Rivers

Extra Investigation: How efficient is the river's channel?

See also the Rivers section of *Geography Fieldwork Projects* on pages 123–139. All page references refer to *Geography Fieldwork Projects* by Jennifer Frew.

> **FIELDWORK TECHNIQUES**
> **You will use the following techniques:**
> - **Measuring the slope angle of the river's long profile (pages 24–27)**
> - **Measuring the speed of flow (pages 52–54)**
> - **Calculating the discharge (optional)**

This investigation can be carried out even if the river's channel is dry.

The techniques explained in this investigation may also be used to discover the river's **discharge**. The river's discharge would make a good project topic (see Project Suggestions on pages 123–125). The investigation of discharge could also be linked with channel efficiency, water supply, flood control, or the way in which the river is used by people.

> **Discharge** is the amount of water flowing past a particular point in a river. It is the area of the cross-section of the river multiplied by the speed of flow. It is usually expressed in cubic metres per second or 'cumecs'.

A river only directly affects the land it touches. This is the bed and the banks of its channel. It carves and smoothes them so that the channel becomes an efficient shape for the river to flow through and to transport its **load** of **alluvium**.

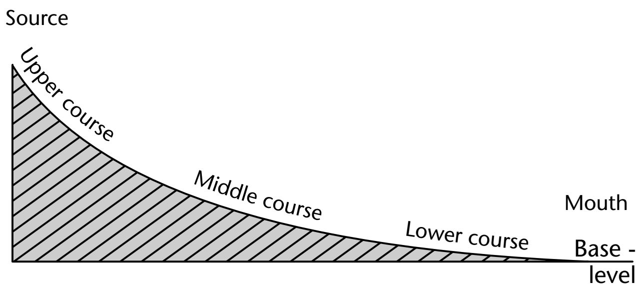
The load is made up of the following:

- material which the river has eroded from the bed and banks, i.e. it is material eroded by the river whilst carving its channel;
- material from the valley-sides (above the channel) which has been loosened by **weathering** and has slipped down into the river under gravity.

The oldest part of a river's course, and therefore the oldest part of the channel, is downstream near to sea level or to a local **base-level**. Some people refer to this part of the river as the 'lower course' or the 'old age stage'. Rivers lengthen their course by erosion in higher ground near to the source. The headwaters are, therefore, the 'upper course' or 'youthful stage' of the river. The upper course and the lower course are two sections of the long profile of a river. In each part of the long profile the gradient affects the river's energy. This in turn, influences the river's ability to modify its channel by erosion and deposition, and to transport its load.

> **In the 1920s, the American geographer W. M. Davis realised that the perfect long profile would allow the river exactly the right amount of energy to carry out the processes of erosion, transport and deposition. He called this the graded profile (see Figure R1).**

Figure R1 The graded profile of a river.



In the old age section of the long profile, the river has had a very long time to carve its channel. As a result you would expect the downsteam section to be smooth and efficient, in contrast to the youthful section near to the source of the river.

You could investigate the efficiency of the channel at two or more places downstream. Alternatively compare the channel efficiency of two different rivers:

- rivers of different stream order, or
- rivers of the same stream order which flow through different areas. They could flow over different types of rock, or through different types of farmland. Another example is a river that has been altered by people (for navigation, industry, recreation, etc.) and one that is more natural.

Before you begin

For the **introduction to your final report**, use your own words to describe the long profile and/or the graded profile. Illustrate your description with a labelled diagram.

Find out more about the processes involved in the carving and smoothing of a channel. Use the list below to help you. Look up the terms in a dictionary of geography or a textbook on physical geography or geomorphology. Write a short paragraph to describe each.

a the processes by which a river erodes its channel:
corrasion/abrasion
hydraulic action
attrition
corrosion/solution

b the ways in which a river transports its load:
suspension
saltation
bottom traction of the bedload
solution

Remember that downward erosion which lowers the bed is **vertical erosion**, and sideways erosion which widens the channel is **lateral erosion**.

An **efficient shape of channel** enables the river to flow smoothly, losing little energy in friction with the bed and banks. Those of you who go fishing will be familiar with the deep pools where you would catch chub and barbel. In deep stretches the river flows smoothly in an efficient channel. The excitement of white-water rafting is only possible because the river is flowing turbulently in an inefficient channel.

The **efficiency of a channel** can be assessed by measuring its cross-section and examining the shape it makes: an efficient channel has a smoothly curved cross-section. Efficiency can also be analysed as the ratio between the width of the channel and the average depth. A perfect gutter has a width:depth ratio of 2:1 (as shown in Figure 120 on page 124).

