Understanding

HYDROGRAPHS

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1. Hydrograph

1.1. Introduction

Hydrology deals with water from its arrival on the land surface until it returns to the atmosphere by evaporation or to the oceans by surface or surface flow [1]. Hydrographs are of utmost importance when carrying hydrological analysis. The graphical relation between any hydrological quantity (stage, velocity, discharge, etc.) and the time is known as a hydrograph. A runoff hydrograph is a continuous record of stream flow over time, it contains information on runoff volume as the area under the hydrograph and peak runoff rates as the maximum flow or peak of the runoff hydrograph [7]. The hydrograph is "an integral expression of physiographic and climatic characteristics that govern the relation between rainfall and runoff of a particular drainage basin" [2].

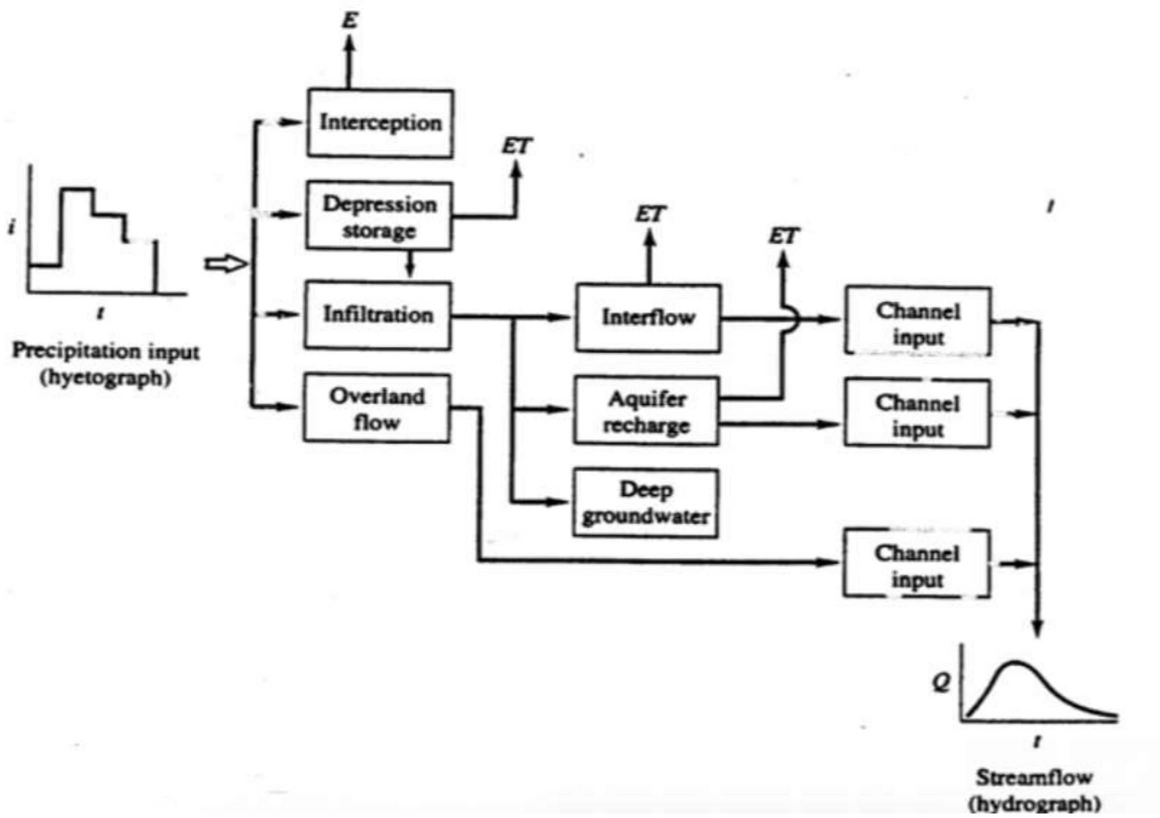

Figure 1 Distribution of Precipitation input

Figure 1 shows the Distribution of Precipitation input in which E is for evaporation and ET is for Evapotranspiration [3].

1.2.Types of Hydrographs

Mainly hydrographs can be divided into these four types,

1.2.1. Discharge Hydrograph

It is the graphical representation of discharge against time. Generally, a hydrograph means discharge hydrograph.

