

**Lesson  
Two**

# What is GIS?

**Aims**

In this lesson we are going to learn:

- about what a Geographic Information System (GIS) is
- how maps for the system are built up
- how GIS is a useful tool for solving problems.

**Context**

This lesson looks at another way in which maps can be used. Geographic Information Systems (GIS) offer a method of joining up many different kinds of information that can be linked to specific places in order to solve problems.



Oxford Home Schooling



He worked out which well each death was nearest to. From his calculations, John Snow showed that the vast majority of the deaths were associated with one well, the one in Broad Street. He removed the pump handle and there were no further cases. As John Snow said himself, the outbreak was already on the wane. Many people had left the area and it could be that the disease was on the point of dying out naturally, but nonetheless the map helped him prove the point that cholera was a waterborne disease.

It will be clear later that this case was indeed an example of the use of Geographic Information Systems, as it shares the same methods and ideas. It also shows that it is possible to do GIS without a computer, but given the limits of human endeavour, any study would of necessity be much more limited than a computer can achieve.

Put a little more fully, Geographic Information Systems are designed to capture, store, manipulate and display all types of geographical data, data that identifies location with the attributes associated with each geographical location. Once the data is organised, it can then be called upon to help solve problems by analysing the GIS data.

Looking back at John Snow: he collected the names and addresses of all the people who died (capture), and he would have written them all down in a list (store). He put them on a map (manipulated and displayed them). Once he had captured, stored and manipulated the well information and put it on a map, he analysed which death occurred closest to which well and removed the pump handle of the well in Broad Street. All these stages occur in modern GIS systems, the only difference being that IT is now a big part of the process.

### **What does the end result of this process look like?**

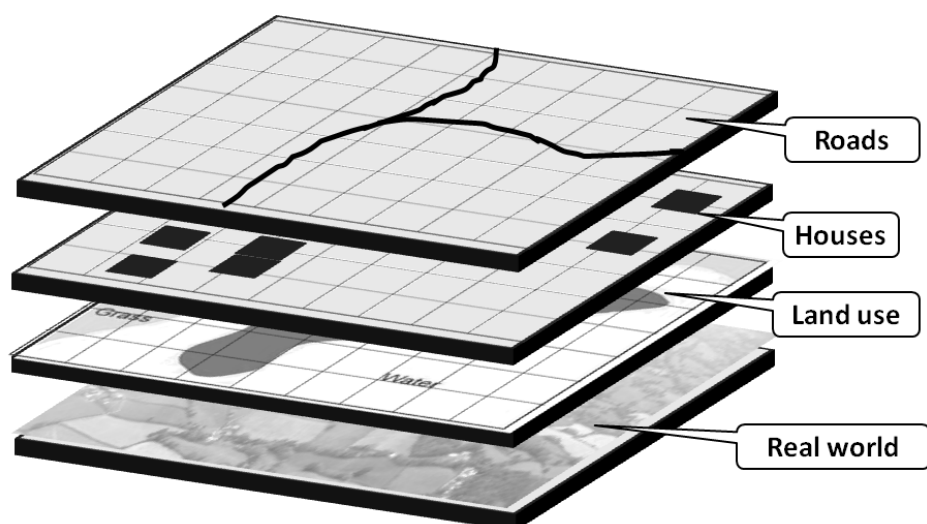
With the map created by John Snow, there was an underlying map showing the location of the streets onto which two data sets were put, deaths and wells. This was not a map having too much data added for it to be useful. But GIS systems as they evolve contain many more sets of data, collected by different people for different reasons. For example, many studies look at types of crime and where a crime takes place.

**Investigate!**

Click on <http://www.police.uk/> , then on 'Crime map' in the middle of the page, when you will be asked for a post code, and you should be able to see the crimes that have been committed in your area. Do zoom in so you can click on each crime and get some details!

Checking up what crime has been committed in your area is all very well, and the crime map gives you as much information as you need. But the police force wants to improve its efficiency, by using its officers in the best way possible. So they need to sort the crimes out into types, and days and times of day when they are most likely to be committed. All these need additional information to be displayed on the map. Each data set will be on a different layer, so that whoever is investigating can concentrate on the information they need, while switching off what they do not need.

More generally they research more wide-ranging issues. What age are the people who commit most crimes? What level of education do they have? Are the areas they come from poor? To get this information, they would need to contact the education department, the housing department, the benefits agency and so on. You may only want to display a few data sets at one time, but in order to check for patterns and links, and therefore actions, you need to move between maps containing different data sets with ease. To do this, all the maps that contain a dataset need to be presented in layers which can easily switch on and off.



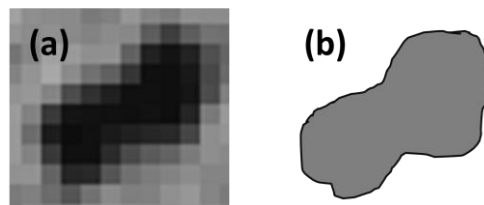
## How is data presented?

It is not appropriate to present all the information in quite the same way. As we found with the uses of different types of map last lesson, this is because not all data is exactly the same.

**Continuous data** can be measured anywhere (e.g. elevation, temperature, land use) and forms a surface.

**Discrete data** shows individual objects and where they are located, as point, line or area features.

Some data can be recorded in either form. Factors such as scale, and the intended use of the data can also help with the choice of the most appropriate technique.