How to choose your fieldwork locations

Begin by looking at an Ordnance Survey map of scale 1:50,000 to find rivers which are at least 5 km long. The Ordnance Survey map of scale 1:25,000 shows individual buildings and field boundaries as well as public rights of way. These details are helpful in finding sites for taking measurements.

Make a tracing of your river(s) and their tributaries within the **catchment area** (see pages 127 and 128), and then work out the **stream order** of each. Mark in pencil the sites at which you intend to carry out your investigations. Include this map in your **final report**, explaining the reasons why you chose your rivers and investigation sites.

Next, confirm your choice of fieldwork sites by making a quick **reconnaissance visit** to each to check the following:

1. Is there public access? If not, find out the name and address of the person whom you should contact to ask for permission to visit (see pages 18–20).
2. Are you likely to disturb anyone? There may be a factory which needs clear water or an angling club downsteam. When carrying out measurements in rivers it is easy to churn up the water unintentionally. It would be courteous to explain what you will be doing and why. A letter from school would help.
3. For your own safety, check that the water is not deeper than your Wellington boots.

During your **reconnaissance visit** it would be a good idea to **practise taking measurements**. You will then find out how long it takes you.

At this stage, decide whether to extend your project by taking two extra sets of measurements:

1. the angle of the slope of the long profile
2. the speed of flow of the river

These extra measurements will enable you to investigate the following **inter-relationships**:

- channel shape and the downsteam slope angle
- channel shape and the speed of flow of the river

Explain in your **final report** that a river's ability to alter its channel depends on its energy. This is related to the gradient of the long profile, and this, in turn, affects the speed of flow. So, they are all inter-related!

*If you decide upon extra sets of measurements, if might be sensible to keep to two investigation sites only. Use your **reconnaissance visit** to try out the time it takes you. You will get quicker with practice.*

Measure the angle of slope of the long profile by using the method described in Figure 17 on page 26. Take your measurements over a distance downstream of 10 or 20 m. Stand in the middle of the stream, or, if the river has built up a flood plain, stand on the flood plain.

The speed of flow can be measured using one of the methods described on page 53.

The **discharge** is the **cross-sectional area of the water** in the channel multiplied by the speed of flow. Use the same equipment and methods as explained on pages 3–4 of this Investigation, but measure only the width and depth of the water in the river.

Finally, find out as much as possible about the **geology** and the **land use** in your fieldwork area. Your public library will help you with the following:

- Maps of the Solid Geology and Drift Geology. The Drift map shows all of the materials at the surface including alluvium and glacial deposits, whereas the Solid Geology maps show only the solid rocks.
- Maps such as those of the Land Utilisation Surveys of the 1930s and 1950s and the Land Classification maps of the Ministry of Agriculture, Fisheries and Food.
- Information on the use of the river by industry or leisure activities.

The Local History section may have interesting information on the **use of the rivers in the past**, e.g. for water power and other uses in mills, or for transport.

Use your **secondary information** from the library in your **final report**.

Caution: Do your best to keep the tape measure dry. Don't rewind a tape which is wet.

You will need the following equipment:

- Washing line or cord to act as a base-line for your measurements
- Tent pegs to secure the line at both ends
- Spirit level
- Tape measure
- Metre rules – at least 2
- Recording sheets – 1 for each investigation site and some spare copies (see Figure R2). Note that if your project includes the river's discharge, you will need two sets of recording sheets: one for the width and depths of the *channel*, and the other for the width and depths of the *river*.

Remember the extra equipment needed if you have decided to measure:

- the slope angle of the long profile
- the speed of flow of the river

Figure R2 Recording sheet for measurements of channel width and depth.

Date .... Site Name: .... Grid Reference: ....

Interval between depth measurements: ....

Measurements taken from left/right* bankside	Width of top of channel surface at bankful level	Depth of channel bed below bankful level

* Cross out whichever does not apply.

Fieldwork method

You will need a friend to help and for safety's sake there should be at least three of you.

Carry out the same procedures at each site:

1. Identify the bankful level of the channel. This is where the ground flattens out above the channel. It is easy to recognise where the river has a flood plain, but even in upper course rivers the ground tends to flatten out above the channel on at least one side.

> **Bankful** is the highest level to which the river can rise within the channel. If it rises any further the river is technically in flood. When the river is at bankful level it is said to be 'in spate'.

