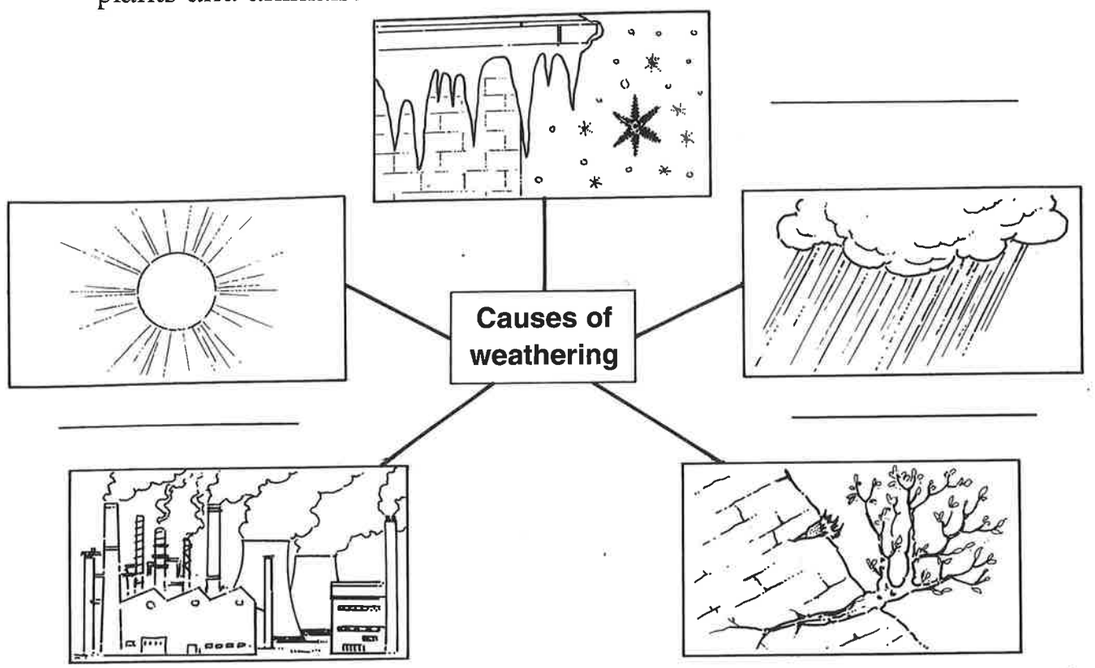
In this activity you will learn about weathering

Weathering is the breaking down of **rocks**.

It is caused by water and frost, by changes in temperature, and by plants and animals.



_____ _____

_____ _____

Activities

1 Use the words in the word box to label each picture in the star diagram above.

Word box

sun • rain • ice • plants
pollution

2 Draw lines to join up the 'heads' and 'tails'.

Sun	heats up rocks so they expand.
Pollution	have roots which grow into cracks.
Rain	makes rain more acid.
Ice	has acid in it.
Plants	freezes in cracks in rocks.

Recap ***Weathering*** *happens where* **r**_____ *are broken up by the* **w**_____.

In this activity you will learn about weathering

Weathering is the breaking down of rocks.

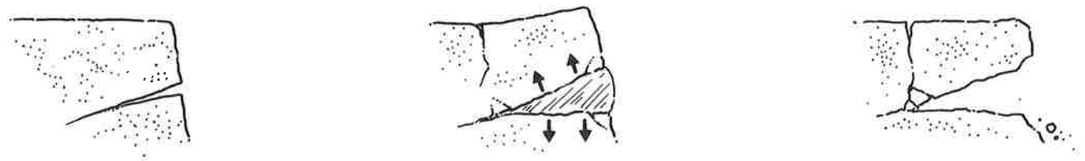
It is caused by **water** and **frost**, by **changes in temperature**, and by **plants** and **animals**.

Activities

1 Complete the diagrams by writing the correct labels in the spaces.

- water freezes and expands
- crack is made wider
- water gets into crack
- in time, rock is worn away
- chemicals in rain attack rock

Freeze-thaw weathering



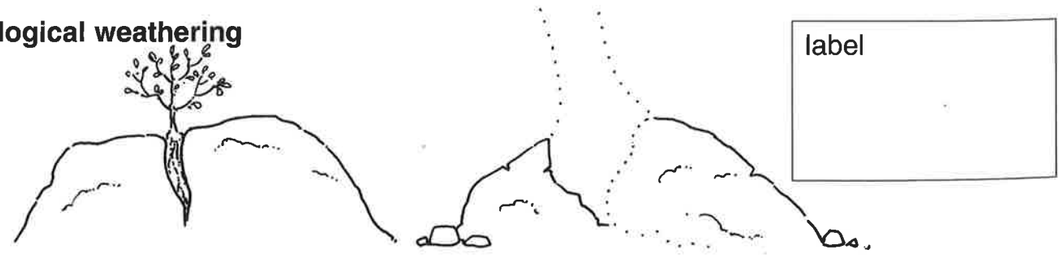
• _____ • _____ • _____

Chemical weathering

• _____ • _____

2 Complete the next diagram by joining the dots. Write a label to show how the rock has been broken up.

Biological weathering



Recap *Weathering is the breaking down of* **r**_____. *It is caused by* **w**_____ *and* **f**_____, *by changes in* **t**_____, *and by plants and* **a**_____.