1.2.2. Stage Hydrograph

It is the graphical representation of stage against time. Stage hydrograph is useful for the design of flood-protection works like embankment.

1.2.3. Velocity Hydrograph

It is the graphical representation of velocity against time.

1.2.4. Temperature Hydrograph

It is the graphical representation of Temperature against time.

1.3. Parts of Hydrographs

In figure 2 we have different parts/components of hydrographs which are explained below,

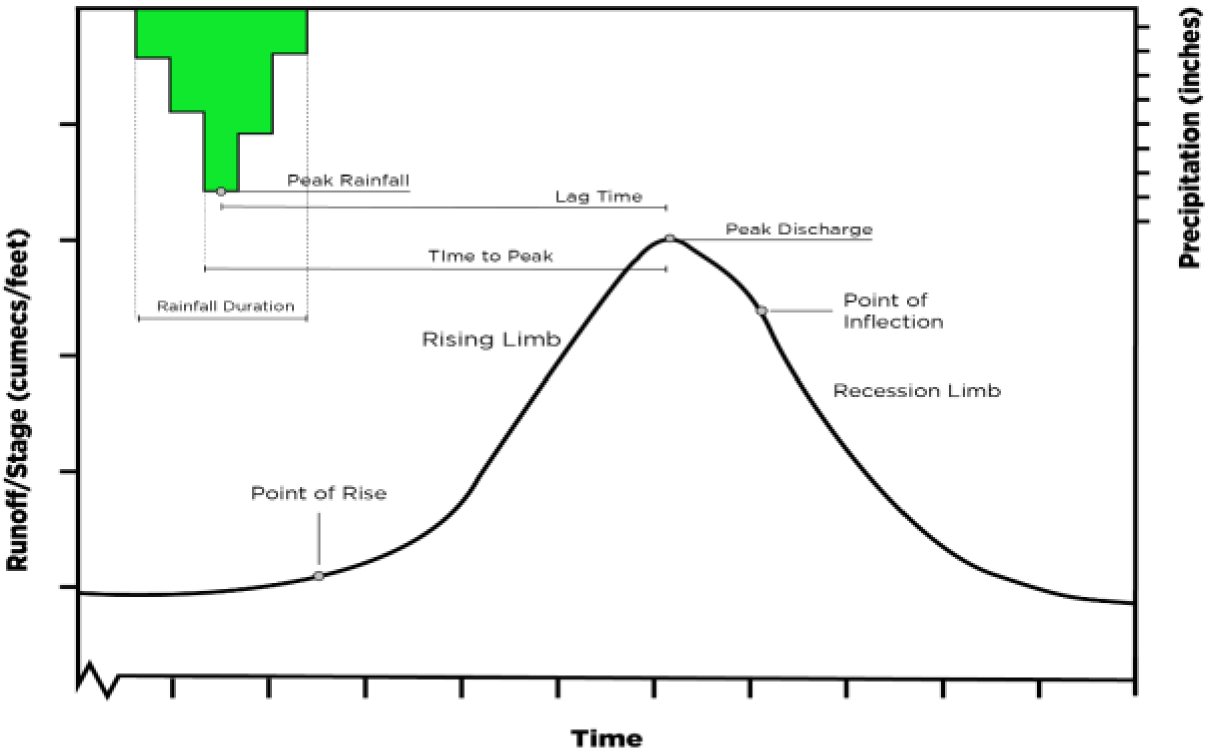

Figure 2 Parts of Hydrograph

1.3.1. Rising Limb

The rising limb of hydrograph, also known as concentration curve, reflects a prolonged increase in discharge from a catchment area, typically in response to a rainfall event. The shape of the rising limb depends upon the storm characteristics which are the duration of rainfall, intensity of rainfall, areal distribution of the rainfall etc. [4].

1.3.2. Recession limb

The recession limb extends from the point of inflection at the end of the crest segment to the commencement of the natural groundwater flow (base flow) which represents the withdrawal of water from the storage built up in the basin during the earlier phases of the hydrograph. The falling limb depends upon the control on storage release, which itself depends upon the geological structure [4].

1.3.3. Peak discharge:

The highest point on the hydrograph when the rate of discharge is greatest. The crest segment is controlled by the storm characteristics and the distribution of streams in the area, which further depends upon geological structure of the area.

