AS Geography 1.2 Fluvial Environments *Student Notes*

The physical and human causes of flooding.

You should be familiar with a single flood event, which has been influenced by both physical and human factors. The examination board likes you to use relatively recent examples (the Lynmouth flood was in 1952!!)

The Mississippi Floods in August 1993 caused 45 deaths and $10.5 million of damage. The floods destroyed 45.000 houses (including the town of Valmeyer in Illinois which has since been relocated on higher ground) and $6.5million of crops. 74,000 people had to be evacuated. Airports, roads and railways were flooded disrupting communications. Nine states were affected and the disaster qualified for Federal Aid. The Mississippi in St. Louis was nearly 16m above its normal level.

The flood had both human and natural influences:

Physical Influences

- Rainfall in the Mid-West USA was much higher than usual during the spring and early summer.
- Some parts of the Mid-West had 200% of their normal summer rainfall.
- In the Appalachian Mountains, heavy rainfall coincided with snowmelt.
- Soils were saturated and the field capacity had been exceeded.
- The Mississippi Flood Plain is broad and flat.

Human Influences

- Many towns and cities such as St. Louis and Valmeyer in Illinois had been built on the flood plain under the assumption that existing flood protection methods had controlled the Mississippi. Excessive growth and development on floodplains is a major problem. High runoff rates from urban areas increased the river discharge.
- Existing flood control measures had been built to a specification that had not anticipated the volume of water in the 1993 flood. Dams and spillways, built to control the floods could not handle the volume of water.
- Flood control levees allowed little room for the excess water and raised the height of water above the natural flood plain. When the levees were breached, the water flowed down hill onto its natural flood plain with much increased velocity.
- Earth levees downstream from protected urban areas were put under greater stress by the increased water pressure and were consequently breached.
- Meanders had been cut through to improve navigation. This reduced the river's lag time and increased its peak discharge and with devastating consequences.
- Wing dykes, built to encourage the river to erode its bed deeper for navigation, may have restricted the flow increasing the velocity and height of the floodwaters.
- Development on the floodplain has removed over 6.6 million hectares of wetlands, which would otherwise accommodate much of the excess water.
- Retuning the river water to its channel (often higher than the flood plain) adds to the problems.

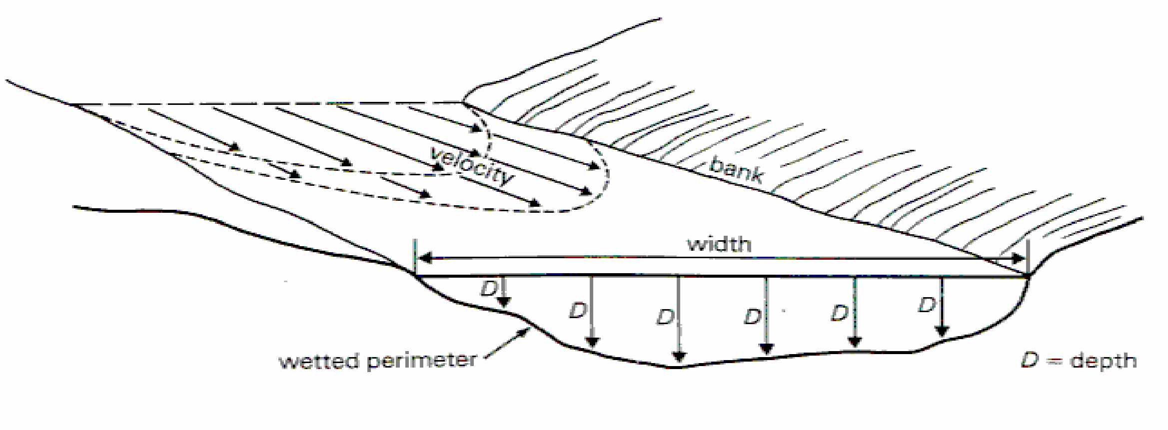
You should be able to research more recent flood events for yourself.

Downstream changes in velocity, discharge, efficiency (hydraulic radius), channel shape, and the factors that influence these changes.

You should be familiar with the downstream changes in a single river (perhaps the River Lyn from you fieldwork notes). You should compare your chosen river with the theoretical changes in the variables listed above. You need to understand reasons for the changes in order that differences may be explained.

