Water Cycle: Lessons using data skills

Royal Geographical Society with IBG
Advancing geography and geographical learning

Lesson 3: Comparing hydrographs: how does land management affect storm discharge?

Lesson Objective

- To understand how the discharge is measured and predicted in rivers and streams
- To understand and describe the impact of rainfall events on discharge patterns
- To understand and describe the effects land use management has on river discharge patterns

Setting the Scene

At least 6 million properties in the UK are at risk of flooding, with the latest floods in December 2015 seeing 16000 properties inundated with insured losses across the UK totalling £1.3billion. The climate change forecast is for an up to 30% increase in monthly rainfall such as to generate a greater number of higher magnitudes, more frequent floods. Consequently understanding the relationship between the river discharge and time is vital if we are to effectively manage river catchments. This is in terms of predicting how rivers might respond to changes in the discharge characteristics such as to reduce their propensity for flooding, reduce potential damage to critical infrastructure, and increase society's resilience to flooding.

The Data

It is often difficult to measure discharge in rivers directly therefore it is normally measured indirectly through automated recording of the depth of water passing through a known point such as a weir as shown in Figure 1. This record of depth is called stage height. Discharge is then estimated by deriving a theoretical stage height-discharge relationship. In order to derive this relationship a number of manual measurements of discharge at a range of different flow stages are needed. Statistical analysis is undertaken to produce a regression equation that can be used to predict discharge for a given stage height and thus convert automated stage record into a discharge record.

Figure 1: V Notch weir used for estimating stage height and discharge (Source: Dr Nick Chappell, University of Lancaster)

1) Measuring Stream Discharge

Stage height has been recorded using a weir such as that seen in Figure 1 at the outlet of a small river. Manual measurements of discharge were also carried out allowing a stage height-discharge relationship to be generated.

- Open the Microsoft Excel Hydrograph data file. In the Stage Discharge Calibration tab there are two columns: 1) Stage height and 2) Discharge.
- Using the data plot a scatter graph
- Add a regression equation by right clicking on one of the data points within the graph and then select ‘Add Trendline’ and click ‘Polynomial’ (Order = 3). Make sure that ‘Set Intercept’ (0.001) ‘Display equation on chart’ and ‘Display R-squared value on chart’ are ticked and then click ‘close’
- You have now created your own stage height-discharge relationship. The equation shown can be used to predict discharge for any given stage height. Your graph should look like the example below in Figure 2.

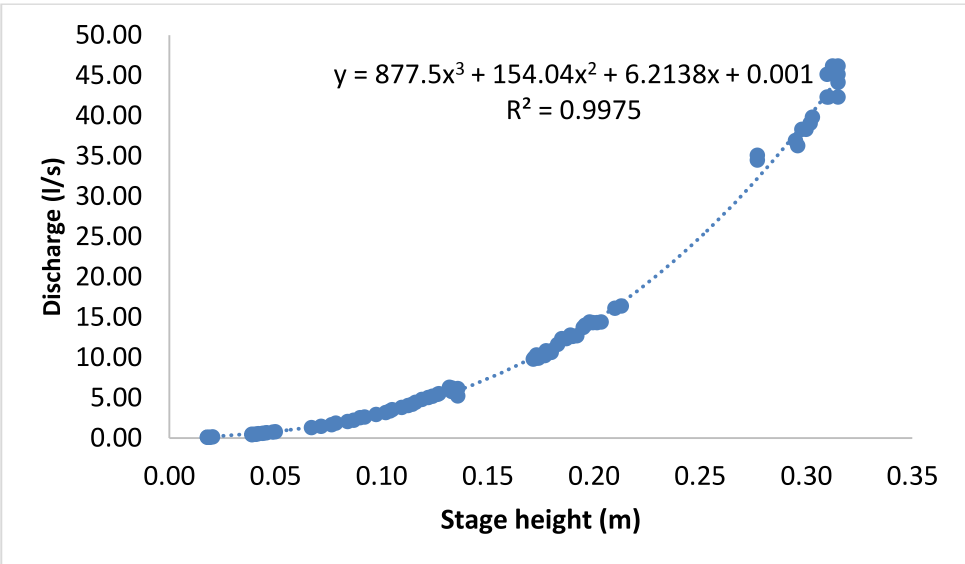

Figure 2: Stage Discharge relationship.