1.3.4. Lag Time

Time interval from the center of mass of the rainfall-excess to the peak of the resultant hydrograph.

1.3.5. Time to Peak

Time interval from the start of the rainfall-excess to the peak of the resultant hydrograph.

1.3.6. Rainfall Duration

Time interval from the start to the end of rainfall-excess.

1.4. Effective Rainfall

All of the rain usually does not go into the stream but a certain part of it reaches the stream & causes rise in the stream flow while the remaining part of rain is accounted for in various forms of precipitation losses. The portion of rainfall which contributes to stream flow is called Effective Rainfall. Based on effective rainfall a typical hydrograph consists of four regions [5]

- Channel Precipitation
- Direct Runoff
- Inter Flow or Sub-surface flow
- Ground or Base Flow

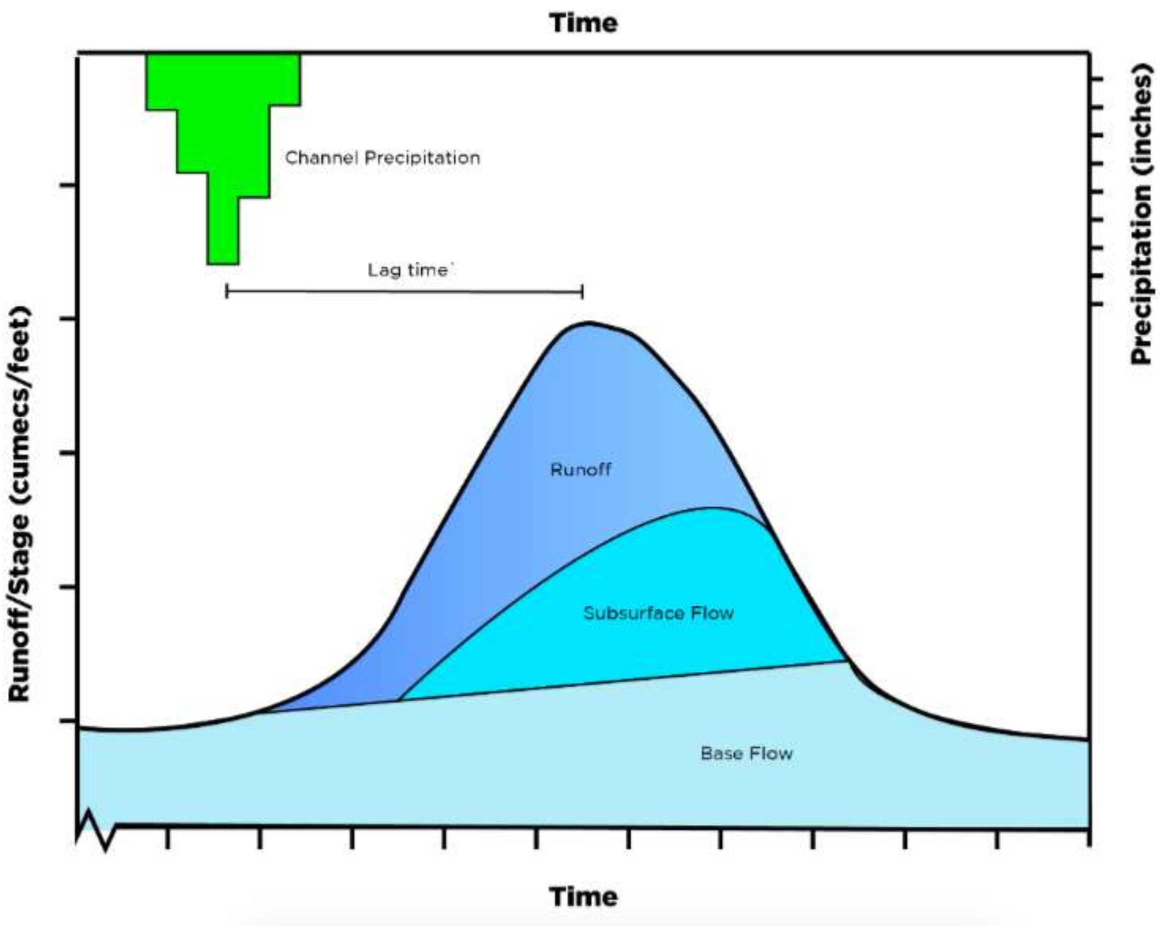

Figure 3 Regions of Hydrographs

1.5. Hydrograph Analysis

Hydrograph Analysis means dividing total runoff indicated by the hydrograph into its (above mentioned) components, of which direct runoff (DRO) and Base Flow are more important. The separation of hydrograph components is done by one of the following four methods [8].