- **Stream Channel Geometry.** This is a term used to describe the various measurable properties of a river channel including, width, depth, velocity, discharge, slope, gradient, roughness and wetted perimeter. (a measure of efficiency).

- **Shape**: (width, depth and cross section). In general terms, width, depth and cross-sectional area all increase with increasing distance from the source. However there will be considerable variation within relatively short distances. In "pools", width, depth and cross sectional area may be high (although velocity may be quite slow). In "riffles" the width may be narrow or wide but depth and cross sectional areas will be relatively small. Velocity, however, will be high. Cross sectional area can be calculated by taking regular depth measurements across the width of the channel both at the bank full level and at the current water level. The cross sectional area can be measured by plotting the data on a graph or by using appropriate software. On Farley Water, a headwater to the River Lyn on Exmoor, low order streams display shape characteristics that support the generalised theory.



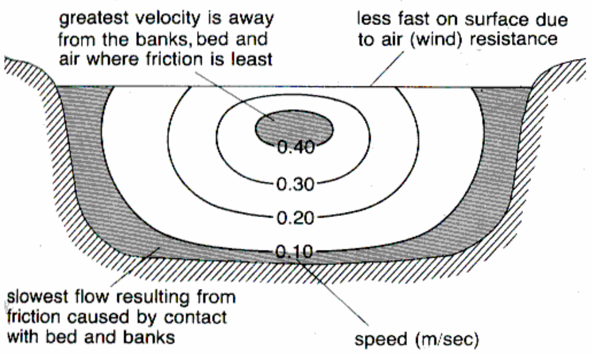
- **Efficiency (Hydraulic radius).** Channel efficiency can be measured by the hydraulic radius which is ratio between the cross sectional area and the wetted perimeter. The wetted perimeter is the length of the bed and banks in contact with the water. (This will vary with the rate of discharge).

  $$\textbf{Hydraulic radius (R)} \quad = \quad \frac{\underline{\textbf{Cross Sectional Area (A)}}}{\textbf{Wetted Perimeter }(\mathbf{P_W})}$$

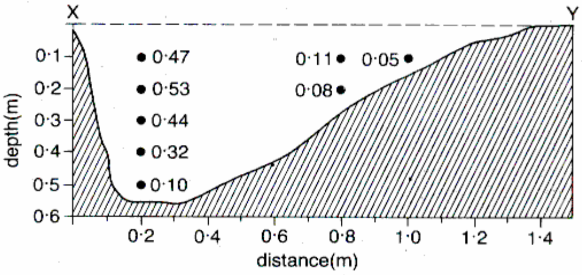
  If the value of the hydraulic radius (R) is large, a large area of water in the cross section is affected by each metre of bed so the frictional effect of the bed is limited and the efficiency is high. If the value of R is small, the frictional effect is large and the efficiency is low. Deep channels are generally more efficient than shallow channels. Larger channels are more efficient than smaller channels. In Farley Water, the hydraulic radius varies considerably over short distances (more efficient in pools). Generally efficiency increases within increasing stream order. The efficiency of the flood control channel through Lynmouth is designed to be highly efficient during times of flood.

- **Velocity.** In general term, velocity in many rives increases downstream as efficiency increases. Locally, there will be considerable variation in velocity depending on the hydraulic radius, the gradient and the level of roughness in the channel. Within a cross-section, velocity increases away from the bed and banks.

  The velocity pattern can be shown using **isovels**. Plot the isovels for the asymmetrical cross section shown below. (*You may wish to redraw the diagram*).



