

UNIT 1 Hydrology and Fluvial Geomorphology

Recommended Prior Knowledge: Students require little prior knowledge for this unit. They may have some foundation from Key Stage 3 and /or IGCSE topics. However it is recommended that to create a level playing field the concept of the hydrological cycle is introduced in the first or second lesson.

Context: Although this is a discrete unit, there are close links with all the units that follow, as water is a vital resource without which none of the other physical units could operate. Processes such as evaporation and condensation introduced here are fundamental to the whole of Physical (and Human) Geography.

The unit covers the functioning of the hydrological, fluvial and human aspects of drainage basins.

Content	Objectives	Terminology	Teaching Strategies (TS) and Activities (A)	Resources
The Global Hydrological Cycle	<ul style="list-style-type: none"> Understanding of hydrology Knowledge of the global hydrological cycle <p>To understand the distinction between open and closed systems</p>	<p>Hydrology Hydrological cycle</p> <p>System-open/closed</p> <p>Components: Flows/stores/ Input/outputs</p>	<ul style="list-style-type: none"> TS. To introduce the idea of a system via analogy. Open Systems e.g. Car, computer, Domestic water supply. Closed system: central heating/air con Global Hydrological cycle-why a closed system? A. Flow diagram Fig 1 Boxes for stores, arrows for flows. Could be completely blank or partially filled in. Same diagram on OHP or board to be filled in by teacher as discussion with class proceeds as they complete their diagram. Written definition of global hydrological cycle containing 3 ideas 1. Closed 2. Water 3. Scale. May or may not contain volumes of water involved. Useful to suggest climatic variation in volumes of water. 	<p>Waugh p.45</p> <p>Hart, OCR text. P1-2 fig.1.4 Ross et al. p.221 fig. 7.1 Bowen and Pallister p.6 Fig.1</p> <p>Guinness and Nagle P.1 Fig.1 Prosser, Raw and Bishop p.41 Fig 1 The Global Hydrological Cycle See Prosser, p.41 Waugh, p.58 fig. 3.1 excellent flow diagram.</p>

<p>The Drainage Basin hydrological cycle (1.1)</p> <p>Components of the drainage basin system (1.1)</p>	<ul style="list-style-type: none"> An open system Appreciate that it is a spatial unit Know its components-flows stores, inputs outputs Understand the links between the components Each component of the system should be developed Remember that the channel is an important store and flow within the basin system Appreciate operation of some of the components eg Overland flow esp. in relation to climatic variations 	<p>Watershed Catchment area Precipitation, interception, throughfall, stemflow, runoff/overland flow Discharge infiltration, throughflow percolation baseflow, groundwater, recharge water tables, evaporation, evapotranspiration Gauging Station</p> <p>Saturated overland flow Hortonian or infiltration excess flow</p>	<ul style="list-style-type: none"> TS. Teacher uses an OHP or board to build up the drainage basin diagram with class. A. Compile a cross-sectional diagram or flow diagram of a drainage basin. Fig 2 The pictorial version is easier than flow diagram to appreciate. Outline of surface, soil, rock water table could be given or done from scratch. Sun, vegetation, urban areas, water bodies and river channel added. Different Colours used for flows, stores inputs, outputs to distinguish them. Students could be introduced to flow diagram as consolidation. A. The component groups of flows, stores inputs and outputs could be coloured. A. Written definitions of the processes. A. A written account of the drainage basin system The concept of discharge needs to be introduced at an early stage. TS and A. Details of all the processes at work within the system and factors that influence those processes and the inter-relationships between the processes, e.g. Soil moisture affects infiltration capacity etc. <p>TS. Relationship between infiltration capacity and rainfall intensity is significant in producing different reasons for overland flow. If infiltration capacity is greater than rainfall intensity then the stores will fill before overland flow occurs. This situation is typical of humid climates. E.g. UK This type of overland flow is known as Saturated overland flow. If rainfall intensity exceeds infiltration capacity then Hortonian (or infiltration excess flow) flow occurs. The water cannot enter the ground so it runs straight off the surface. This occurs in arid and semi-arid environments where the rain is</p>	<p>Fig 2 Flow diagram of the drainage basin system Hart p.5-7 Good pictorial diagram fig. 1.13 p.7</p> <ul style="list-style-type: none"> Ross et al. p.222-224 good cross sectional diagram p. 224 Bowen and Palliser p.7-10 Guinness and Nagle p.2 Good definitions of components of interception. Prosser et al. p.44 A useful diagram p.44 fig. 2.8 p.61 Nagle Good cross section and definitions Ross et al p224 useful practice questions p.19 Hart passing ref no detail
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			<p>intense or in areas of impermeable surfaces</p> <ul style="list-style-type: none"> Water table variation as a function of ppt-evap rates 	
<p>Rainfall-Discharge relationships The concept of Water balance (1.2)</p>	<ul style="list-style-type: none"> Understand the water balance equation Knowledge of components Understanding that a drainage basin responds to a given input of rainfall. Ability to draw such a graph 		<ul style="list-style-type: none"> Water Balance equation $P = Q - E + S$ Explanation of all the elements of the equation, emphasising how storage may be an addition by large volumes of antecedent moisture or subtracted via abstraction for instance. Articulate practical difficulties of measurement of evapotranspiration for instance. However useful concept. 	<ul style="list-style-type: none"> p.60 Nagle 226 – 228 Ross et al
<p>The storm (flood) hydrograph</p>	<ul style="list-style-type: none"> Understanding of factors Knowledge of a range of factors Understanding the inter-relationships between the factors 	<p>Storm Hydrograph Lag time Rising limb Falling limb Peak Baseflow separation line Flashy hydrograph Attenuated peak</p>	<ul style="list-style-type: none"> Begin with a theoretical diagram of the storm hydrograph. Label fully including the axes. Fig 3. Give some figures and a graph can be constructed. This could be reinforced by a “living graph” exercise – give students a basic outline of a hydrograph with a series of explanatory captions which need to be inserted/attached around the diagram. This can be very effective way of promoting discussion of the relative influence of different processes as well as a possible revision exercise. This could then be developed to look at the effects of different factors. 	<ul style="list-style-type: none"> p.48 Prosser P.229 Ross et al Fig. 3 P.14 Bowen and Palliser P.61 Waugh p. 62-3 Nagle <p>Fig.3. Storm Hydrograph</p>