GIS uses two formats, known as raster and vector views.

- (a) is an example of continuous data in a **raster format**. It employs a grid of information representing a single variable or category. It lends itself well to continuous data such as population density, rainfall and other similar data.
- (b) is an example of discrete data in a **vector format**. It shows data that is made up of points, lines and lines enclosing areas where points are not confined to a grid. It lends itself to discrete data, such as power line location, roads and field boundaries or, as above, a lake.

## Raster Maps

Raster maps are images made by a series of coloured dots on a screen called pixels, such as those used in digital photographs. Aerial views and satellite pictures are one source of raster images. However there are other examples storing continuous data, such as rainfall, temperature change and population density, among others.

**Investigate!**

Here is an example of raster data presentation.

Look at two satellite images on :

<http://earthobservatory.nasa.gov/IOTD/view.php?id=83157>

It shows the 'before' and 'after' of the floods on the Somerset Levels in 2013-14.

Below both images there is a button 'view image comparison'. Both images appear side by side, with a sliding line down the middle, so that you can see how each changed over time.

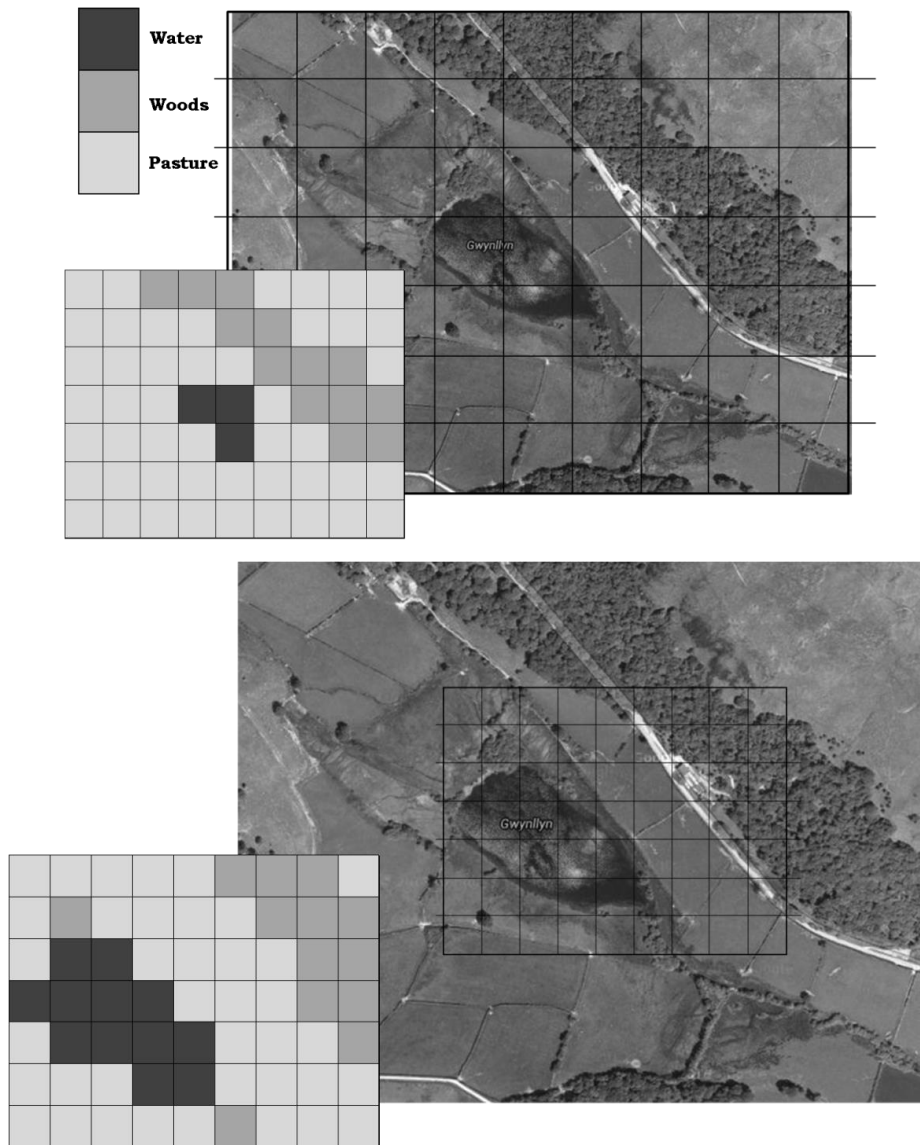
To the right are other examples of flooded areas that you may like to explore.

Raster maps can be thought of as 'unintelligent' as you can only obtain information that is visually represented on them. It is not possible for example to distinguish a factory from a house or a river from a road on aerial view raster map, as we see is possible on vector maps.

Raster maps take up a lot of computer storage space but can be very useful as background maps to other information. Any photograph is made up of pixels and so are raster maps.

All liquid crystal displays use pixels. Raster modes consist of rows and columns of equal-sized mostly square pixels. Due to the use of squares, these are called grid-based systems.

Each pixel has a location value and a single attribute value, found by averaging all the items within it. For example, in the map below each square takes on the value associated with land use that predominates in that square. If a square is mostly water, then is shaded with the darkest colour.