I. Straight Line Method
II. Fixed Base Length Method
III. Variable Slope Method
IV. Recession Curve Equation

1.6. Factors Affecting Hydrograph Shape

Hydrograph shape depends on Metrologic and catchment characteristics. Among the Metrologic characteristics the most important are the rainfall intensity, duration. Among the catchment characteristics, the topography and geological conditions are more important. [6] These are discussed below:

- Storm Characteristics
- Catchment Characteristics

1.6.1. Storm Characteristics

1.6.1.1. Intensity of Rainfall

The intensity of rainfall has a predominant effect on the shape of the hydrograph. If other conditions remain the same, a higher intensity storm will produce a rapid rise in the hydrograph and a higher peak than that in case of a low intensity rainfall. Such floods give little warning time and so are dangerous. In figure 4 the variation in intensity of rainfall changes the shape of hydrographs.

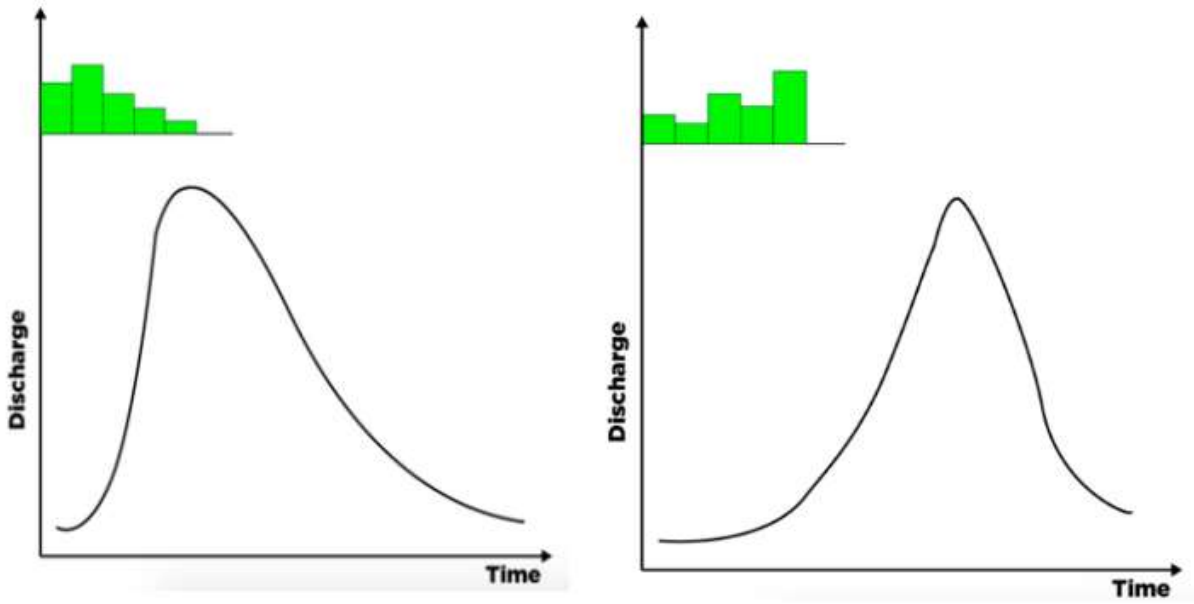

Figure 4 Intensity of Rainfall

1.6.1.2. Duration of Rainfall

The duration of rainfall is important if it is greater than the time of concentration (defined as the time of travel from the farthest point in the catchment area to the gauging station). In such a situation, if the rainfall of certain intensity occurs uniformly, the whole of the catchment area is contributing runoff at the gauging station and the hydrograph attains its high peak. The runoff will remain constant at the peak rate if the rainfall occurs for duration longer than the time of concentration. If rainfall of the same intensity occurs for duration less than the time of concentration, the hydrograph will rise to a smaller peak.