<p>The factors that influence the hydrograph of a river</p>	<ul style="list-style-type: none"> Knowledge and understanding of land use changes and their effects on inputs outputs stores, flows in the drainage basin and hydrographs 	<p>Land use Rainfall duration and intensity</p> <p>Drainage density Porosity Permeability, Aquifer Wilting point Field capacity</p>	<p>A range of different hydrographs could then be shown as a springboard to for discussion about the factors which influence the nature of hydrographs. Fig 4</p> <p>Drainage Basin characteristics: size, shape, drainage density, soil moisture, rock type, slope, vegetation land use.</p> <p>It is worth emphasising that shape is a factor when area is the same. Attenuated response in elongated whereas flashy in round basins. Case studies could be effective in illustrating these general principles.</p> <p>Extension Study: Detailed drainage basin morphometry in terms of bifurcation ratios etc.</p> <p>TS. Introduce the idea of permeability: ability to transmit water and porosity: volume of pore space. The two are linked via the connectivity of the pore space. If the pores are interconnected then the rock/soil may be porous and permeable e.g. Sandstone. If the pores are tightly packed water holding is possible but transmission is very slow e.g. clay. Optional-Introduce idea of a pervious rock which is one which is permeable via joints and bedding planes.</p> <ul style="list-style-type: none"> Clays are porous but not permeable, sandstones are porous and permeable, chalk is not as porous as clay and is permeable Limestone is pervious but not porous. Analogies can be used like sponges-real and synthetic and colanders! Links to water tables, aeration zone and saturation zone 	<ul style="list-style-type: none"> p.49 Prosser has a good detailed table of factors p.230 Ross <p>Ex. P.231</p> <ul style="list-style-type: none"> Hart P.24 has a summary table P.62 Waugh P.65-6 Waugh p.236-7 Ross p.83-86 Nagle <ul style="list-style-type: none"> p.63 Waugh p.14 Hart <p>p.46 Prosser</p>
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<p>The Human Impact (part of 1.4)</p>			<p>The important aspect here is how these factors and combination of factors influence the nature of the response of the river. Therefore they should be studied together with a selection of hydrographs. Develop ideas of changes in these factors cause different responses and changes to the volumes and nature of the flows. Human activities are a significant factor in influencing hydrographs. It may be useful to include human activities in this section as well in terms of river basin management (1.4). Equally human activities could be considered in that section only. E.g. Land use changes such as deforestation, afforestation, pasture to arable farming or vice versa, dam and reservoir building, urbanisation- concrete surfaces are impermeable hence their inability to transmit water therefore increased surface run-off. Make sure students can develop a full explanation rather than assuming that it can be taken as read that concrete is impermeable. Water abstraction and water quality should be consideration either as part of a relevant case study or in general terms. Depending on the river basin chosen political factors may be relevant where the river crosses international boundaries.</p>	<p>Fig.4 Hydrographs for catchments under different catchments</p> <ul style="list-style-type: none"> • p.64-5 Nagle has very good detailed diagrammatic visual material on urban hydrology. Also good on deforestation p.69 and dams p.68 • P.100 Waugh • P.51 Prosser • P.232-3 Ross • P.28 Hart • Waugh p.69-70 • P.72 Waugh • For data on UK drainage basins, try the National Water Archive on http://www.nerc-wallingford.ac.uk/ih/nrfa/river_flow_data/ • Also hydrology web on http://etd.pnl.gov:2080/hydroweb.html • For rivers and dams, try http://www.irn.org/basic/s/ard/
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<p>The Channel as a system (1.3)</p>	<p>Dynamic equilibrium</p> <ul style="list-style-type: none"> • Knowledge and Understanding of channel variables • Relationships between the variables 	<p>Gradient of channel bed Load-capacity and competence</p> <p>Hydraulic radius Discharge Wetted perimeter</p> <p>Channel efficiency</p> <p>Channel roughness Capacity Competence</p>	<p>TS Discussion with the group the basic ideas and concepts can be introduced.