Look at Figure 2 and discuss the findings. You might want to think about:

- Describe the relationship between stage height and discharge – is it linear? If not what does this mean?
- There are sections of the stage height discharge relationship you generated which are relatively poorly populated by data e.g. between ~0.15m and 0.2m and 0.25m and 0.3m stage height. How do you think this will affect our ability to describe the relationship between stage height and discharge?

Take it Further

Using the equation derived in Figure 1 predict the discharge value for a stage height of 0.5m, 1.0m and 1.5m. Plot them on the graph produced for Figure 1.

- What do you think the problems may be when predicting discharges beyond those which have been measured?
- This relationship describes the stage height–discharge characteristics of one river. How representative do you think it is of other rivers? What might affect the shape of stage height–discharge relationships in other rivers?

2) The Impact of Rainfall Events on Discharge Characteristics

Discharge in rivers is affected by factors such as local catchment characteristics, rainfall event characteristics and catchment management practices. During rainfall events the response of the river discharge will vary through the rainfall events and can be visualised as a hydrograph which plots discharge through time. Rainfall volumes and timing can also be added to a hydrograph plot to allow links to be made between rainfall characteristics and river discharge response. The following data is taken from a small river in Devon and details the response of the river discharge to different rainfall events.

Task

- Open the Microsoft Excel Stage Hydrograph data file. In the Event 1 tab there are four columns: 1) Date/Time 2) Drained Discharge 3) Un-drained Discharge and 4) Rainfall Intensity.
- Plot a column graph of Date/Time and Drained Discharge (ignore how this looks for now).
- Right click on the X axis and select format axis. Under Axis type, select 'text axis'. Under 'Labels' and 'Interval between labels' click 'specify interval between labels' and type 30
- You have now created a hydrograph of the storm event but the rainfall which caused the storm event is missing.
- To do this right-click on the graph and select 'select data', then click 'Add'. Name the series 'Rainfall Intensity (mm hr)' and highlight the column of data containing the rainfall intensity data (Column D).
    - You will notice that the rainfall has been plotted on the same axis as the flow data. To correct it, right-click on the rainfall data series in the chart. Click 'Format Data Series' and then select 'Plot the series on a secondary axis'. Lastly, in order to present the rainfall data with a more appropriate scale, right-click on the secondary Y axis and click 'format axis'. Format the secondary Y axis so that the maximum value is 7. To improve ease of viewing rainfall is plotted upside down to the flow. In order to do this right-click on the secondary Y axis and select format axis. In axis options select 'values in reverse order'.

- You have now plotted a hydrograph with both your discharge data and the rainfall data which caused the storm event so you can begin to link the two. Your graph should look like the example below in Figure 3.