Pixel sizes vary; with the examples above, the pixels are quite large in both, but notice that the lower raster map only covers a quarter of the area of the upper one. Even so, we do not get a very clear impression of the totality. All digital photographs you take are in this same raster format, but the number of pixels per square cm (resolution) can be so huge, the detail is amazingly good, even with tiny objects. However, if that amount of detail were to be used in raster maps for GIS systems, the storage would be vast for just one layer. Obviously, the larger the pixel size, the fewer the pixels per square cm and the less reliable the information being recorded is, so compromises have to be made.

The size of the pixel or resolution is determined by the length one side of the square represents in reality, e.g. a square representing 10m by 10m, it is said to have a pixel resolution of 10m. You may recall from Year Eight that map scales are

of the form 1:50,000 for a regular Ordnance Survey map. A page in an atlas showing Europe that I just looked at was 1:22,000,000. These two scales mean that for every one unit you can see, this represents 50,000 or 22,000,000 units respectively, in reality. What this means for example on the Ordnance Survey map is that 1 centimetre on the map represents 50,000 centimetres or 500 metres or 0.5km on the ground.

It has been established that if you look at such a map, you can distinguish an object that is one thousandth of the ratio in metres. So if you look at an Ordnance Survey map you could see something that is 50 metres in size; similarly the size of the object you could see on the Europe map is 22,000 metres or 22 km in size. There is a rule of thumb that says you get reasonable detail from looking at the scale of the map on which you are basing the raster view. To make the raster work well enough, the pixel square needs to represent half of the size of the object you could see. So if the scale of the raster map is based on 1:50,000, then the pixel resolution should be 25 metres. On the map of Europe the pixel resolution should be about 11 km.

### **How is the information stored?**

Each pixel cell has one geographical value and one data point value. Each pixel must hold a data value, even if it is zero. The value must represent an attribute, e.g. if elevation is the raster image, then the value associated with a pixel will be the average height of that pixel in metres above sea level. If it is land use, then often there are conventions e.g. 1 stands for grass, 2 represents agriculture and so on.

### **Advantages and disadvantages of Raster Maps**

They are easy to generate, from for example a digital camera, phones or a satellites.

They are best for mapping continuous data, such as temperature or relief.

As each square only takes a single value, e.g. it could be an average height or ground cover, then perceiving a pattern is very straightforward.

#### BUT

The files are often large and get bigger as the resolution gets ever finer. You may have noticed this with digital cameras.



The memory cards soon fill up if you use the highest resolution.

Efforts to reduce file size by having larger pixels quickly lead to a loss of detail.

Overall detail is soon lost as you zoom in and can see the squares the image is made up of. Try using a powerful magnifying glass on a newspaper picture!

### Activity 1

Check back and find all the different uses of raster maps. Then try to think about three others not mentioned.



Three given examples of the uses of raster maps:

Three other examples of possible uses of raster maps:

### Vector maps

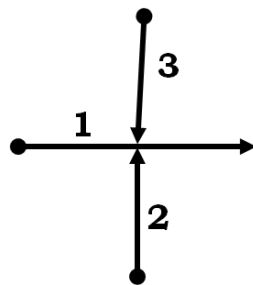
Vector maps represent discrete (= separate) individual features. All features are represented using geometrical forms, points, lines and polygons.

Points can represent a tree or a lamp post on a large scale map (recall this means small items appear large) or a village on a smaller scale map (where bigger items appear quite small). Each item will be recorded by its position using the coordinate references system, in either 2D or 3D depending on what is needed, as sometimes vertical height is not relevant. It will also be identified by what kind of object it is and further data or **attributes** may then be added.

Lines include at least two points or vertices and usually more. The segments between the vertices are always straight. This means that a line which wiggles a lot will need more vertices than a line that is generally straight. To identify a line on the database that records the data, so that the beginning and the end of a line can be identified, each line has a header, which states the number of vertices there are, besides the coordinates of each vertex. In addition the line will be identified by what it is and also one or more attributes will be associated with it, for example: Road that is tar-covered has 10 vertices.

Polygons are lines that begin and end in the same place. Again each polygon will be associated with a role and have further attributes associated with it, for example: a polygon may be the boundary of a property, with a four-bedroomed house in it.

There are a few conventions in vector maps, one of which is that line can never cross:



Lines 2 and 3 may approach line 1 but they can never cross it and join. In the same way, the margins of a polygon must not cross each other either.

## Layers on GIS Systems

We saw that only a single variable could be recorded on a raster map, as each square can only have one value, thus several raster maps might be required for different criteria. In theory, the points and lines and polygons of a vector map could all appear together on one map. In practice this is not done. Points are kept separate from lines and from polygons. Not only that, but in most cases, different functions for points are also kept separate, so for example lines representing major roads will be on a different layer to lines showing footpaths. The order in which layers are shown is also carefully controlled. For example you would not want rivers to appear over the top of roads. Why not?

## Advantages and disadvantages of Vector Maps

As only single vertices are recorded, not each pixel, it has a relatively compact data structure so storage requirements are less.

Due to the accurate location of each vertex, features can be precisely located. Unlike raster mapping, there are no computational costs to storing increased accuracy. Global positioning systems (GPS) can record down to metres of accuracy and so even if the vertex is being viewed on Ordnance Survey 1:50,000 maps, the positional accuracy of a point or line is still there if you zoom in.