1.6.1.3. Effect of storm size on surface runoff

For larger storm the rainfall is distributed over a larger area due to which most of tributaries contribute to the stream discharge which results in the hydrograph with larger peak and vice versa. As we can see in figure 5 Storm A is smaller storm that’s why it covered less area in graph while Storm B have relatively bigger Storm size then Storm A so it has cover large area.

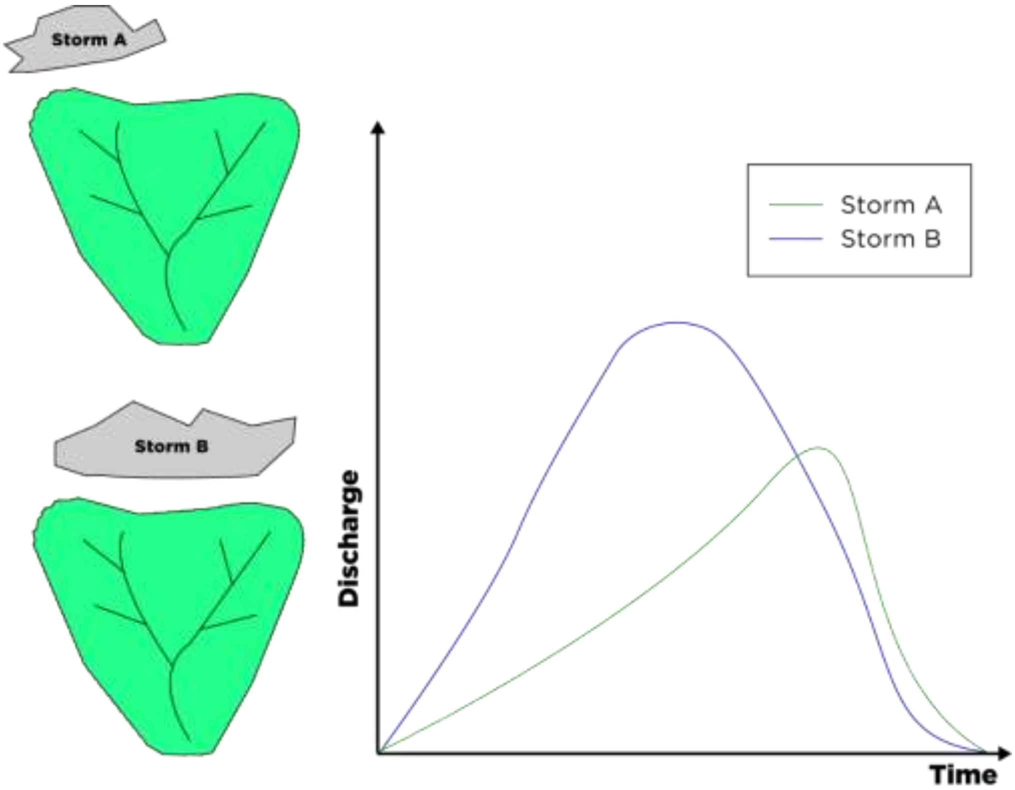

Figure 5 storm size on surface runoff

1.6.1.4. Weather

The shape of the hydrograph greatly depends on the seasonal distribution of rainfall. During summer losses due to evaporation may produce a small peak hydrograph. On the other hand, in winter, losses are small with the result that even a small intensity storm may produce a relatively rapid rise and high peak of the hydrograph. Antecedent soil moisture conditions (generally being higher in winter) are important as for high soil moisture; the storm will produce more runoff.

1.6.2. Catchment Characteristic

1.6.2.1. Size of Catchment

The catchment area affects the stream flow in a variety of ways. Even if the intensity and depth of precipitation is assumed to be constant. The hydrograph of a smaller catchment rises to its peak and then recedes more rapidly than that for a larger catchment, because for the latter, it takes longer for the runoff to reach the gauging station and the hydrograph of a larger catchment area, therefore, has broader base than that of a smaller one. Moreover, the larger the area, the greater will be the heterogeneity in soil and vegetation cover, with a consequent effect on the stream flow of each part of the catchment. The vegetation cover increases the time of concentration. The hydrograph of a larger catchment area, therefore, has broader base than that of a smaller one.