2. Stretch the washing line across the channel from one side to the other at right angles to the direction in which the river is flowing. Overlap the channel by up to half a metre on both sides. Pull the line taut and secure it at both ends with tent pegs or tie it around a tree root or trunk. Use the spirit level to make sure that it is horizontal. **Check it from time to time during your investigation because if it becomes slack your measurements will no longer be accurate.** The washing line forms your base-line for your measurements of the depth.

3. Choose as small an interval as is practicable to take measurements of the depth of the channel across your base-line: a 10 cm interval is ideal. **Practice during your reconnaissance visit** will have helped you to choose the best interval for the time you have available. Explain in your **final report** why you chose your particular interval: it may form part of your **evaluation of the method**.

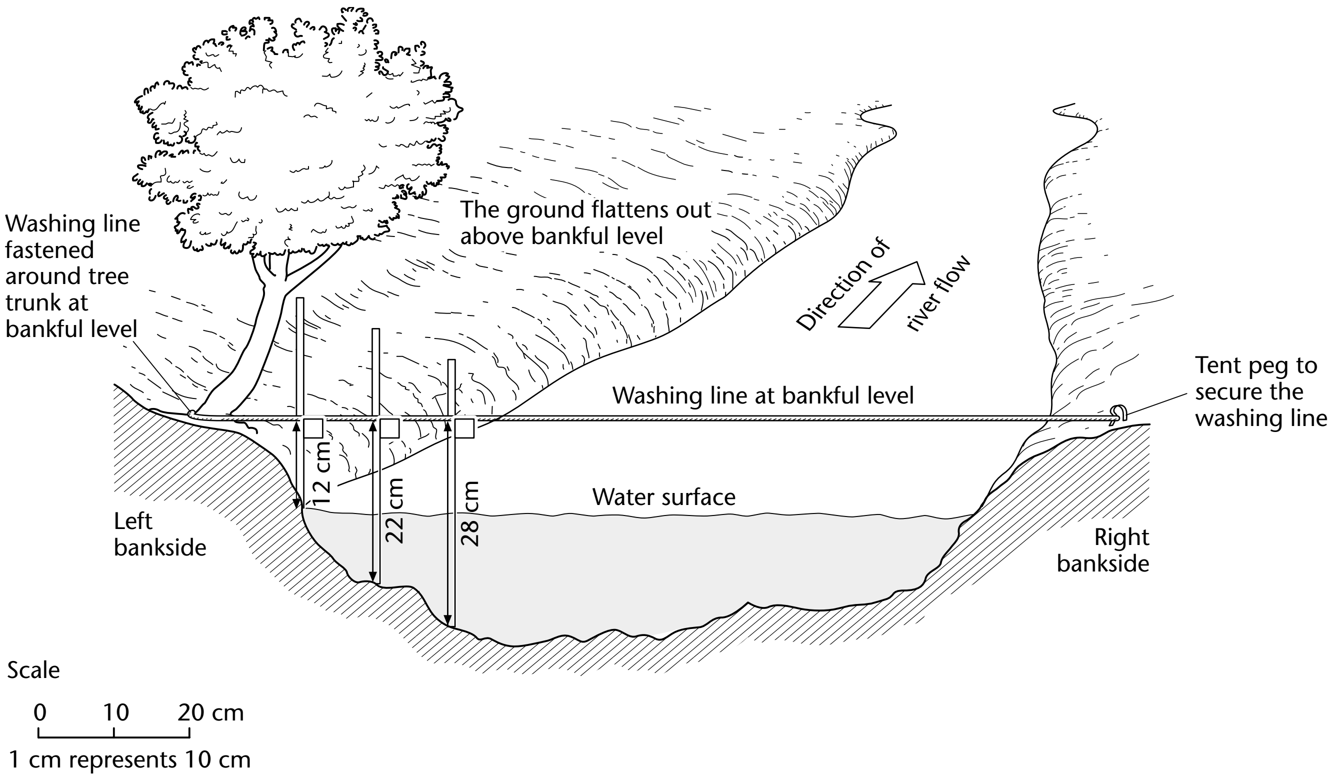
Your measurements are a **sample**, and for this project a systematic or regular sample is the most appropriate. You may decide to give your views on this in your **final report**. You will then be **evaluating** the method. Sampling techniques are explained on pages 15–18.

4. Begin at the left bankside or at the right bankside. Note this on your Recording Sheet. As shown in Figure R3, at each of your chosen intervals across the washing line, dip a metre rule down until it touches the river bed. It should be at right angles to the washing line. Record the depth below the washing line.