In this activity you will learn how rivers shape the land

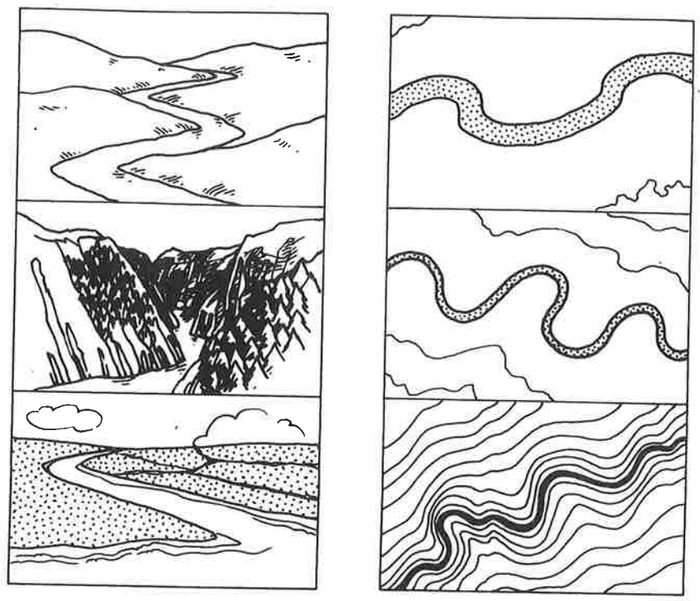
Rivers flow across the land. As they flow they **erode** the land to form **valleys**.

Activities

1 The information below shows a river at **three** places along its course from near where it starts, its **source**, to where it ends, its **mouth**.

Draw lines to join up the picture with the correct map and description.

The narrow river scrapes stones along its bed and erodes down. It flows in a deep, narrow 'V' shaped valley.
Weathering weakens the rock on the valley sides. The loose rock falls into the river and is carried away. The valley becomes wider.
The river is wide as it nears the sea. It is in a very wide valley.



2 Copy the statements in the Word box into the table below under the correct heading.

Word box

highest land • lowest land • near sea • near start • steep sides
almost flat land • wide valley • narrow valley • small river • bigger river

Source	Mouth

Recap Rivers **e**_____ the land to form **v**_____.

In this activity you will learn how rivers shape the land

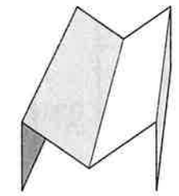
Rivers erode the land as they flow across it.
Stones are moved by a river and they scrape down into the land.
Weathering weakens the rock on the steep sides.
This loose rock washes into the river and is carried away. This is how the river cuts a **valley**.

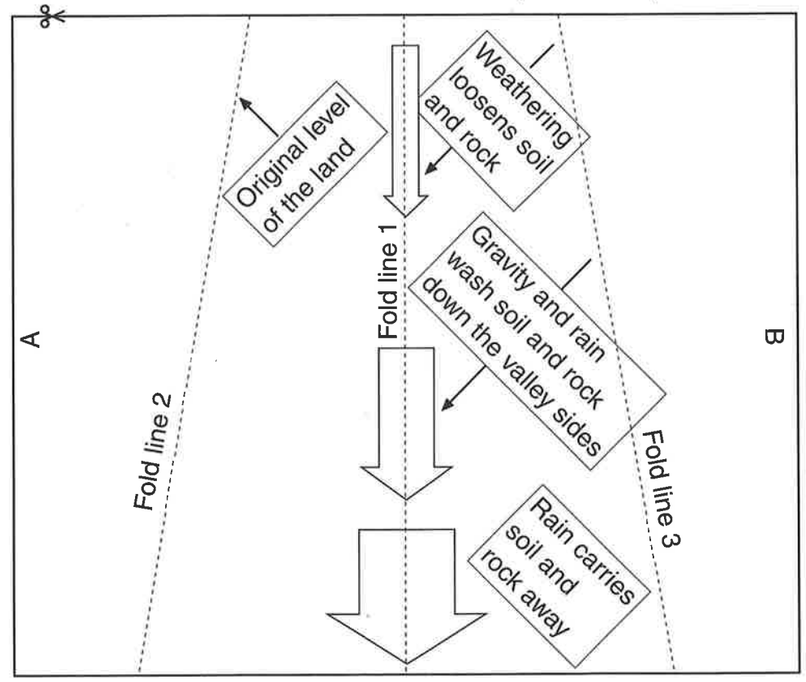
Activities

1 Follow these instructions to make a model river valley.

- Colour the large arrows in **blue**.
- Colour the boxes in **red**.
- Colour the rest of the area between the dotted lines in **green**.
- Cut out carefully along the thick cutting line.
- Fold edge A up to meet edge B along Fold line 1.
- Fold edge A back down along Fold line 2.
- Fold edge B back under along Fold line 3.

You should now have a valley model like this. →





2 Use the information on this page and on your valley model to explain in **four** sentences how a river cuts a valley. Write this in your own way in your exercise book or on paper.

Recap *Rivers shape the land by* ***e***_____ ***v***_____ *with the help of* ***w***_____ *and* ***gr***_____.

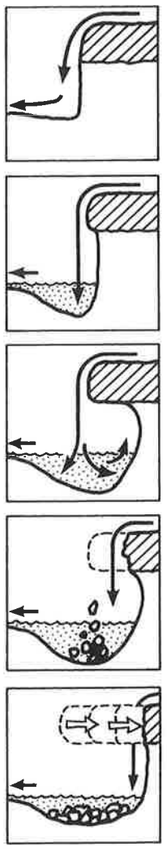
In this activity you will learn about waterfalls

Waterfalls are formed where rivers flow over bands of **hard rock** and **softer rock**.

In time a waterfall is eroded back.

Activities

1 The diagrams show **five** stages in the making of a waterfall. Match each of the following statements to the correct diagram by writing its letter on the line.



a The **falling water** erodes a deep lake called a **plunge pool**. ____

b The **hard** rock **collapses**. ____

c River **erosion** wears away **soft** rock to form a **step**. ____

d The **waterfall** moves **back** a little way. ____

e The **swirling water** undercuts the **hard** rock above. ____

2 Find four famous waterfalls in the circle diagram below.

Start at the top and work clockwise, writing down **every other** letter as you go.