As each vertex is logged in three dimensions, E-W, N-S and altitude, exploring shaped surfaces is easy. This is unlike raster maps. Data about individual features can easily be retrieved for updating or correction. This means that if there is a change in a road layout or a new house is built, additions and modifications can easily be added. In a raster map, in order to change one part, the whole map has to be recalculated or photographed.

BUT

As more pieces of information can be linked to a vertex or a feature, the data structure is more complicated.

This also makes finding patterns within data more difficult to achieve electronically, as the software needs to be more sophisticated and thus more expensive and more difficult to interrogate, needing highly trained technicians to organise it.

Collecting the pin-point accurate position of each vertex is very time consuming, often requiring fieldwork.

### Activity 2

Check back and find two different examples of point, line and polygon uses of vector maps.

Then try to think about three others not mentioned, one point, one line and one vector.



Given examples of the uses of vector maps:

Three other examples of possible uses of vector maps:

### **An example of using GIS: Where should the wind turbines go?**

Wind turbines can provide a source of alternative energy, but finding the right locations can be difficult. It needs to be a place where there is enough wind and enough space for a group of turbines to exist together.

Also the electrical grid needs to be close enough and robust enough to export quite large volumes of electricity to the users. Not all rural systems are close enough to remote sites or have the capacity to carry enough current.

The most productive sites are often on high ground which can be seen from some distance away. Those living in the vicinity often have many concerns. If they are too close to houses, less than about 300 metres in the case of individual dwellings, the wind turbines appear to be associated with some people suffering headaches and sleep problems and there may be TV interference. Large wind turbine farms are usually built more than 1 km away from settlements, to avoid any potential challenges.

Another environmental impact, often written about but not really understood, is the number of birds and bats killed by wind turbines. Due to the remote locations of most sites, the numbers of deaths are not known, although individual instances are reported. So when siting a new wind farm, bird reserves campaign to keep the wind farm as far as possible from the reserve.

Yet more notice needs to be taken of established infrastructure, such as mobile phone masts and where airfields are located, as wind farms cannot be too close, otherwise the larger modern turbines might interfere with landing and taking off.

### **The GIS component**

Wind speed data is only available nationally on a fairly crude raster map that takes the average of large squares. Within these squares, the variation can be quite great. For example there could be hill top ridges or sheltered valleys which will give very different results from the average. So having chosen an area that looks promising using the raster map, then more detailed data collection is needed to make sure the list of possible sites will work well. Whilst very high winds can mean that the turbines have to be shut down temporarily, in general the higher the average speed the better. Having explored the average speeds of a number of sites in the target area, these can be put on a new point vector map.

A line vector map showing the contours may be simpler to produce than a raster map of sufficient clarity.

A polygon vector map can show the areas available for building the turbine towers.

As the turbines are large heavy structures that need to be installed, the sort of ground and access to it are both considerations. A line vector map of roads and either a raster map showing ground-cover, or notes on the potential site being added as attributes to the polygon vector map of the sites, are both ways to achieve this.

Concerns about local impact could lead to further vector maps, polygons for example of settlements and also of protected areas. Attributes would be included: in the case of the settlements, their size and what the residents felt about the proposal nearest to them could be added after consultation; while the protected areas could be National Trust buildings or bird sanctuaries or a site of special scientific interest protecting endangered plants.

## Activity 3

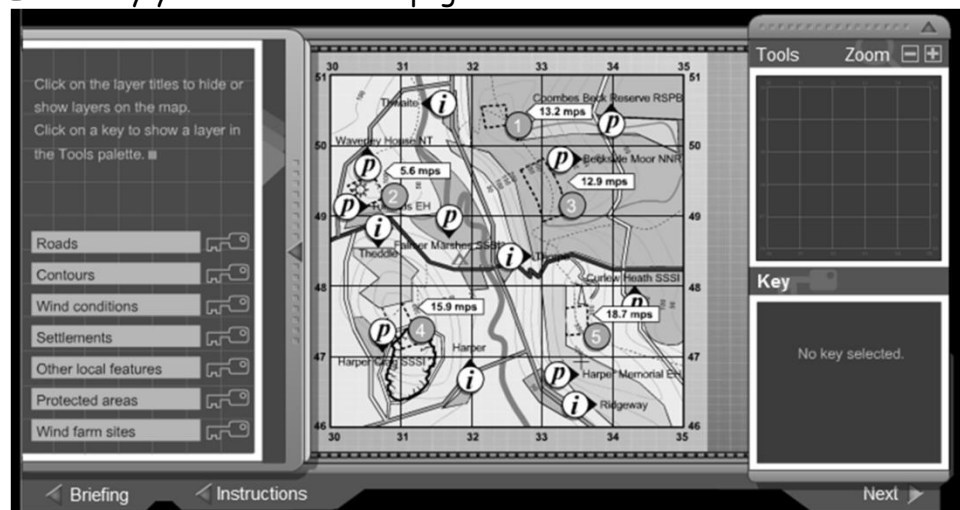
Go to [www.ool.co.uk/9854dt](http://www.ool.co.uk/9854dt)

where you will find a simulation of a GIS problem associated with wind farms.



Click on the small > on the bottom right hand corner and read the text to see what is expected.

Eventually you will reach this page:



Each layer can be switched on or off. If you click on the key symbol, this will give you the keys to the symbols used in that layer on the lower right hand side of the screen. For example click on the key beside the road button and you will see that red roads are A roads, orange ones are B roads, etc. Note, with regards the roads, which sites are easiest to reach is important.