> Which side is left and which is right? If you stand facing the direction in which the river is flowing, i.e. facing downstream, the left bank is on your left side and the right bank is on your right side.

> SAFETY NOTE: When standing on the bank do not go too near the edge. The river may be eroding sideways into the bank and your weight could make it cave in.

Figure R3 How to measure the width and depth of a river's channel.



Measuring the speed of flow and the downstream angle of slope

- If you have decided to investigate the river's discharge, follow the same method but deduct from your depth measurements the interval of the gap between the washing line and the water surface. The washing line used for your channel measurements will be the base-line for your measurements of the speed of flow if you use a mechanical flow-meter, and it will form the starting line if you use floats.
- Measure the downstream slope angle from the washing line too.

Analysing and interpreting your data

The aim of this investigation is to assess the efficiency of the channel. **The ways of analysing the river data are exactly the same as those of the channel**.

Begin by tabulating (making a table of your results) site by site. In your **final report**, put these under the heading 'Results' or include them in an appendix.

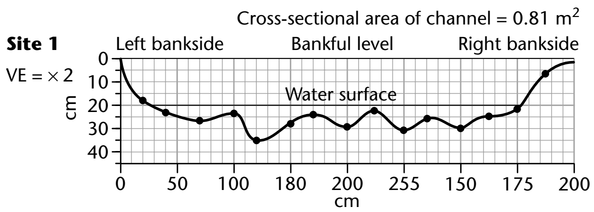
Now proceed as follows:

1. Drawing to scale cross-sections/cross-profiles of the measurements at each investigation site

Use graph paper and choose the scale carefully. The **range** of measurements recorded will help. To discover whether the channel is more efficient downstream, it would be helpful to draw your cross-sections in order, below one another, as in Figure R4.

It is easier to calculate the cross-sectional area if the vertical scale is the same as the horizontal scale (as in Figure 75 on page 70). The exaggeration which may be necessary to show the features on the vertical scale is explained on page 71.

Figure R4 Cross-sections of measurements taken on the River Goyt.



123 little squares lie between bankful level and the water surface = 123 × 50 = 6150 cm² = 0.62 m²

Horizontal scale
1 cm represents 50cm (1:50)

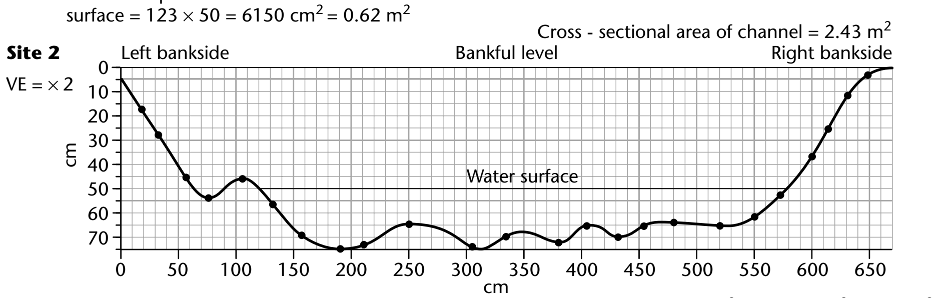
Vertical scale
1 cm represents 25 cm (1:25)

Vertical exaggeration (VE) = × 2

1 little square on the graph paper = 10 cm (horizontal) × 5 cm (vertical) = 50 cm²

1 little square on the graph paper = 10 cm (horizontal) × 5 cm (vertical) = 50 cm²

Each little square was marked by a dot when it was counted.
Each big square was marked by a trick when it was counted.



292 little squares are between bankful level are the water surface = 292 × 50 cm² = 14600 cm² = 1.47 m²
189 little squares are covered by water = 189 × 50 cm² = 9450 cm² = 0.96 m²