Write the letters in the spaces in the sentences on the right of the diagram.

N _ _ _ _ _ _ in Canada in North America

_ _ _ _ _ _ _ _ _ between Zambia and Zimbabwe in Africa

_ _ _ _ _ _ _ _ _ in the USA in North America

_ _ _ _ _ _ _ between Brazil and Paraguay in South America

Recap *Waterfalls form when rivers flow over bands of* **h**_____ *and* **s**_____ *rock. Some famous waterfalls are* _____.

In this activity you will learn what happens on a river bend

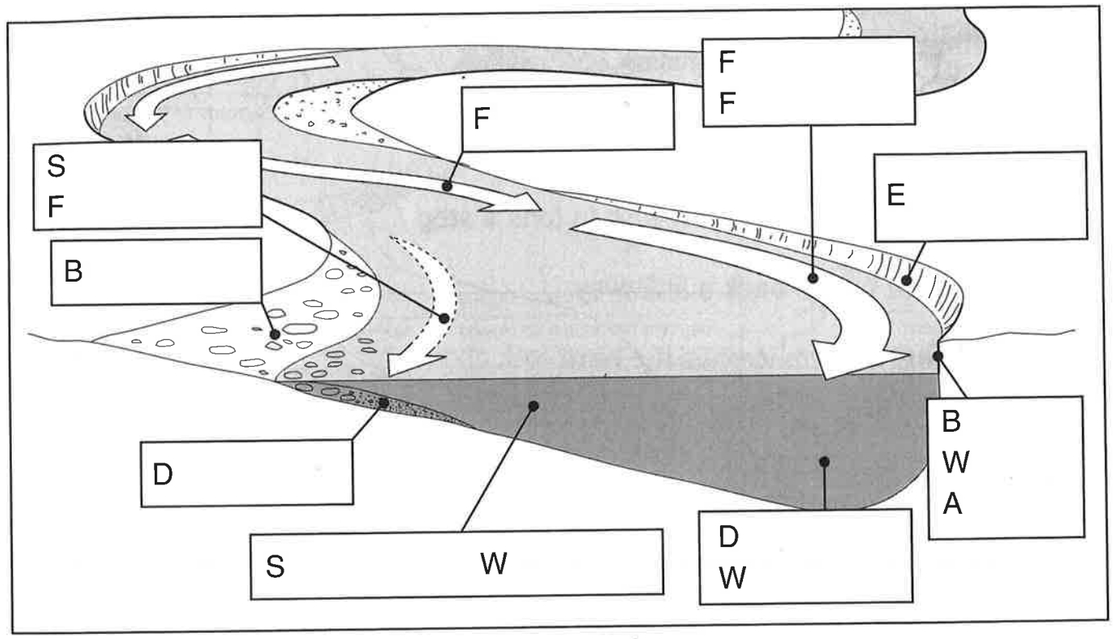
Meanders are **bends** in rivers.

There is **erosion** and **deep water** on the **outside** of the bends.

There is **deposition** and **shallow water** on the **inside** of the bends.

Activities

1 The diagram below shows a **meander** (river bend). Write labels in the boxes. Use the words in the Word box. The first letters are there to help you.



Word box

slowest flow • erosion
shallow water
bank worn away
deposition • fastest flow
deep water • beach
flow

2 To make the diagram clearer, colour:

- the banks in **brown**
- the beaches in **yellow**
- the arrows showing the **flow** of the river in **dark blue**
- the water in **light blue**
- the land in **green**.

Recap A river bend is called a **m**_____. Erosion happens on the **o**_____ of **m**_____.

In this activity you will learn what happens on a river bend

Meanders are **bends** in rivers.

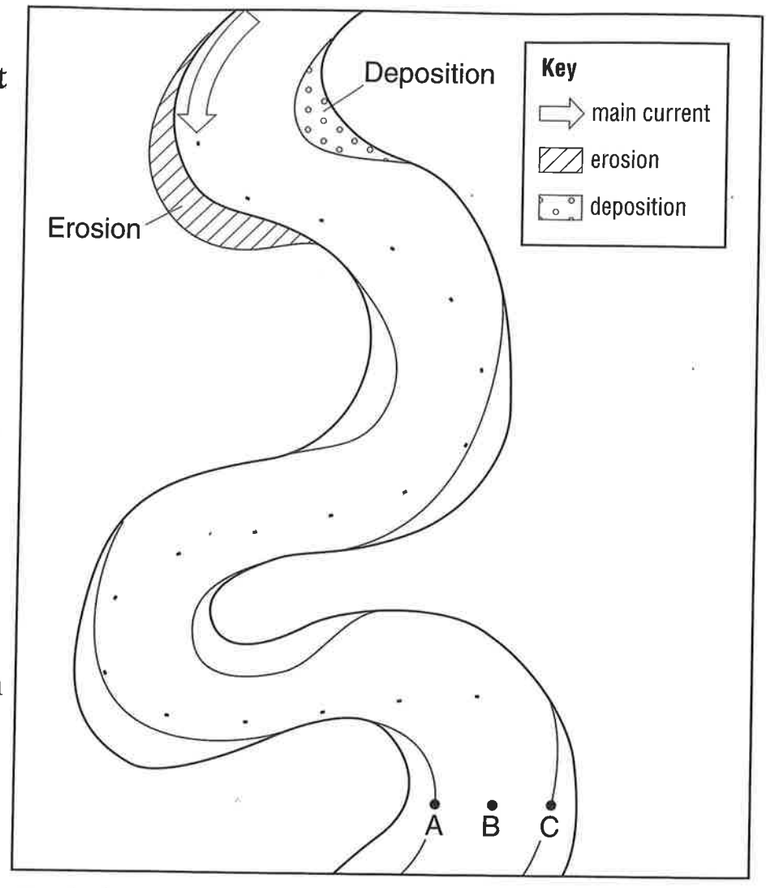
There is **erosion** and **deep water** on the **outside** of the bends.