It is a good idea to leave the wind farm sites switched on and switch all the others off. Then one by one, select only roads, contours, etc, as too many layers of information can be confusing! When looking at wind conditions, list the sites in order of speed, highest as 5, etc.

When you get to settlements and protected areas, check each *i* and *p* and make notes of what you find out; for settlements, include the population size and how happy they are to have wind farms. Also assuming each square is 1km by 1km, estimate the straight line distance from each site to its nearest settlement. Once this part is complete and all the notes are ready, now is the time to start scoring each site, by clicking on each flashing number circle in turn, where you will find interesting information about the site itself.

The 5 scores they ask for are:

1. Availability of land: size here is everything as if the number of turbines is too small, then it is too costly to set up.
2. Suitability of wind conditions: already discussed.
3. Distance from settlements: but also take into account the size of the settlement and how they feel about renewable energy, when deciding how to order them 5 to 1.
4. Distance from protected areas: and do bear in mind what kind of protected area it is and how much damage the wind turbines could cause to the items being protected.
5. Ease of access: this is not just roads to it but also the state of the ground. Think about the heavy machinery.

If you get part way through and need to check up on some detail, you find you cannot close it until you have given every line a score. Just add 1 to each you are uncertain of, close the view and check the information you need. Press that number circle the settlement again and you can get back into it and modify anything you wish.

Do this for all five sites and press next (bottom right).

You will then be presented with a table of a summary of your scores. You can accept the scores as giving the best answer and select your three best or you may choose any of the others if you think the scoring system was unfair.

You may like to press confirm and it will tell you what it thinks!

If you like, you can view why they gave the scores they gave by pressing the green view button. I do not necessarily agree with the reasons for their decision and I do think there can be a good case for some other ideas to be taken into consideration.

(a) Here is copy of the table. Please fill it in.

Site	Availability of Land	Suitability of wind	Distance from Settlements	Distance from Protected areas	Ease of Access	TOTAL	Selection
1							
2							
3							
4							
5							

(b) For each of those you gave (i) highest and (ii) lowest scores to, explain how you allocated the marks of the 3 most significant items.

i.e. for the highest score, three of the items with the highest scores and for the lowest, the three with the lowest scores.

(i)

(ii)



## Conclusion

Having looked at different types of maps and mapping technologies, we have looked at ways in which they can be applied to help solve different problems faced by today's changing society. For example the small case study carried out in Lesson One, in Rhayader, counting cars could be (and in fact has been) applied to looking at whether a bypass should be built and, if so, what route it should take.

Building and managing GIS systems for local and national government has a long way to go. With all the detailed information that it is possible to collect, perhaps we will be able to make the right decisions more often in future?



**KS3  
Geography  
Year 9****Tutor-marked Assignment A**

1. (a) (i) What are the lines on a map showing air pressure called?
- (ii) What particular type of map are Ordnance Survey maps examples of?
- (iii) What sort of map are both isoline maps and symbol maps examples of?
- (iv) What is a map in which the area covered by each country is distorted according to the theme of the map?
- (v) What is a choropleth map? (2 marks)
- (vi) What would an isotach map show?

(7 marks total)

- (b) This is the centre of Rhayader, and yes, the four main roads really are called North Street, East Street, South Street and West Street! I spent a bit of time sitting outside the Old Swan tea room...



... on the corner between West Street and South Street, counting vehicles in order to construct a flow line map, showing how many vehicles were using each road. I have to confess that the numbers were massaged a bit to make the flow line map easier to construct and to read from, but the

pattern of numbers remained the same, so any trends you notice are valid.

The partial flow chart map and a partly completed table are over the page. A complete map will show all the arrows, drawn to scale, entering and leaving each road and all the columns on the table will be filled in.