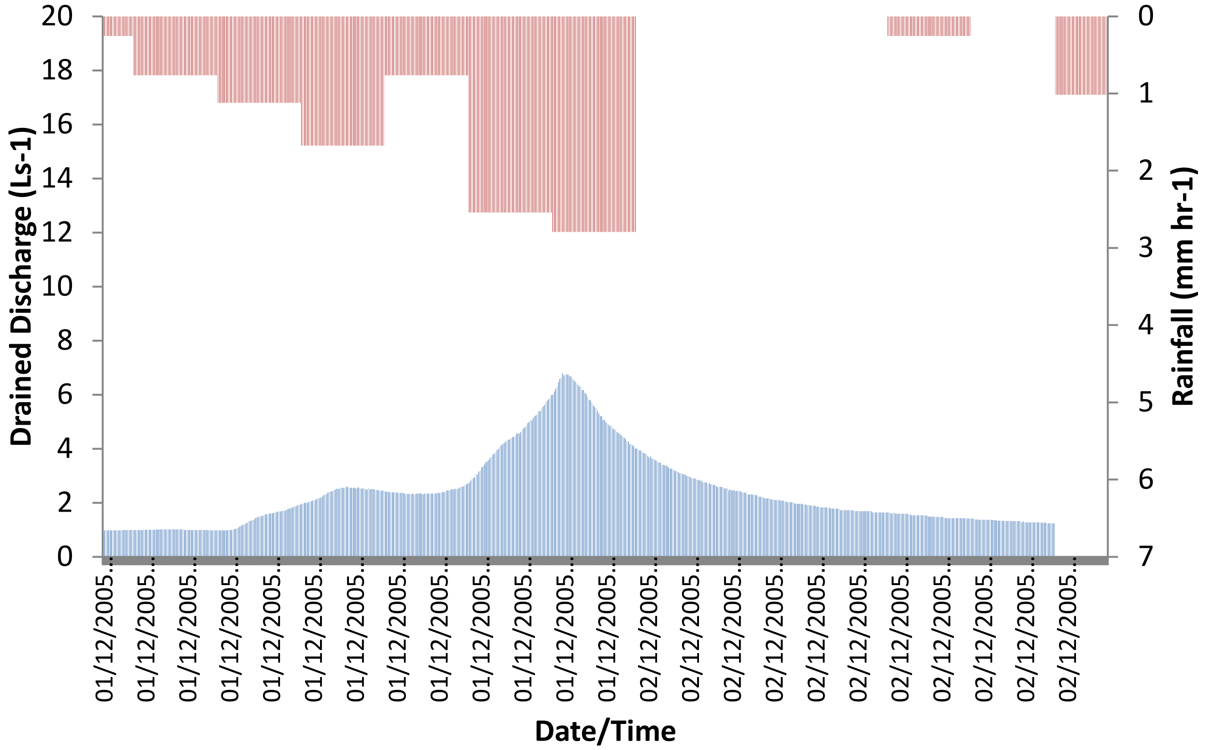

Figure 3: River hydrograph plotting discharge through time. Rainfall has been added to allow links to be made between rainfall characteristics and river discharge response.

Looking at the raw data and at Figure 3 discuss the findings. You might want to think about:

- Describe the shape of the hydrograph. Compare the shape of the rising and falling limb. Is there more than one peak discharge?
- What is the relationship between the rainfall and the stream discharge?
- What was the first peak rainfall intensity value and at what time did it occur?
- What was the first peak discharge value and at what time did it occur?
- What was the lag time where lag time is the time of the first peak discharge minus the first peak rainfall intensity?

Take it Further

Repeat the process and generate a hydrograph for the drained data for all 5 events. You can see how the 5 events are related to each other by looking at the Date/Time column for all 5 events.

- Compare the flood hydrographs for all 5 events – what are the main similarities and differences?
- Does the discharge response change when there have been two rainfall events happened close together? Why might this be?

3) The Impact of Land Management Practices on Discharge Characteristics

To try to improve agricultural land it is becoming common practice to add in drainage to fields so that water drains away from the soil more quickly, preventing water logging. However this practice has implications for flood risk since the drained water enters the river channels more quickly following a rainfall event. The following exercises uses the same data as the previous exercise, taken from a small river in Devon but directly compares drained data with un-drained data. The drained data measures water entering the stream from a field which is underlain by drains. The un-drained data measures water entering the same stream from a neighbouring field which has no drains.