There is **deposition** and **shallow water** on the **inside** of the bends.

Activities

1 The **map** shows a **short section** of a river.

- Draw a line to show the **main current** (fastest water) down the river. Start by joining up the dots.
- Colour the area labelled **erosion** in **red** and complete the key.
- Colour **three** other areas of erosion on the map, also in **red**.
- Colour the area labelled **deposition** in **yellow** and complete the key.
- Colour **three** other areas of deposition on the map.



2 Find **A**, **B** and **C** on the map.

At which of these points is the water **deepest**? ____

At which point is the water **shallowest**? ____

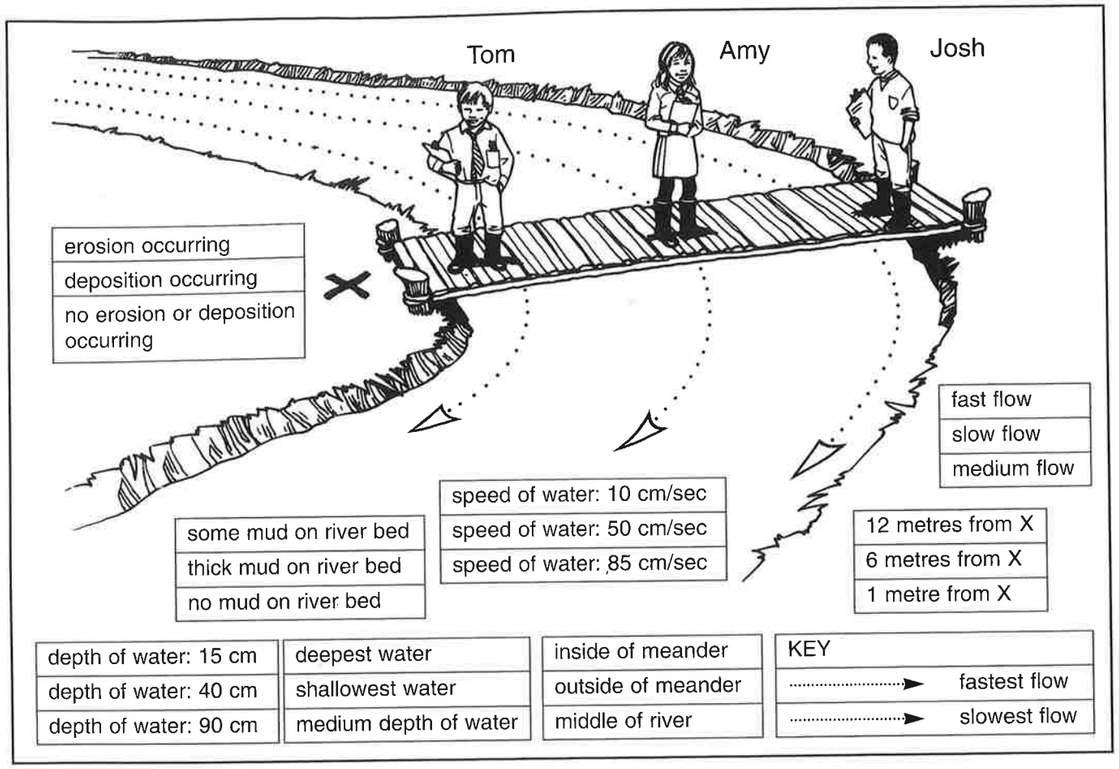
At which point is the river flowing **fastest**? ____

At which point is the river flowing **slowly**? ____

Recap *A river bend is called a* **m**_____. *The water flows fastest around the* **o**_____ *of* **m**_____. *The water flows most slowly around the* **i**_____ *of* **m**_____.

In this activity you will learn what happens on a river bend

A **bend** in a river is called a **meander**. The river flows **fastest** around the **outside** of the meander. As it flows it cuts into the bank and **erodes** it away. The river flows **slowest** around the **inside** of the meander. It drops **mud** here.



Activities

1 Tom, Amy and Josh (above) are standing at three points on a footbridge over a river. They are recording measurements and observations about the river at each point. Look at the statements around the picture. Colour:
   - Tom's statements in **blue** • Amy's statements in **red** • Josh's statements in **green**.
2 Draw over the dotted line which shows the **fastest** flow of the river with a **bold black** line. Complete the key with the same symbol.
3 Draw over the dotted line which shows the **slowest** flow of the river with a bold line in **yellow**. Complete the key with the same symbol.

Recap A m_____ is a bend in a river. The river flows fastest around the _____.
The river flows slowest around _____
_____.

5.1 » River valleys in their upper course

On this spread you'll learn about the importance of erosion in a river valley's upper course.

Buckden Beck

The photo on the right is of Buckden Beck – a small stream, or **tributary**, which flows into the River Wharfe in northern England. It has just begun its journey to the sea. In the photo, the stream looks as if it's flowing quickly over the small rapids and waterfalls. However it's actually flowing quite slowly, because a lot of its energy is lost through **friction** with the stream bed.

V-shaped valleys

The second photo shows the valley of Buckden Beck. Notice that:

- the valley has steep sides and a narrow bottom. It is **V-shaped**.
- the stream winds around ridges, or spurs of land, which jut into the river valley. These are called **interlocking spurs**.