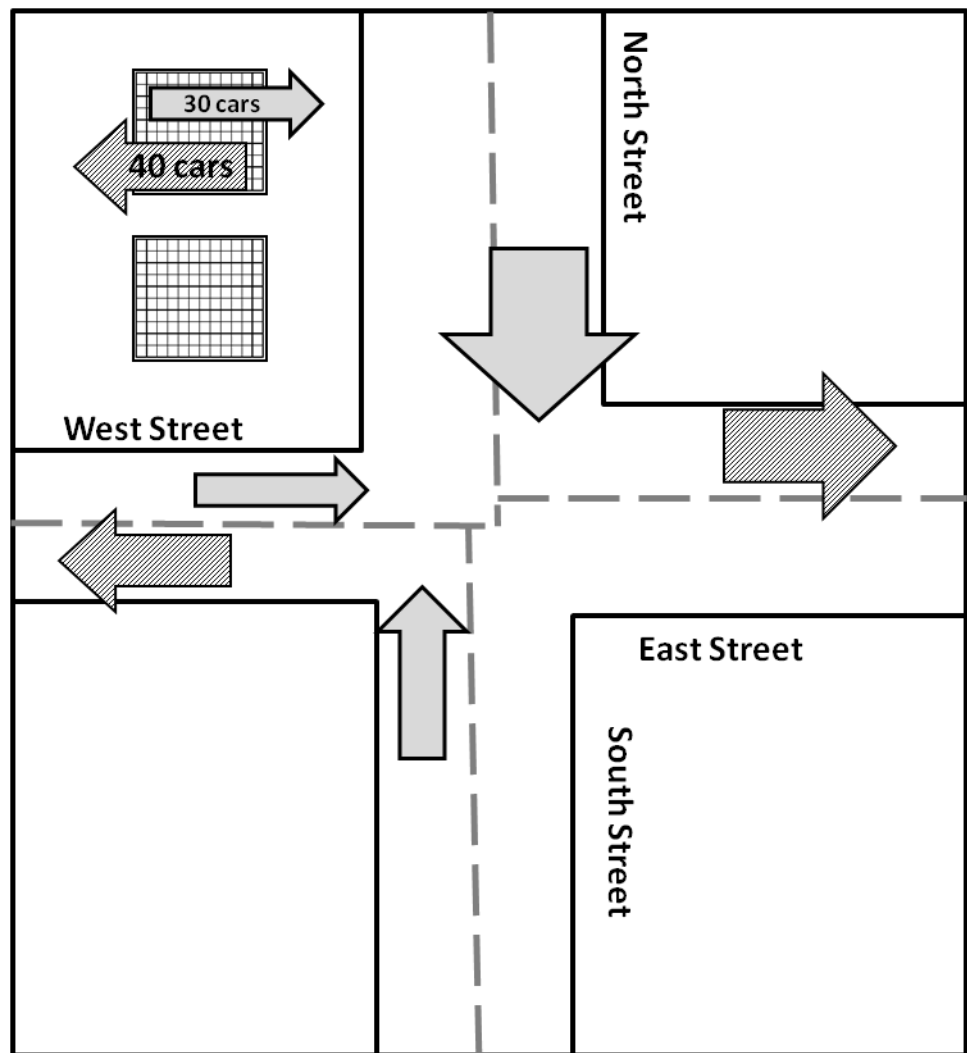
West Street is complete, with scaled arrows and their values filled in on the table, and there is a copy of these arrows on squared paper used to construct the arrows to scale.

Use the other sample of squared paper:

- (i) to measure the width of the missing arrow numbers in the table, from which you can fill in their value. (3 marks)

and

- (ii) to draw the scaled arrows for those missing on the map. (The scale portion is the shaft only, not the arrow head, that is the long bit!) (6 marks)



	Leaving	Entering
North Street		60
East Street	60	
South Street		50
West Street	30	40

- (c) You may have noticed that two of the streets are much busier than the others? Which are they?

For bonus points: on Google maps, find Rhayader, Powys and zoom in to find North Street, East street... etc and then zoom out to give you a better view of the big picture. Why do you think these two streets are busier?

(2 + 2 marks)

Q1 total: 20 marks

2. The maps on the attached sheets all come from a GIS (Geographical Information System). They all relate to the same location and cover the same area.

[It is not usual to add a grid to each GIS map (as, if they are switched on and off by the computer, it is unnecessary); but as you are going to be carrying out non-computerised activity, it seemed only fair to include them so you can line the different maps up more easily. Each square represents an area 1km by 1km, as most Ordnance Survey maps do.]

- (a) What is the name given to a single map from a GIS? (1)
- (b) (i) Both Maps A and B are of the same type. What is that? (1)  
(ii) What is a main difference between these two maps and the others on the attached sheets? (2)  
(iii) I hope you can see the pixel resolution is very different on A and B. What do you think the pixel resolution is for A and B? Choose from 10km, 1km, 100m or 10m. (2)  
(iv) Where are you most likely to have seen this type of image (referred to (b)(i))? (1)
- (c) (i) What types of map are the remaining three? (1)  
(ii) Maps C and D are both a particular example of (c)(i). What is that? (1)  
(iii) Map E is different type of (c)(i). What is that? (1)
- (d) What A describes the additional information associated with points on maps C – E? What V is the technical term for these points? (2)

You are now going to undertake a Decision-making Exercise (often called a D.M.E.), in which you will be given information about a situation. You will make a decision about what action to take, based on the information.

Additional Information about the items on Map E:

**Protected area X:** Known as Forest Beck Bird Sanctuary, it is a known site where the lesser spotted woodpecker, a bird on the endangered list, is known to roost.

**Protected area Y:** Mill brook Vale is a moorland area with several rare ferns and bog plants.

**Settlement A: Forest Falls.** Has population of nearly 1,100. It has a church, a village shop, pub; also a saw mill just up the road. Most people are employed in farming or forestry or they travel to Bridgeton for work. Several farmers run B&Bs or have a campsite on their farms.

**Settlement B: Milford.** It has a population of 750 and few local services. It is on a regular bus route to and from Bridgeton. The bus travels from Bridgeton to the other side of the hills, up the B Road ten miles beyond Forest Falls. While a few residents are employed locally, many use the bus to go to work in larger towns.

**Settlement C: Bridgeton.** A market town and a tourist centre with a permanent population of around 2,500. There is some employment in a couple of small engineering works; but most people are involved in one way and another with the services industries, in particular those associated with tourism, providing both catering accommodation and a number of activity-based opportunities. There is a good range of local shops with no major supermarket chain.

Given you have been provided with an average wind speed map, you may have guessed that you are going to be asked to site wind turbines. This time it is a little different. Villages in Milford have decided to see if they can put two or three turbines up locally and run it as a community enterprise. With the money the government pays communities to produce green energy, the village wants to start up one or two small businesses as employment is hard to come by.

