were extracted from data held in the new core data model. Topographic points for mile stones and posts also came from this source.

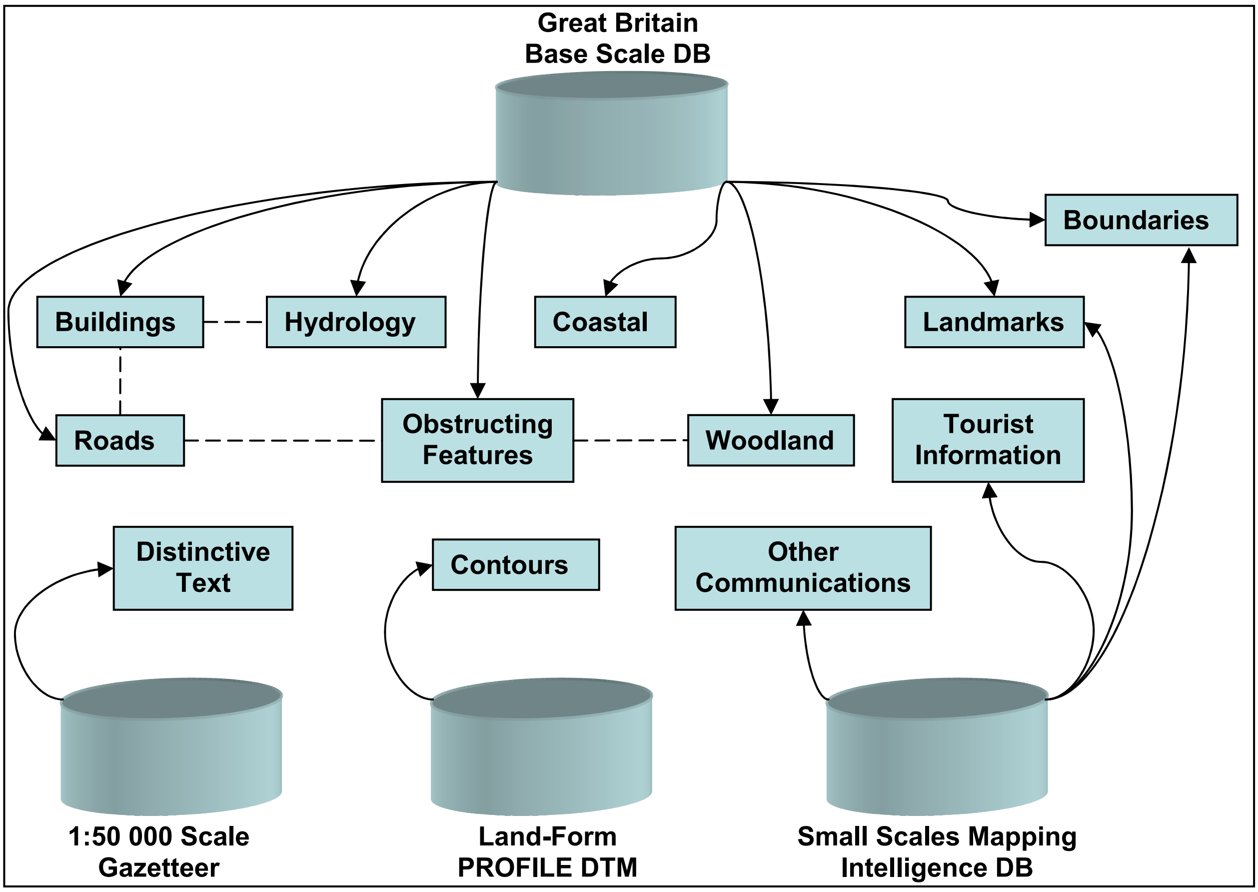

Figure 8. Summary of data sources, themes and interdependencies for the final map.

2.11 Distinctive text

The new core data model provides a rich source for distinctive text, but there was not time during the project to extract and generalise such detailed information. As an alternative, the 1:50 000 scale gazetteer was utilised, since this comprises all the distinctive names used on the current 1:50 000 scale maps. The 1:50 000 scale gazetteer text file was imported into Excel and reformatted to remove all columns except the national grid coordinates, the name and the feature code. This was then imported to ArcGIS and reclassified using the feature code into: farm, village, town, city, forest or wood, water feature, hill feature, roman antiquity, non-roman antiquity and other feature.

Each text class was assigned a font and the ESRI standard label engine was used to position the text to avoid overlaps. Unfortunately the gazetteer only stores the co-ordinates to the nearest kilometre, so most of the text appears in the centre of the grid squares. Another problem is that the text sizes are not proportional to the importance of the feature they are describing. It would also be useful for the text to be referenced to the features being labelled, so that it can be placed more intelligently. The 1:50 000 scale gazetteer is an excellent record of the text relevant to 1:50 000 scale, so perhaps it can be used in an query to select the corresponding positionally accurate text from the base scale data.

2.12 Evaluation and conclusions
A diagram summarising the data sources for the final map and the themes is shown in Figure 8. The dashed lines show where there is interdependency between themes.