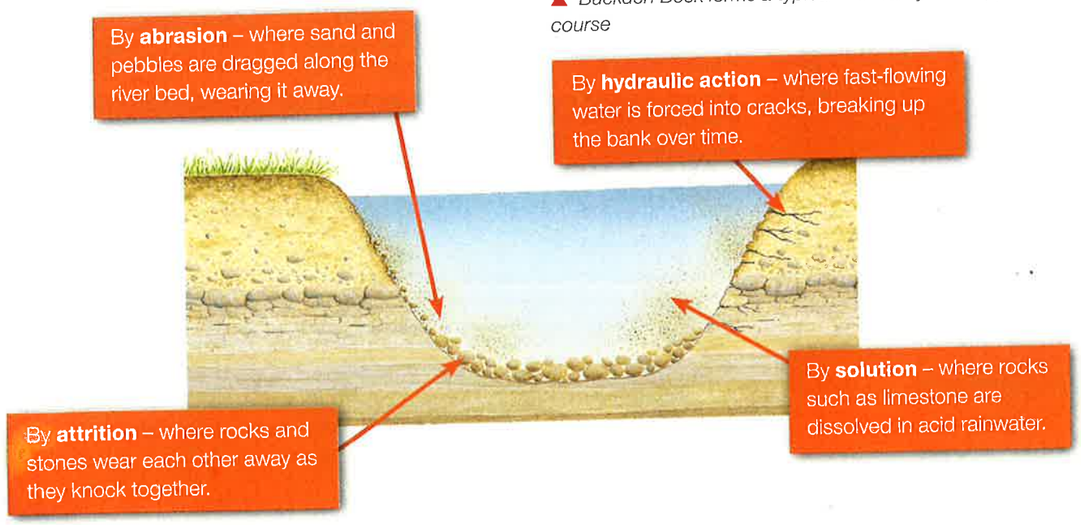
River processes

A river's energy allows it to **transport**, or carry, boulders and stones downstream (especially when heavy rainfall increases the energy). The stones then wear away, or **erode**, the river's **channel**. The river also transports smaller material in its current.

▲ *Small rapids and waterfalls are typical of a river's upper course, which tends to have a steep **gradient**, or slope*

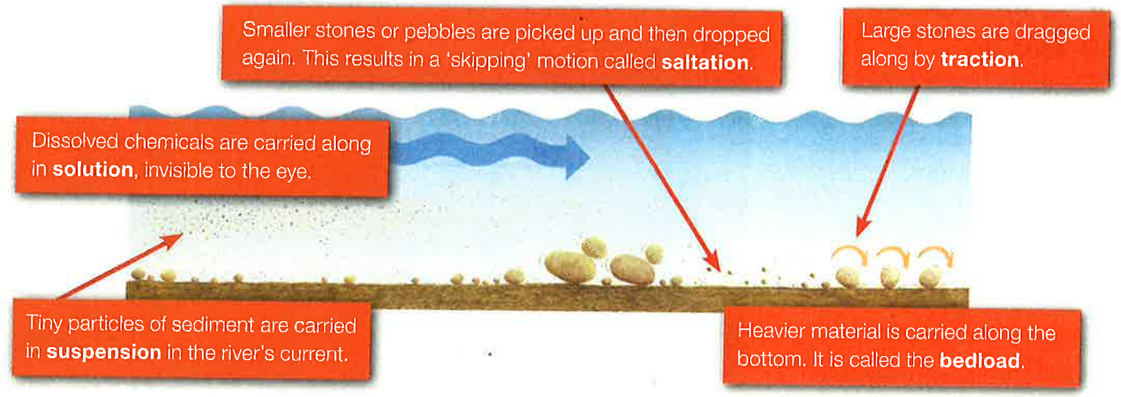
▲ *Buckden Beck forms a typical river valley in its upper course*

How a river erodes its channel



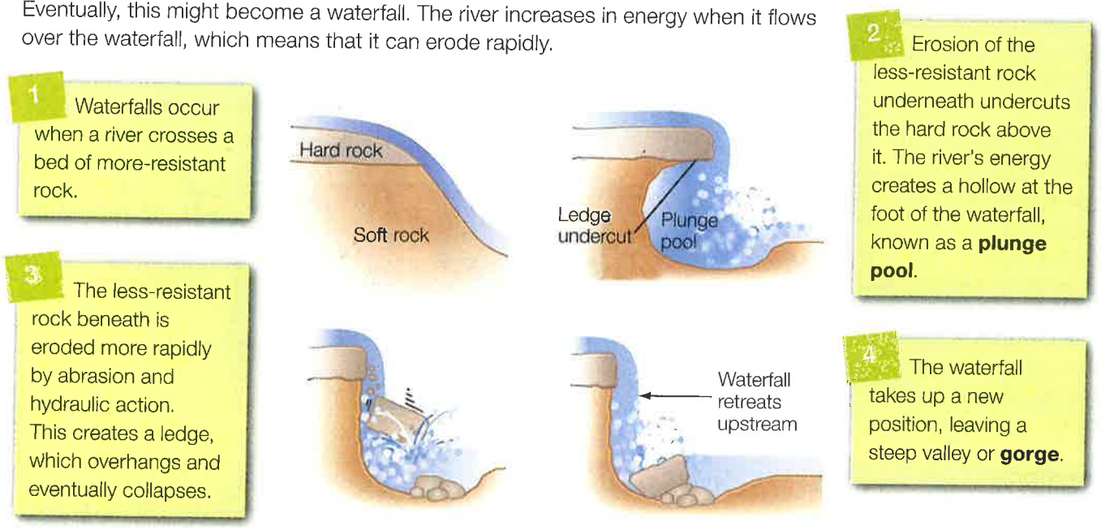
How a river carries its load

The material that a river carries is called its **load**. The size of the load that can be carried by a river depends on the amount of energy it has.