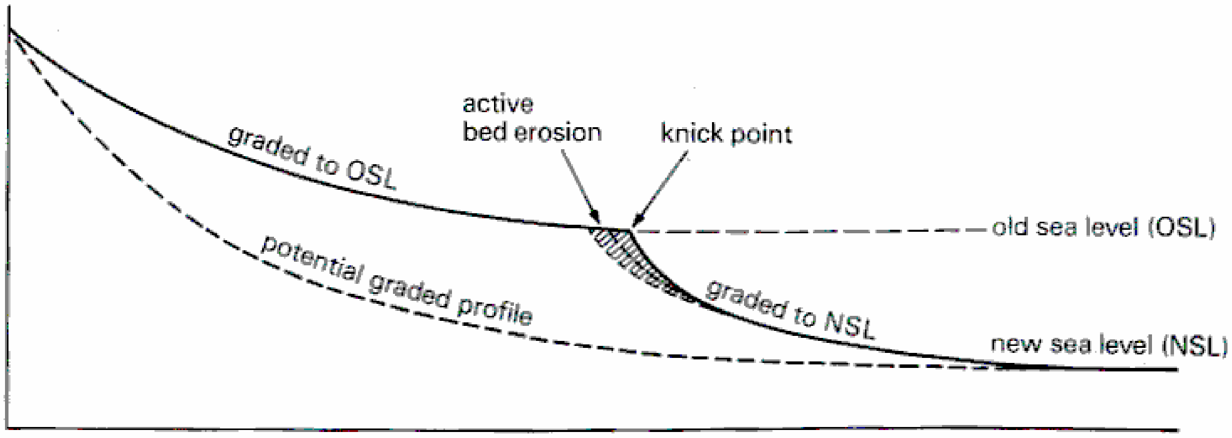
Depth (metres)	Distance from left bank (X) (metres)				
	0.2	0.4	0.6	0.8	1.0
0.1	0.47	0.29	0.23	0.11	0.05
0.2	0.53	0.32	0.18	0.08	
0.3	0.44	0.22	0.07		
0.4	0.32	0.10	0.01		
0.5	0.10				



In the Lyn, velocity increases with distance from the source but there are considerable small-scale local variation, particularly between pools and riffles and with distance from the bed and banks. Velocity is also influenced by the bed roughness which also creates turbulence in the flow.

- **Discharge** is the rate of flow of a river at a particular location at a particular moment in time. It is measured in cumecs (cubic metres per second or m^3/s) by multiplying the cross sectional area (in m^2) by the velocity (in m/s) In the Lyn there are clear "Steps" in the discharge with increasing stream order. Discharge also changes quickly after a storm event. The River Wye (Wycombe) by contrast shows much less variations in discharge as it is largely fed from ground water sources. Chalk streams can display declining discharge with distance from source due to seepage through the permeable bedrock when the water table is low.

- **Slope / Gradient.** In general terms, most rivers show a gradual decline in gradient with distance from source. This is described as a graded profile (see below). Over short lengths of stream, gradient is usually steeper in riffles and less steep in pools. Some rivers, including the river Lyn display sudden increase in gradient, which may result either from geological variations (see later notes on waterfalls and rapids) or where changes in the rivers base level has resulted in rejuvenation. The gradient increases at a knick point as the river tries to achieve a new graded profile. In the case of the Lyn, rejuvenation has resulted from coastal erosion into the side of the rivers valley (at Lynmouth), which has shortened the route to the sea thus increasing the gradient. The step gorge-like valleys of the lower Lyn are a response to this change. Over time, repeated rejuvenation may lead to the formation of river terraces.



- **Roughness.** The friction of the bed and banks of a river varies with how "rough" it is. A bed of smooth silt creates much less frictional drag than a bed with coarse angular gravel and boulders. Channel roughness is difficult to measure directly. In 1889, an engineer called Manning calculated a roughness coefficient by linking cross section (A), discharge (Q), hydraulic radius(R) and channel slope (S). Manning's coefficient is "n". The higher the coefficient, the rougher the bed and banks.

$$\mathbf{Q = A \times \frac{R^{0.67} \times S^{0.5}}{n}}$$

Examples of Manning’s Coefficient of bed roughness:

Surface	**Manning’s “n”**
Very smooth like glass	0.010
Concrete lined channel	0.013
Winding natural Channels	0.025
Mountain stream with rocky bed	0.040-0.050
Alluvial channel with small ripples in the sediments	0.014-0.024

The River Lyn shows high levels of roughness throughout its course, with the exception of the flood control channel through Lynmouth itself. This is due to the steep slopes of the valleys which have weathered and eroded providing large quantities of rough rocky material, some of which has entered the stream channel, either through direct rockfalls, or through having been washed into the channel during past flood events.