The resulting map was given to the cartographers who maintain the current 1:50 000 scale product. This was accompanied by a document describing the data source for each feature class, how it was generalised, how it was symbolised and any known problems with the result (Revell 2005d). They commented that overall the map is very impressive, but it would still take considerable time to give it cartographic finishing to the high standard of the current product. Displacement and caricature of road junctions was highlighted in particular as something which would take a lot of manual correction. Some problems were easily corrected with help from the cartographers, such as the colours and ordering of the layers. An updated map was printed following this correction. The results are shown in Figure 9, with a comparison against the current 1:50 000 scale raster.

Towards the end of the project the Generalisation Team were asked to process some OS MasterMap data for the Street Atlas cartographers. Ordnance Survey prepare Street Atlas pages mostly at 1:36 206 scale, with detailed pages at 1:18 103, using Adobe Freehand. The current preparation process is dependant upon digitising from 1:50 000 scale raster data. Street Atlas is then published by Phillips in spiral-bound atlases in a county series. The Generalisation Team processed an area covering the Borders and Dumfries & Galloway counties in southern Scotland. Generalised buildings, woodland, hydrology and coastline were supplied to the Street Atlas cartographers. The trial demonstrated that Street Atlas pages can be created more efficiently using the automatically generalised data.

The Generalisation Team have also processed OS MasterMap data for an area corresponding to the 1:50 000 scale Birmingham Landranger map sheet. Generalised roads, buildings, woodland and hydrology were created. This data is being used by the 1:50 000 scale cartographers to perform a visual comparison against the current raster data, for the purposes of detecting change.

An incredible amount of progress has been made in generalisation research at Ordnance Survey, with the potential for delivering immediate cost-saving to the business. During the research a good knowledge of Ordnance Survey base scale data has been acquired. Many of the generalisation techniques developed during the project can be adapted to other scales. The skills acquired during the project will be of immediate benefit, since the Generalisation Team are currently moving on to investigate generalisation of base scale data to 1:10 000 scale.

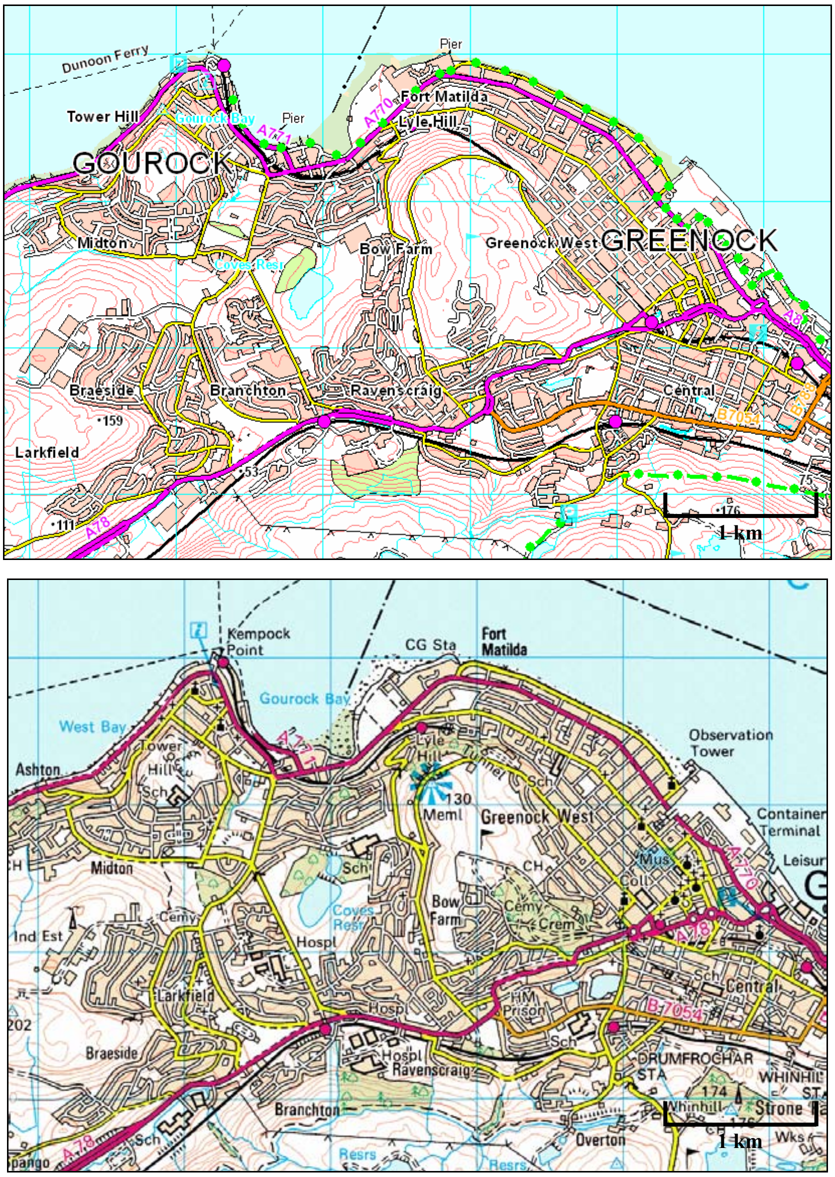

Figure 9. Automatically created (above) and manually created (below) 1:50 000 scale mapping.

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