Waterfalls and gorges

In their upper course, rivers mainly erode downwards – or **vertically**. If the river flows from harder (**resistant**) rock onto softer, less-resistant rock, a step will form. Eventually, this might become a waterfall. The river increases in energy when it flows over the waterfall, which means that it can erode rapidly.



YOUR QUESTIONS

1 Work in pairs and test each other.
- **a** One partner should try to describe the four types of erosion.
- **b** The other partner should try to describe the four ways in which a river carries its load.

2 For each set of words below: **a** say which is the odd one out, **b** explain your choice.
- stream, tributary, river, waterfall
- solution, attrition, plunge pool, abrasion
- suspension, gorge, traction, load
- hydraulic action, saltation, suspension, traction

3 Draw a large simple sketch of the photo of Buckden Beck's valley. Add labels to show the features of the valley.

Hint: Start by drawing a frame the same shape as the photo. Draw lines to show the shape of the land and valley, but don't add lots of detail.

5.2 » River valleys in their middle course

On this spread you'll find out how rivers and their valleys change in the middle course.

The River Wharfe in its middle course

The photo shows the River Wharfe between Kettlewell and Starbotton, downstream from Buckden Beck. By now, the river is in its **middle course**. Several streams like Buckden Beck have joined the Wharfe, making it wider and deeper. In wet weather, the volume of water in the river can be so great that sometimes it floods over a broad flat area, known as the **flood plain**.

The valley shape has also changed. From the V-shaped valley of Buckden Beck, the flood plain has now broadened out the valley of the River Wharfe into a U-shape. The valley side rises steeply in the distance, where the flood plain ends. The OS map extract shows the wide, flat flood plain of the River Wharfe.

The river's energy

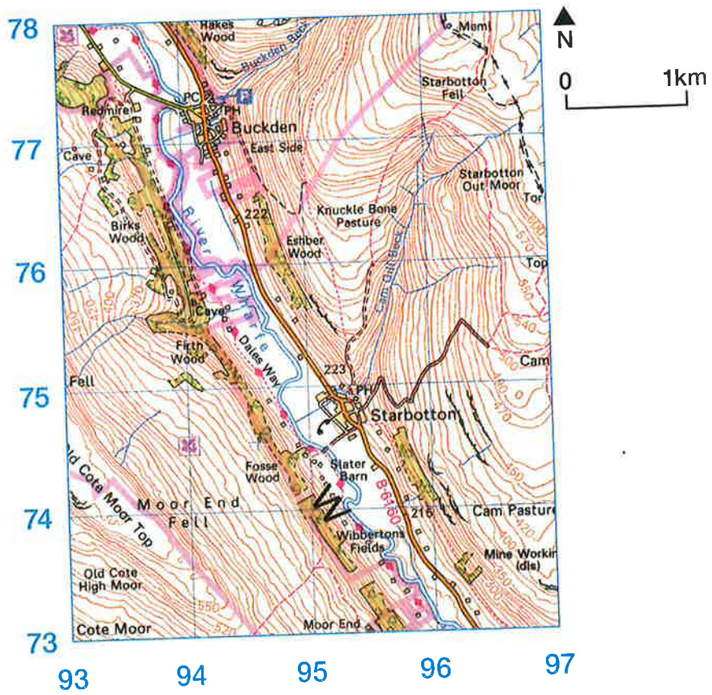
The River Wharfe has a gentle gradient by the time it reaches its middle course – but it actually flows faster than the upper course. This is because the greater volume of water in the river has more energy (once it's overcome friction). Now instead of eroding downwards, the river erodes sideways – or **laterally**.

Deposition

When a river no longer has enough energy to transport its load (such as in drier weather), it drops or deposits whatever it's carrying. It deposits the larger, heavier stones first, and then the smaller, lighter ones. The deposited material is called **sediment**. When the river floods over the flood plain, it deposits the lightest sediment – fine sand and clay – to form layers of alluvium, which is fertile and good for farming.

▲ *The valley of the Wharfe in its middle course. This is a **meander** and flood plain near Starbotton in Wharfedale.*

▼ *A 1:50 000 OS map extract of the River Wharfe in its middle course. Notice Buckden Beck in grid square 9477.*



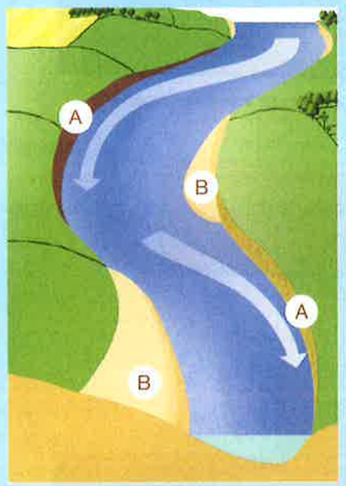
How meanders change the valley

Meanders are bends found in the river's middle course. They're natural features, which form as a result of both erosion and deposition.

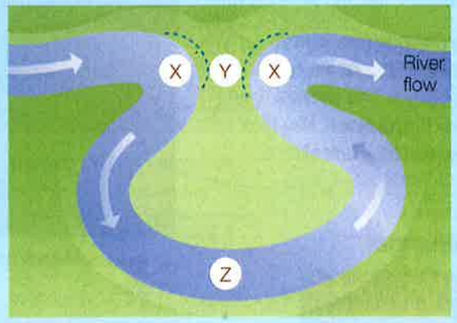
1 The water in a river flows naturally in a corkscrew pattern. This is called **helical flow**.