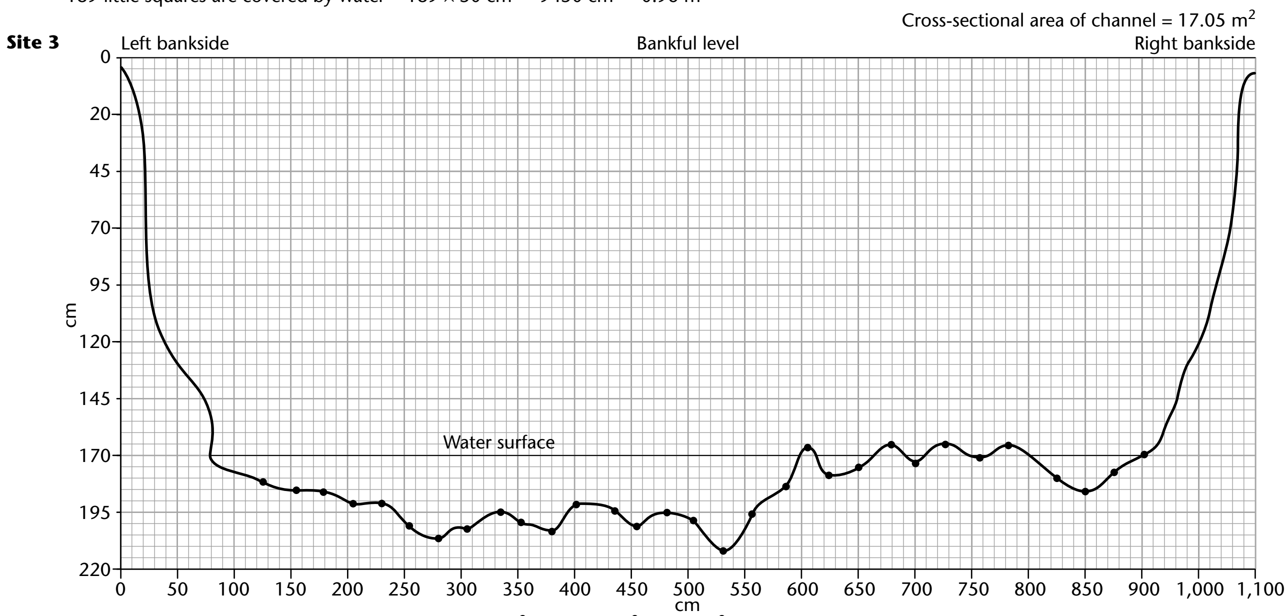
Results from cross-sections

Site 1:
Goyt's Clough
(Near to the source)
Cross-sectional area of water = 0.19 m²
Cross-sectional area of channel = 0.81 m²

Site 2:
River Goyt above reservoirs
(Local base level)
Cross-sectional area of water = 0.96 m²
Cross-sectional area of channel = 2.43 m²

Site 3:
River Goyt below reservoirs
Cross-sectional area of water = 1.19 m²
Cross-sectional area of channel = 17.05 m²

An obvious conclusion is by the seven fold increase in hannel area between sites 2 and 3, but with a decrease in water area,Why?



237 small squares are covered by water = 237 × 50 cm² = 11850 cm² = 1.19 m²
3,172 small squares are between bankful level are the water surface = 158,600 cm² = 15.86 m²

If you have had to draw your cross-section with a vertical exaggeration, multiply the area calculated by the vertical exaggeration. For example, if your vertical exaggeration (VE) is × 2, multiply your result by 2 to find the actual area; if the VE is × 5, then multiply your area by 5.

Both the bankful level of the channel and the water surface can be drawn on the same cross-section.

Describe briefly what each of your cross-sections shows. Does the channel appear to be smoother, and therefore more efficient, downstream or not?

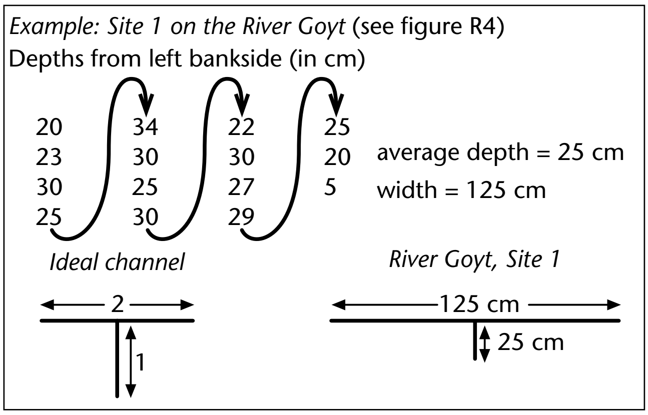
Your opinion of the efficiency could be reinforced by making mathematical calculations. Try one or both of the following:

a The width:depth ratio of the channel

For each investigation site, use your table of depths to calculate the average (or mean) depth (see page 84). Place this beside your measurement of the width so that the width:depth ratio is shown. Illustrate this as a diagram drawn to scale (see Figure R5). Show the width as a horizontal line, and draw the average depth as a vertical line at right angles to the horizontal. Remember that the most efficient channel has a ratio of 2:1.

To obtain an index of channel efficiency divide the width by the depth. The closer your answer is to '2' the more efficient is your channel.