</p> <ul style="list-style-type: none"> • Recap on the concept of a system- inputs outputs flows, discharge. Idea of moving water because of gradient, therefore energy to carry out work. • Ask what the work would be in a channel. • Introduce idea of dynamic equilibrium with respect to a river channel. i.e. Adjustment of channel bed to transport its load. • Suggest that there would be a changing dynamic downstream as a result of a number of aspects of the channel which vary. i.e. variables. • What are they and how may they change downstream? • Discharge. Define and use as a springboard for discussion of cross sectional area which links directly to hydraulic radius via wetted perimeter. Look at two or three comparative diagrams of cross sectional area. <p>A. Students could do an exercise where they plot channel cross sections on graph paper and then calculate the hydraulic radius. That links to the idea of channel efficiency which can then be discussed. Introduce idea of how variable discharge can influence channel efficiency by changing the level of water in the channel. (This idea will be picked up again in relation to landforms like braided channels.</p> <ul style="list-style-type: none"> • The other variables can be discussed once this route has been plotted to form the foundations of the succeeding 	<ul style="list-style-type: none"> • Ross et al. P.241-3 This is a good source with practical exercises on hydraulic radius and channel efficiency • P.79-81 Nagle • The Virtual River web site at http://vcourseware5.alstatela.edu/VirtualRiver/
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		Flows-laminar, turbulent, helicoidal	<p>sections on process and form</p> <ul style="list-style-type: none">• Channel roughness. Mannings' N could be considered as a measure of roughness.• Gradient• Velocity• Competence• Capacity• Friction/flow characteristics • To reinforce all these ideas field work or use of a sand tank would be ideal. However if this is not possible then discussion of measurement in the field in theory can aid understanding. e.g. difficulty of measuring discharge in low / high flow conditions. Orange peel and cork v. flow meters in terms of accuracy and practicality.	<ul style="list-style-type: none">• p.103 Nagle
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<p>Fluvial Processes (1.3)</p>	<p>Knowledge and Understanding of processes of erosion transportation and deposition'</p> <ul style="list-style-type: none"> • Direction of erosion • Hjulstrom curve-Link between process and load 	<p>Abrasion/corrasion Corrosion/Solution, hydraulic action as erosion and transportation Traction Suspension Saltation Entrainment Critical erosion and deposition velocity Bed load Solutes</p>	<p>At the outset emphasise that these processes are influenced by the dynamics of the channel, inter-relate and produce landforms which will be the next section of the work.</p> <p>Result from the energy possessed by the river.</p> <p>Processes of erosion most authorities consider that abrasion and corrasion result from the action of the transported load. The load is the tool for erosion. Closest analogy like 'sandpaper'. Assists in undercutting and bank caving. More especially linked to turbulent flow and potholes in river bed. Hydraulic action sheer power of water. Cavitation is the implosion of gas bubbles in turbulent flow causing shock waves and weakening the banks of the channel in particular. Both processes lead to bank caving.</p> <p>Vertical, headward and lateral erosion should be covered either here or in connection with landform development.</p> <p>Processes of transportation can be done easily by means of one diagram, which shows traction/bed load, saltation, suspension and solution.</p> <p>Hjulstrom curve Fig. 5 Begin with a diagram of the graph. Emphasise what it demonstrates via the axes of the graph. Explanation can be done by annotating the graph, highlighting critical erosion and deposition velocities in relation to fraction of the load. Reasons why clay needs such a high velocity when they are such small particles. Distinguish between entrainment and settling</p>	<ul style="list-style-type: none"> • Erosion p.87 Nagle • p.54 Prosser • p.240 Ross. Good exercises 242 - 244 • p.19 Bowen and Palliser • p.72-3 Waugh Contains a good case study of the Afon Glaslyn in Wales. There is a video to go with it. • p.20 Bowen and Palliser • p.88-91 Nagle • p.21 Bowen and Palliser • p.55 Prosser • P.240 Ross Fig 5 Hjulstrom curve • P.72 Waugh • P.21 Bowen and Palliser • P.241 Ross
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			<p>location of these curves on the graph. Entrainment (ability of the river to transport material) is the velocity line between erosion and transportation and the settling velocity marks the division between transportation and deposition</p>	<ul style="list-style-type: none">• P.55 Prosser• P.95 Nagle-good whole page spread