1.6.2.2. Shape of Catchment

The shape of the catchment area affects stream flow by altering the time of concentration and the pattern of drainage tributaries. If the length of the catchment along the main stream is less than the width across the same stream, separate runoff peaks generated by a heavy rainfall are likely to reach the gauging station at the same time from the tributaries, with the result that the flood peak in the main stream increases. Thus, a hydrograph with a high peak and narrow base is obtained. However, if the length of the catchment along the main stream is larger than width, the tributaries will be of shorter length and contribution from each tributary area is likely to reach the gauging stations at intervals. After an intense storm over the whole of the catchment area there will be some lag between the times at which the peak from each tributary reaches the gauging station. The hydrograph will therefore, have a low peak and broader base, because the remote tributaries will continue contributing for some time even after the rain fall has stopped.

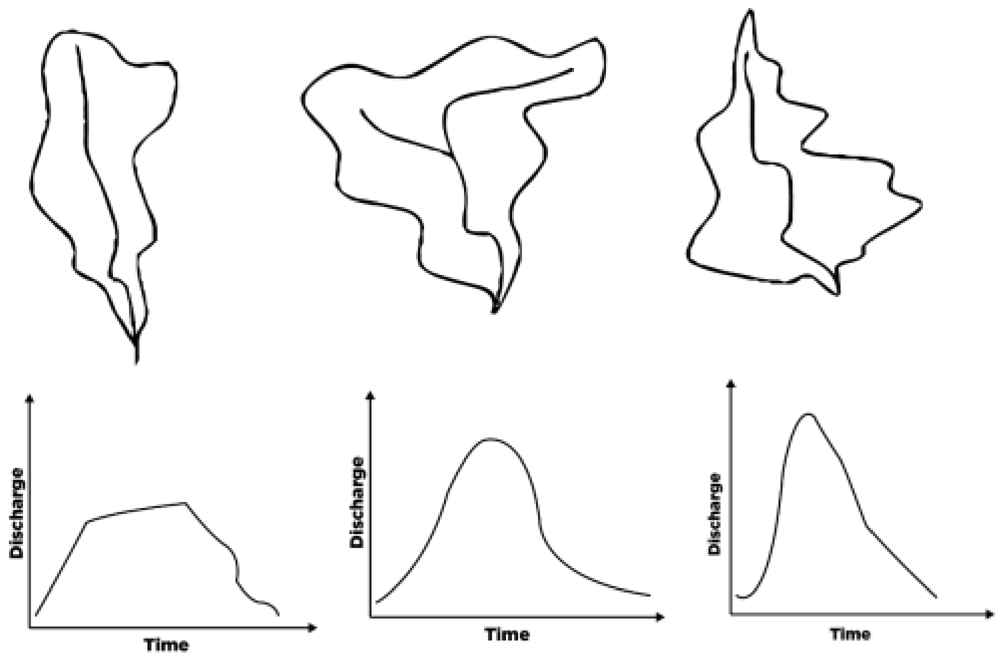

Figure 6 Variation in hydrograph due to difference in shape of catchment area

1.6.2.3. Elevation of Catchment

The elevation of the catchment also plays an important role in some hydrologic characteristics of hydrograph, particularly due to variation in temperature and precipitation. The temperature reduces with the increase in elevation with the result that above a certain elevation, the temperature becomes so low that all precipitation falls as snow. The floods from snowmelt are of usually low peak and broader base.

1.6.2.4. Catchment Slope

The slope of the catchment affects stream flow by reducing the rate of infiltration due to increased speed of water-movement towards drainage channels. The steeper the slope the faster will be the flow and rise in the hydrograph. The hydrograph in such a situation will have higher peak and smaller base.