Figure R5 The width:depth ratio of a channel compared with that of the ideal channel.



b Index of possible friction

This is another indicator/index of the channel's efficiency for transporting water.

(i) Calculate the cross-sectional area of the channel, following the method explained on page 5 and this page.

(ii) Use a map measuring wheel or the pin and string method (see page 70) to measure the actual length of the perimeter of the channel. Convert the perimeter length into the same unit of measurement (centimetres or metres) as your cross-sectional area.

(iii) Divide the cross-sectional area by the perimeter length:

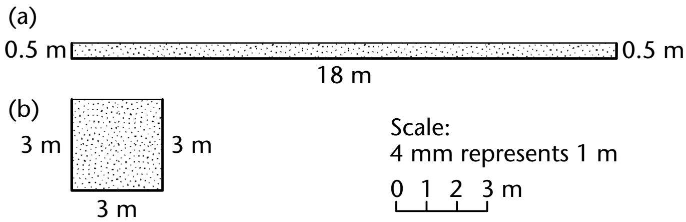
$$\text{Index of possible friction} = \frac{\text{cross-sectional area}}{\text{perimeter length}}$$

You will realise that you have calculated the possible friction to the water – and therefore loss of energy to the river – in relation to the area of the river.

Look carefully at Figure R6 and you will see that the higher the index you have calculated, the more efficient the channel.

Figure R6 The index of friction.

The cross-sectional area of these two channels is 9 m^2



The length of the channel (bed and banks) that could cause friction is 5 m in (a), and 3 m in (b).

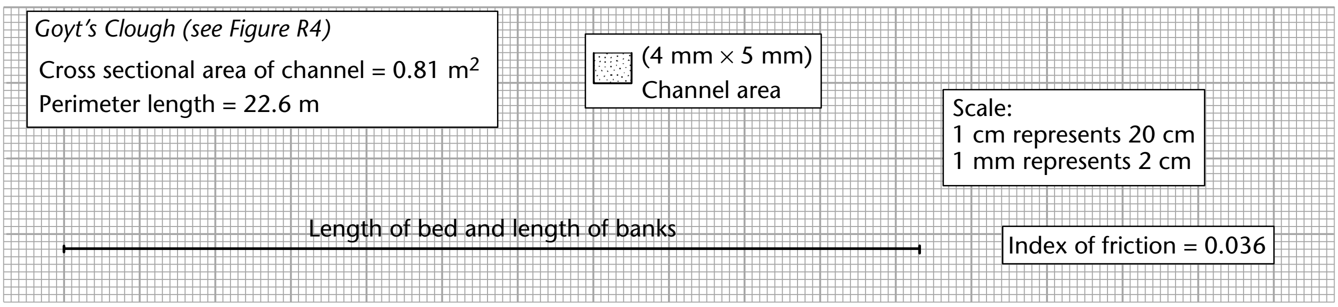
The index of friction for each diagram is

Diagram (a) $\frac{9}{19} = 0.47$

Diagram (b) $\frac{9}{9} = 1$

The channel of Diagram (a) is less efficient than of Diagram (b).

Try calculating the index of friction for the cross section in figure 109. Here is the first one completed to help you. You can see immediately that the channel has a very low efficiency index.



2. Draw bar charts to show the speed of flow of the river

First tabulate your results for each set of measurements taken. Calculate the average/mean speed of each set. If you have used floats, divide the distance covered by the average time taken, and express this in distance per second:

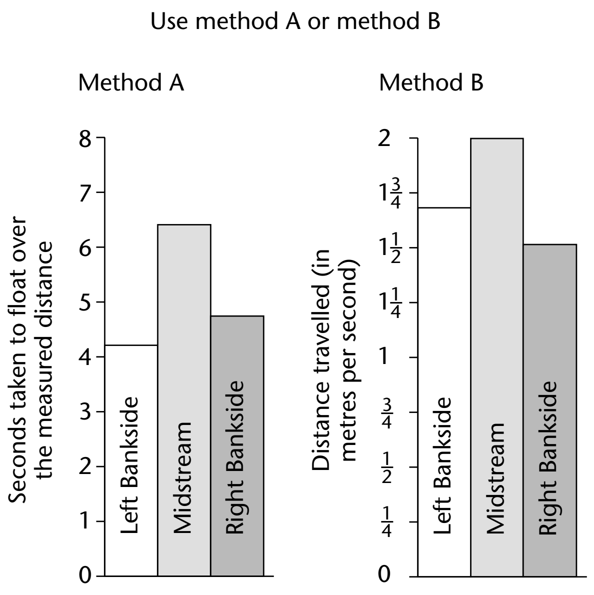
$$\text{Average speed} = \frac{\text{distance}}{\text{average time}}$$

Remember to multiply your results by 0.8 (see page 53 for the reason) and explain in your own words why you have done so. Include in your **final report** both your tabulation and the way in which you calculated the average speed.