As it is a small scheme, involving a few much smaller turbines, no-one is against it; in fact the other two communities are very supportive of the people of Milford. However, they want to be sure that the damage to wildlife will be kept to a minimum and even those from Milford appreciate that the site needs to be at 1.5 km away from the settlements to reduce the possible impacts of noise and electronic interference.

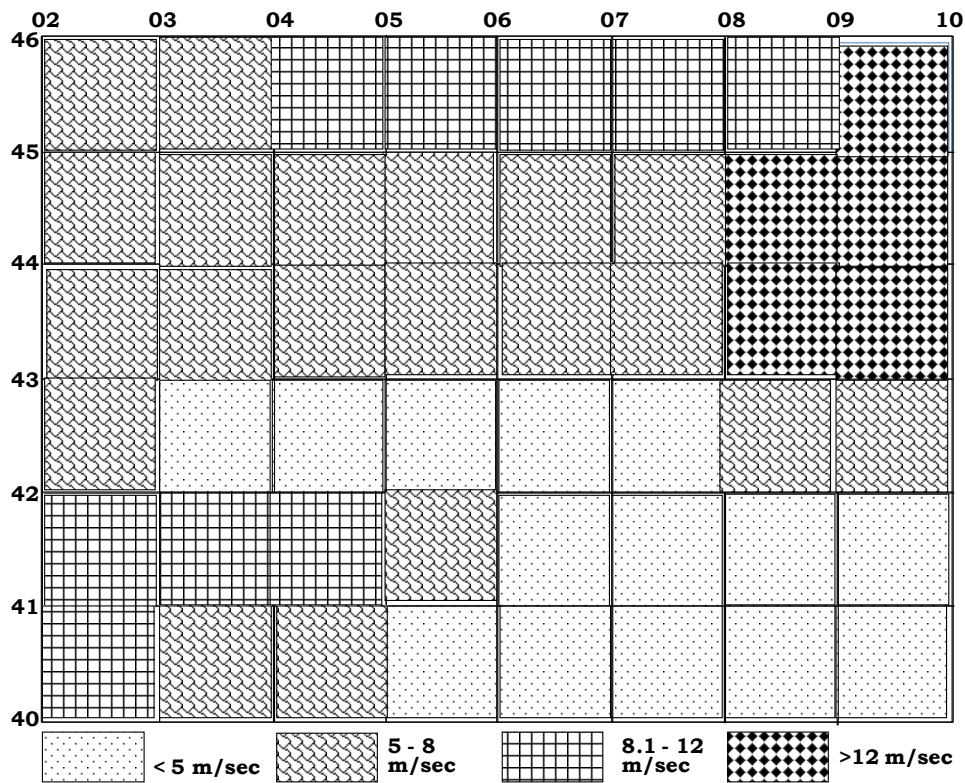
- (e) (i) Using information from the whole GIS, select *three* separate sites that will be candidates for development. Draw them on the blank map and label them. (3)
- (ii) Explain why each was chosen. (3 x 3 = 9)
- (iii) You only have some of the information you need to decide which one will turn out to be best. Think of two more pieces of data that might be required to help you. (2)
- (iv) If you think you know which one will turn out to be best, explain why. If you really do not know, explain what in particular the problem is. (4)