2 Helical flow sends the river's energy to the sides (laterally). The fastest current (called the **thalweg**) is forced to the outer bend (A), where it undercuts and erodes the bank to form a river cliff.

The helical flow then transports sediment from (A) across the channel to the inner bank (B), where the slower-moving water deposits it to form a **point bar**.



3 Continued erosion sometimes creates a narrow neck between two meanders (X). Eventually, the neck is cut through at Y, and the river creates a new channel for itself across the neck of the meander (an easier route for the water). The old meander then becomes an **oxbow lake** (Z), when deposition seals the ends – completely separating it from the river.



YOUR QUESTIONS

1. Draw a sketch of the photo opposite and add the following labels: flood plain, alluvium, lateral erosion, meander, thalweg, undercutting, point bar.
2. Using the information above to help, draw 3-4 labelled diagrams to show how an oxbow lake is formed.
3. The photo on the opposite page was taken at grid reference 957737 on the OS map extract, looking west towards Wibberton's Fields.
   - **a** Find the grid reference on the map.
   - **b** Describe the shape of the valley of the River Wharfe at this point.
   - **c** Explain why the valley (and the River Wharfe in its middle course) is different from the valley of Buckden Beck on page 96 and in grid square 9477 on the map extract.

5.3 » River valleys in their lower course

On this spread you'll find out how rivers and their valleys change in the lower course.

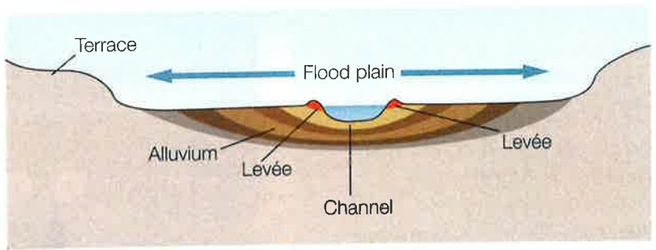
The lower course of the Wharfe

By the time the River Wharfe has reached its lower course, the differences with its upper course are really obvious! The river – once narrow with waterfalls – is now wide and deep, flowing over a gentle gradient. It has large meanders, it carries a large volume of water – and it has a wide, flat flood plain. This is low-lying and floods easily.

There are embankments beside the river. These can be either natural or artificial, and are known as **levées**.

- Natural levées form beside the river's bank where it first floods. As a river reaches **bankfull** i.e. before it spills onto the flood plain – it deposits sand and clay particles where the flow is slower. These build up beside the river and form a levée.
- Artificial levées are built by engineers to protect places from flooding. They are common in the UK along rivers like the Severn and the Ouse, and along some of the world's giant rivers, e.g. the Mississippi in the USA.

▲ *The lower part of the River Wharfe at Tadcaster*



▲ *Levées and flood plains*

Towards the sea

The River Wharfe joins the Ouse and eventually the Humber and forms an estuary – where the river meets the sea. Water flows in two directions here. The river flows **outwards**, taking water out to sea, and the sea flows **inwards** at high tide. Twice a day, incoming tides meet the outgoing river and the water flow stops, forcing the river to deposit its sediment, or mud, creating a broad wide area of **mudflats**.

▲ *Mudflats and salt marshes on the river Humber, near its estuary. Notice the artificial stone levée in the top right of the photo.*

Because the estuary is tidal, it is submerged by seawater twice a day. Plants which grow there have to be able to withstand salt water as well as fresh. **Salt marshes** are very important for wildlife. Migrating birds use them as shelter during stormy weather, and the mud is rich in shellfish and worms. But salt marshes are under threat from ports and industries – as the photo on the right shows.

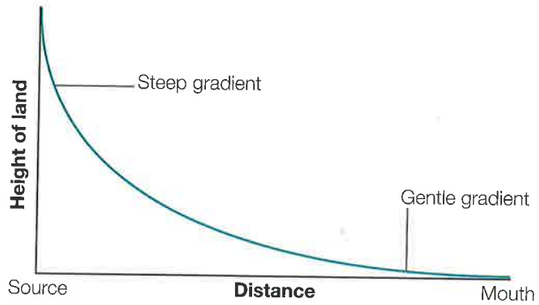
Long and cross profiles

As a river flows from its upper to its lower course, two kinds of changes happen.

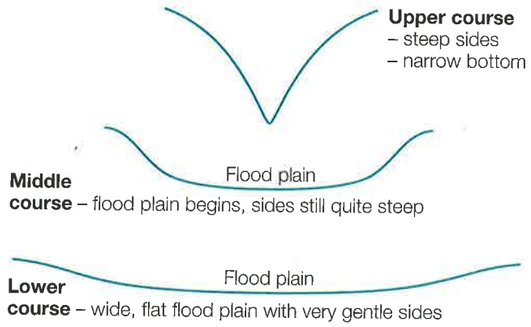
There are changes in its **long profile**. As the diagram below shows, the long profile is the way in which the gradient of the river changes. It is steep in upland areas and gentle in the lower course.

There are also changes in the **cross profile**, or valley shape. The valley is V-shaped in the river's upper course and almost flat by the lower course (see the diagram on the right).

▲ *An aerial view of the Humber estuary at Immingham. Estuaries have enormous economic value – providing both shelter for shipping and flat land for industrial development. But this can conflict with their value as a haven for plants and wildlife.*



▲ *The long profile of a river – showing how river gradient changes as the river moves from its upper to its lower course*



▲ *The cross profile of a river – showing how valley shape changes as the river moves from its upper to its lower course*

YOUR QUESTIONS

1 Explain what these terms mean: levées, bankfull, mudflats, salt marshes, long profile, cross profile.

2 Put the following phrases in the correct order to show how levées are formed:
- sand and clay particles are deposited where river flow is slower
- natural levées form next to the river bank where it first floods
- artificial levées are built to protect places from flooding
- these build up beside the river to form a levée
- as a river reaches bankful

3 Make a large copy of the table below and compare the river in its upper, middle and lower courses.

	Upper course	Middle course	Lower course
River features			
River processes			
Main landforms			
Outline sketch of valley shape			
Words to describe the long profile			

5.8 » Managing river flooding

On this spread you'll find out about the options we have for managing floods.