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<p>The nature of channels (1.3)</p>	<p>Link between process and form</p> <ul style="list-style-type: none"> • Straight • Meandering • Braided 	<p>Braided channel Eyot Meander Pool Riffle Flows-laminar, turbulent, helicoidal</p>	<p>TS. Fig 6 and 7 can form the basis for introduction of different types of channel Discussion can focus on the contrasts and reasons for the contrasts. Conditions under which each occur, e.g. Braided channels found in areas of variable discharge and large loads whereas gradient variation causes meandering channels Fig 8 and Fig 9 can be used as additional teaching aids</p>	<ul style="list-style-type: none"> • P.62 Prosser <p>Fig. 6 A Meandering Channel Fig.7 A Braided Channel Fig 8 An annotated braided channel Fig. 9 A typical flood plain</p> <ul style="list-style-type: none"> • p.93 Nagle very good on meandering channels • p.248 Ross. 'The Great Meander Debate' contains useful graph correlating bankfull discharge and channel slope and plots meandering and braided channels-has been used as stimulus material in exam questions
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<p>Landforms (1.3)</p>	<p>Classification according to processes of formation</p> <ul style="list-style-type: none"> • Erosional forms- waterfalls, gorges • Meander characteristics • Depositional- point bars floodplains, levees, alluvial fans, deltas. 	<p>River cliff Slip-off slope Point bar Waterfall Plunge pool Rapids Gorge Bluff Floodplain Levee Cut-off/ox-bow lake Alluvial fan Delta</p>	<p>Description, explanation and an example or examples of these landforms is needed. Annotated diagrams can be a useful way of condensing the material. The floodplain with its assemblage of features can be considered as a section of work. This could be a way of creating the link between the geomorphology and the human impact on the physical environment i.e. The final section of work in this unit.</p>	<ul style="list-style-type: none"> • p.75-80 Waugh • p.23-31 Bowen and Palliser • p.245-252 Ross • p. 58-65 Prosser <p>Good flood plain diagrams Ross p.257 and Prosser p.64</p>
<p>The Human Impact (1.4) Floods</p>	<ul style="list-style-type: none"> • Knowledge of causes of river flooding. (The unit is about fluvial processes so examination questions refer to river flooding as opposed to flooding by the sea.) • Understanding of effects. Floods as a hazard • Prediction • Prevention • Amelioration • management 	<p>Bankfull discharge Overbankfull discharge</p> <p>Recurrence interval</p> <p>Hard engineering</p>	<p>Flood risk, prediction in terms of measurement like recurrence intervals. (Prediction is often given insufficient attention and it may be examined in its own right). Factors such as global warming and climate change could be covered as factors influencing prediction and management. Inadvertent changes versus management strategies which are part of possible amelioration could be considered</p> <p>A case study would be the obvious route. River basin management and river channel management. There are many well-documented examples other than the Mississippi.</p> <p>Hard and soft engineering techniques. General principles of physical geography could be the starting point for instance, increasing channel capacity, decreasing discharge and then how the engineering</p>	<ul style="list-style-type: none"> • P.100-1 Nagle • Causes of floods Guinness and Nagle p.18 <p>Bowen and Palliser p.32 Ross p.259</p> <p>Flood prediction Hart p.29-30 http://www.pbs.org/wgbh/nova/flood/deluge.html</p>

		<p>Soft engineering Management strategies- wing dykes levees, etc.</p>	<p>schemes can achieve these objectives rather than just a catalogue of measures. Perhaps the catalogue can be the starting point and students are asked what the objective is and then a classification can be drawn up. Emphasise the impact of the human activities upon the physical environment rather than the human activities as ends in themselves i.e. Hydrograph changes, modifications to channel and impact on discharges which then result in floods. The case study could include consideration of human use of, and impact on, flood plains</p>	<p>p.68-73 Prosser Good on soft engineering p.71</p> <p>Management - Guinness and Nagle AS concepts Several case studies. P.18-34 Also found in AI Concepts and cases p.249-292 Mississippi and Yangtze</p> <p>Ross distinguishes between channel and basin management p. 253-268</p> <p>Bowen and Palliser Case Studies in LEDCs AND MEDCs Severn and Bangladesh 1998 4 further case studies</p> <p>Waugh Mississippi very detailed p.87-90</p> <p>Yangtze p.91-7</p> <p>Hart p.31-2 Good on protection measures</p>
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