Draw bar charts to illustrate the speed of flow at each site. Place your bar charts beside the cross-sections and calculations of the channel shape at each site. Describe any relationships that you see.

If you have investigated more than two sites and if you have calculated the index of channel efficiency by either of the methods explained on the previous page, it would be worthwhile to draw a scattergraph (see pages 76–78). On it plot the index of channel efficiency and the speed of flow. Afterwards, describe whether or not this shows the relationship more clearly than the description you have already written.

Figure R7 Bar charts to show the speed of flow of the river.



3. Show the angle of the downstream gradient at each investigation site

Here is a simple way of showing the downstream slope angle beside your cross-sections of the channel: Draw a horizontal line 4 or 5 cm in length, and use a protractor to draw a second line at the angle of degrees from the horizontal that you measured during your fieldwork.

Describe any relationship that you see between the shape of the channel, and the calculations you may have done of the channel's efficiency and the downstream gradient.

4. River discharge shown as a flow-line map

a. Multiply the **cross-sectional area** of the river in square metres by the **average speed of flow** in metres per second. The results will be the discharge in cubic metres per second, or 'cumecs'. If your river was very small you may decide to express the discharge in litres per second. There are 1000 litres in 1 cubic metre, so multiply your cumecs by 1000.

You may be interested to compare this with the average consumption of water per person per day (see page 129).

b. Illustrate your calculations of discharge as a flow-line map. Place tracing paper or acetate as a **tracing overlay** (see page 64) over the map of your fieldwork rivers. You may have to redraw the map with a bigger scale such as 1:500. Choose a scale for the flow-lines to represent the discharge. Draw this on the overlay, marking each site at which you carried out investigations (see Figure R8).

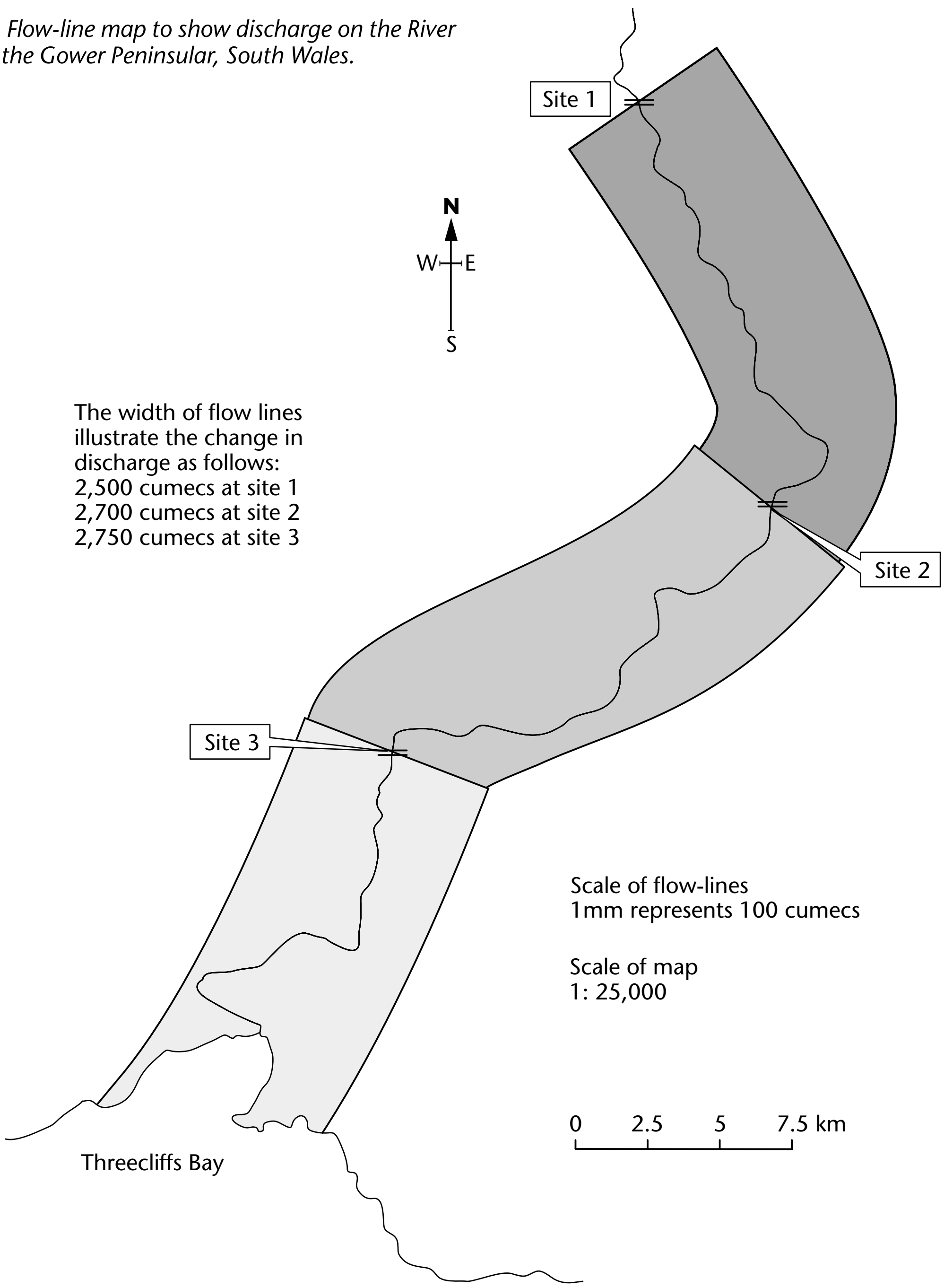
c. Describe any relationships that you can pick out between the cross-sections of your channel and the discharge. As with the speed of flow, if you have investigated more than two sites, it would be worthwhile to draw scattergraphs to pick out the relationship between:

(i) the cross-sectional area and the discharge; and

(ii) the index of channel efficiency and the discharge.

Describe what the scattergraphs show.

Figure R8 Flow-line map to show discharge on the River Ilston, on the Gower Peninsular, South Wales.



Drawing conclusions

Finally, place a neat copy of your fieldwork map showing the location of your investigation sites in the centre of the page. Surround it by the cross-sections, the results of your calculations, scattergraphs and bar charts. In other words, draw together all of your findings.

Summarise the changes in the channel in relation to its position on the long profile. Remember that, in the lower course, the river has had longer to adjust its channel.

If the channel has not become more efficient downstream try to give reasons why not. Look in more detail at maps of the geology and the land use. Find out whether the river's course has been altered by people at any time.

Describe briefly the relationships that you have been able to pick out between the changes in the channel's efficiency and

(i) the speed of flow of the river
(ii) the downstream slope angle at each site
(iii) the discharge

Evaluating your work

- When you took your measurements of depth was the interval between them small enough for accuracy, or did it mask some large boulders in the bed and some very deep pools?
- Was a systematic sample the best **sample** method to use? You took a systematic sample of the depth at regular intervals across the channel. What effect might a random sample have had? What effects would it have had on your data collection?

Do the hardness and other characteristics of the rock over which the river flows affect your result? Explain how.

Does the widthñdepth ratio give an accurate picture of the channel's shape and efficiency? Is the index of friction a more accurate way of describing the shape and efficiency of the channel?

If you have measured the speed of flow of the river does it seem to reflect the efficiency of smoothness of the channel?

Interesting extra ideas

- Look carefully at your cross-sections. Does the channel appear to be more smooth or less smooth above the water surface when you took your measurements? Can you think of reasons why?
- It would be interesting to return to your investigation sites in different weather conditions. Alternatively, write to the Meteorological Office at the address given in Appendix 2 (page 201) and on this website and calculate along the lines of the Trial Run on pages 126–129 the amount of rainfall received by your river's catchment. How quickly does your river respond to rainfall? Link this with your studies of the hydrological cycle.
- When the river is at bankful level it is the time *just* before flooding may occur. You have calculated the cross-sectional area of the channel at bankful level. Now, using measurements of the speed of flow, estimate what the bankful discharge would be. How much greater is bankful discharge than that which you have already measured?

  What advice would you give to prevent floods from occurring: (i) raising the banks, (ii) shortening the river's course where it meanders, (iii) dredging large boulders from the bed to make the channel more efficient?

This Extra Investigation has been created as an additional resource to accompany *Geography Fieldwork Projects* by Jennifer Frew, published by Thomas Nelson.

ISBN 0-17-434374-4

Thomas Nelson
Nelson House
Mayfield Road
Walton-on-Thames
Surrey KT12 5PL

Customer Services ☎: 01264 342992