Task

- Open the Microsoft Excel Stage Hydrograph data file. In the Event 1 tab there are four columns: 1) Date/Time 2) Drained Discharge 3) Un-drained Discharge and 4) Rainfall Intensity.
- Plot a scatter plot of Date/Time and Drained Discharge
- Onto the same graph add in the Date/Time and Un-drained Discharge data so you can compare.
- Your graph should look like that in Figure 4
- Repeat this for all 5 events

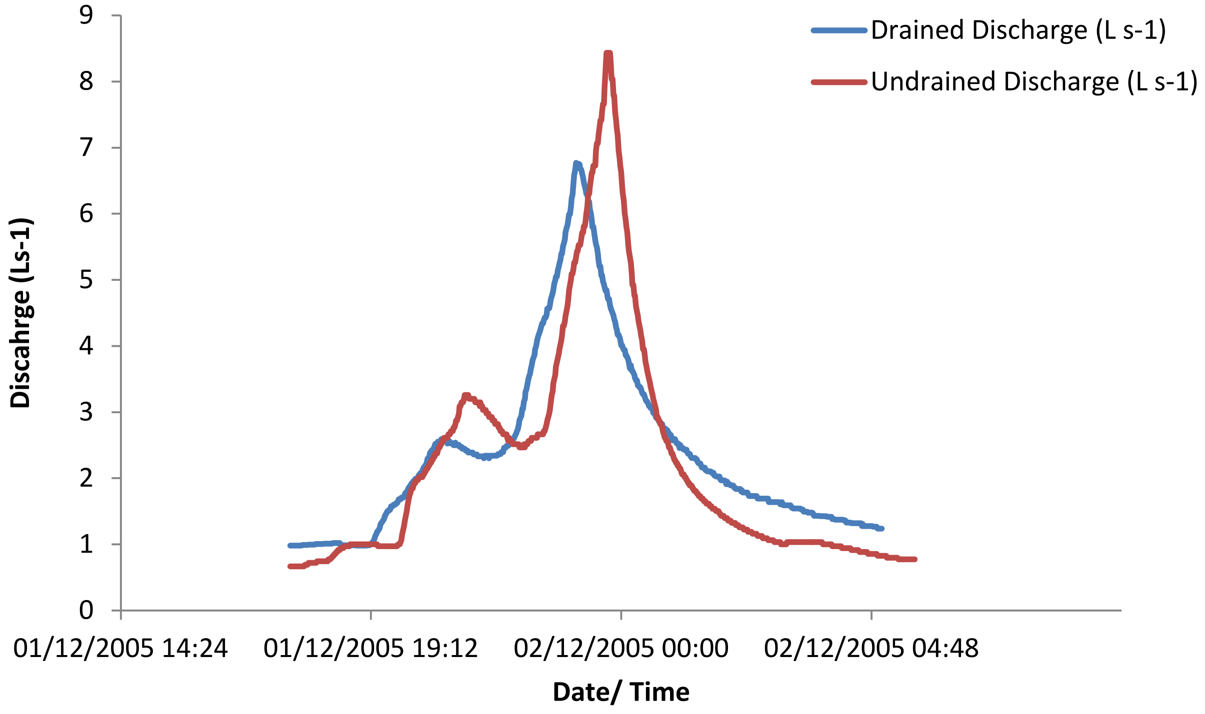

Figure 4: Comparison of two river hydrographs comparing drained and un-drained data for the same rainfall event.

Looking at the raw data and at Figure 4 discuss the findings. You might want to think about:

- Discussing the similarities and differences between the drained and un-drained hydrographs
- Discuss why there might be similarities and differences between the hydrographs. Relate this to the timing of the rainfall events and the processes which might be occurring within the catchment as a result of the rainfall events.

Take it Further

Calculate the lag times for the drained and un-drained data for all five events.

- Are the lag times affected by the drainage?
- Are the lag times affected by the timing of the rainfall events?
- Describe the processes which might be occurring within the catchment which are causing the differences between the lag times

Plenary

Return to the main lesson question. Ask the students to discuss to discuss:

- What the response of river hydrograph characteristics might be under future climate change scenarios where a greater number of higher magnitude, more frequent flood events are predicted?
- How would you manage this catchment such as to reduce the likelihood of flooding?