What's more important?

In the aftermath of the 2009 Cumbrian floods (see pages 104-106), local people were angry that more hadn't been done to prevent them. They accused the authorities of 'putting salmon before people', after their earlier request to lower the river bed by 3 metres in Cockermouth had been turned down, because it might harm fish stocks.

The cost of protection

Professor Samuels advises the government on managing rivers. He said 'It is technically possible to defend places like Cockermouth against extreme events, but only by building huge walls and embankments along the river, which would cost billions and alter the character of the town. For most people, that would be as unacceptable as the floods.'

No-one wants to go through what the residents of Cockermouth and Workington experienced. But as the likelihood of flooding increases, what options do we have to try to prevent flooding – or at least minimise its effects? And what are the costs?

▶ *New flood walls built next to the River Rother, at Rotherham, to protect homes and businesses there*

Hard engineering

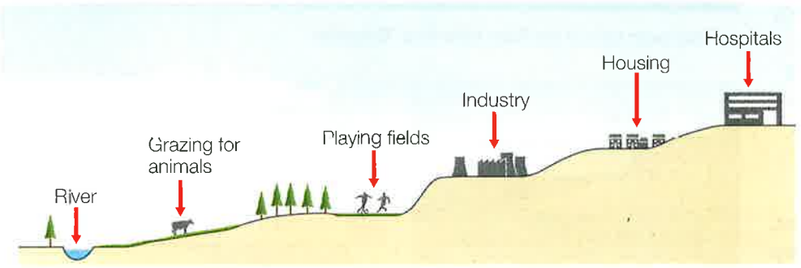
Hard engineering involves building structures to defend places from floodwater.

Method	How it works	Comment
Build flood banks	Raise the banks of a river, so it can hold more water.	Relatively cheap, one-off costs. Looks unnatural. The water moves quickly and increases the flood risk downstream.
Straightening and deepening the river	Straighten the river channel to speed up the flow, or line it with concrete. Dredge the river to make it deeper and able to carry more water.	Dredging needs to be done every year. Lining with concrete is expensive. Speeding up the flow increases the flood risk downstream.
Dams and reservoirs	Trap and store water, and release it in a controlled way. Can be multi-purpose and generate electricity.	Very expensive. The creation of a reservoir means huge changes to the ecosystem. Dams trap sediment.
Flood walls	Built around settlements, industry or roads.	Expensive and looks unnatural. Effective if the flood isn't too extreme.
Storage areas	Water is pumped out of the river and stored in temporary lakes. It's then pumped back when the water level in the river has dropped.	Effective, but it needs large areas of spare land.
Barriers, e.g. Thames Barrier	The barrier is raised when a high tide or flood is forecast.	Very expensive and, in the case of the Thames Barrier, a new one may be needed in future to protect London from higher flood surges.

Soft engineering

Soft engineering involves adapting to flood risks, and allowing natural processes to deal with rainwater.

Method	How it works	Comment
Flood abatement	Change the land use upstream, e.g. by planting trees.	This slows down the flow of rainwater into rivers, e.g. by increasing interception.
Flood proofing	Design new buildings, or alter existing ones, to reduce the flood risk.	It's expensive to alter existing buildings.
Flood plain zoning	Different uses are allowed, depending on the distance from the river (see the diagram below).	Land close to the river might only be used for grazing. The land furthest from the river is used for hospitals, old people's homes, etc.
Flood prediction and warning	The Environment Agency monitors river levels and rainfall. They use this information, plus weather forecasts, to predict flooding.	They issue warnings (see page 107) and produce Flood Maps, which show areas at risk from flooding.
Washlands	These are parts of the flood plain that are allowed to flood.	Washlands can't be built on. They're usually used for sports pitches or nature reserves.



◀ *Flood plain zoning*

Decisions ...

Flooding will keep on happening. In 2007, not only Gloucestershire flooded (see pages 58-59), but Sheffield did as well. Since then, the Sheffield authorities have debated what they can do to avoid serious flooding again. They have a choice of hard or soft engineering solutions. However, any decision has to take into account the costs involved, and the impact on people and the environment.

The Environment Agency believes that hard engineering is not the answer, and that soft engineering will make managing floods more sustainable. And that applies to other places too, not just Sheffield.

Phil Rothwell is the Head of Flood Strategy at the Environment Agency. After the Cumbrian floods, he said: 'The future isn't about hard engineering. We can't stop floods, and, in any case, people don't want us to turn our rivers into canals hidden behind huge embankments.'

Of course, there is one more option – and that is to do nothing.

YOUR QUESTIONS

1 Explain the difference between hard engineering and soft engineering options for managing floods.

2 Work in small groups.

- **a** Go to the Environment Agency website www.environment-agency.gov.uk and find the Flood Map for Cockermouth. (Follow the link 'Prepare for flooding'.)
- **b** Go to www.geograph.org.uk and look for photos of the river (either the Cocker or the Derwent) flowing through Cockermouth.
- **c** Use the Flood Map, the photos, and all the information on this spread to make a decision about the best way to protect Cockermouth from flooding in the future. You need to think about the costs involved, and the impact on people and the environment.

Hint: There is no one 'right' answer. But you must be able to justify the decision you make.