Q2 total: 30 marks  
Total for TMA: 50 marks

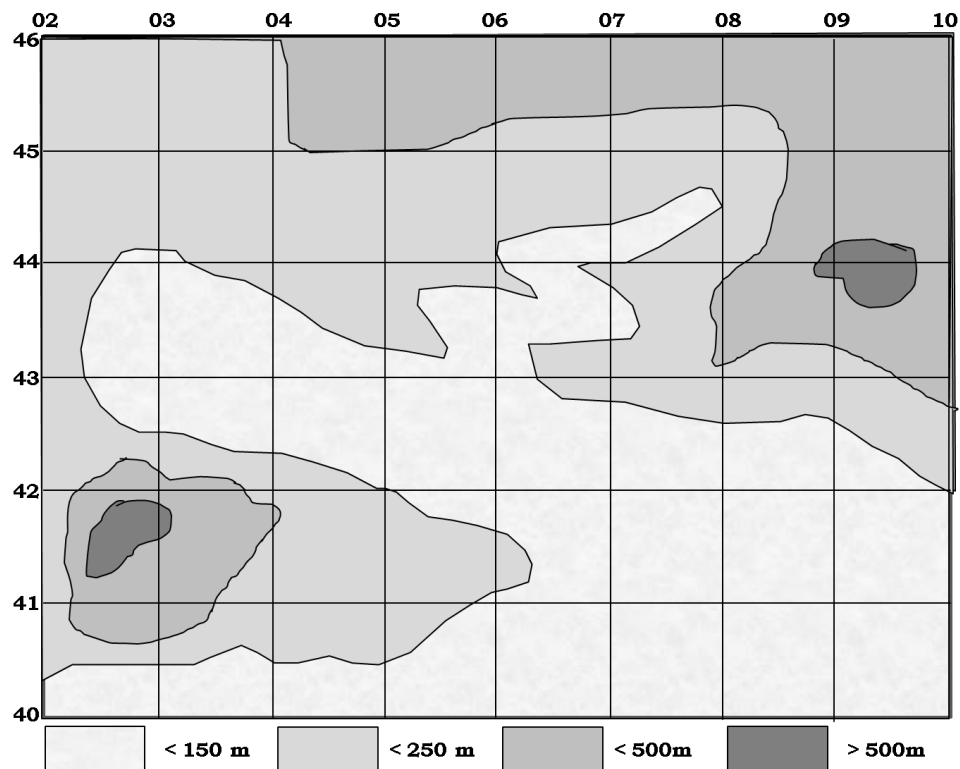




## MAP A Average wind speeds



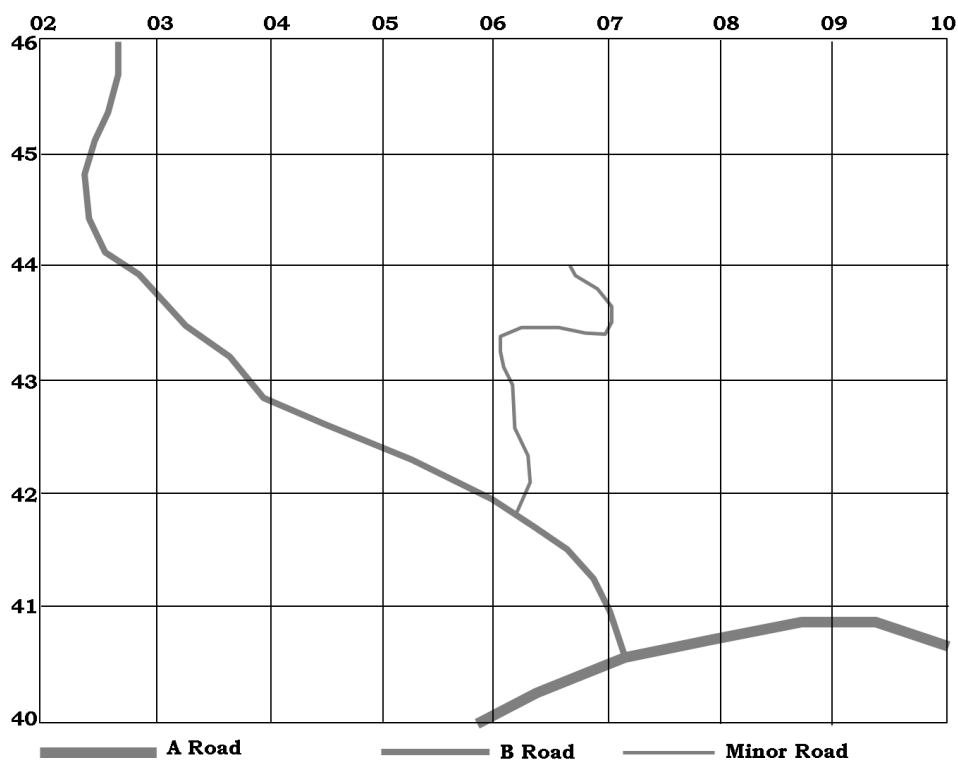
## MAP B Relief map



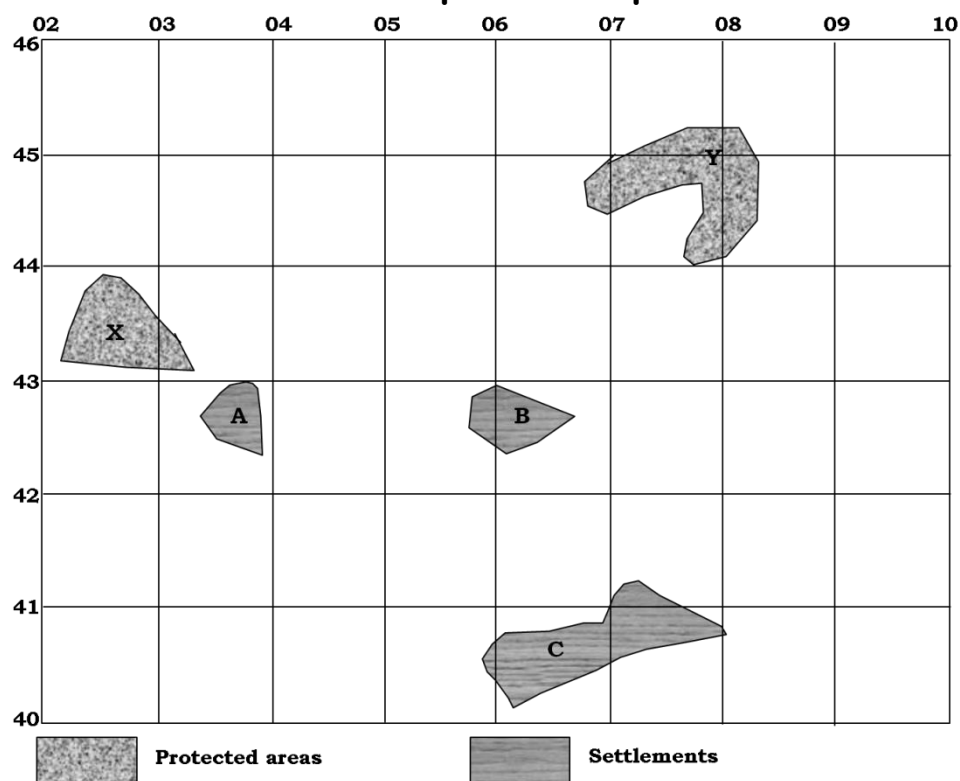
### MAP C Water courses



### MAP D Roads



## MAP E Settlements and protected places



## Blank Grid for use!