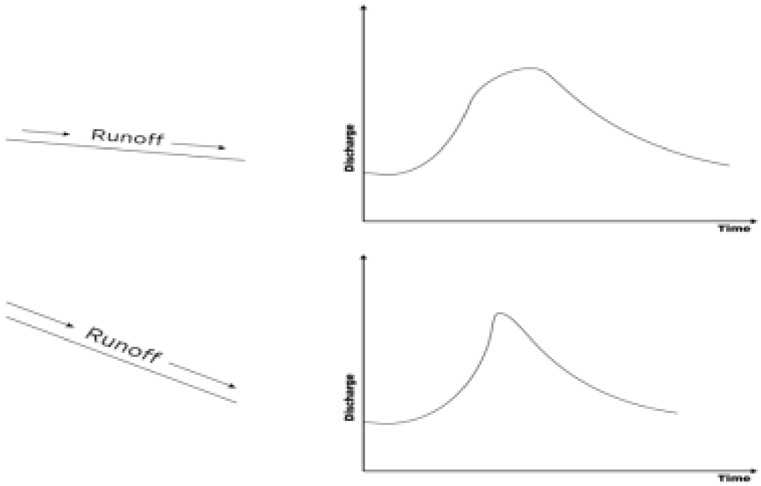

Figure 7 Catchment slope

1.7. Interpretation of Hydrographs

All the discussion above was to make you able to interpret/decipher complex hydrographs by just looking at it. The hydrograph we saw in figure 2 was just to give you an understanding of a hydrograph and its components, in reality, a channel might have hydrographs having more than one peaks and a different structure. We'll now look at some real-life examples of stage hydrographs based on the real-time data obtained by toltHawk, an online source for hydrological data based in the United States of America.

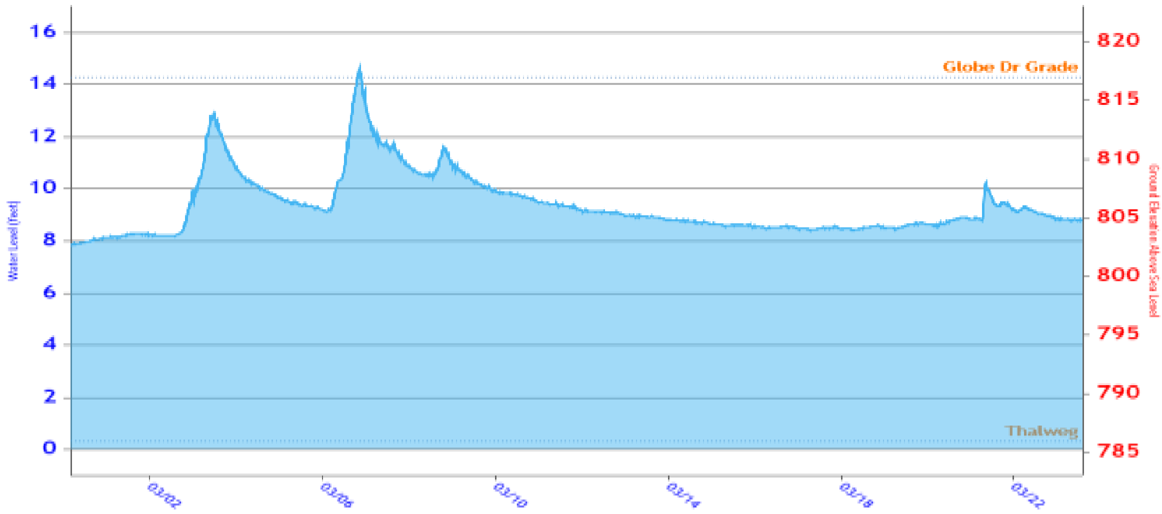

Figure 8 Lower Globe river in Tulare California

This is a one Month hydrological data of Lower Globe river in Tulare California. First break down the hydrograph.

- On the left (y-axis) is the depth of water level in feet and on the right (y-axis) is the ground elevation above sea level
- In the bottom it is one-month timeline.
- There are four prominent peaks.
- Almost no flooding occurs as the water level doesn’t exceed the river capacity.

Reasoning

The peaks are pointy and rising rapidly as compared to the recession limbs achieving the base flow relatively slow. There might be several reasons for that;

- The river is based in a sub urban area which means most of the area is covered with buildings and pavements which prevents the water to be infiltrated into the soil rather it flows directly into the river.
- This data is recorded in the months of February and March that is during winters, there would be less losses due to evaporation resulting in high peaks of hydrograph.
- The first three peaks are rapid, also due to the rainfall occurring consecutively which keeps the surrounding soil to maintain the moisture resulting in less infiltration and more runoff.
- The recession limbs are relatively broader than the rising limb due to the late arrival of water from the mountains nearby.

Now let’s see another example.

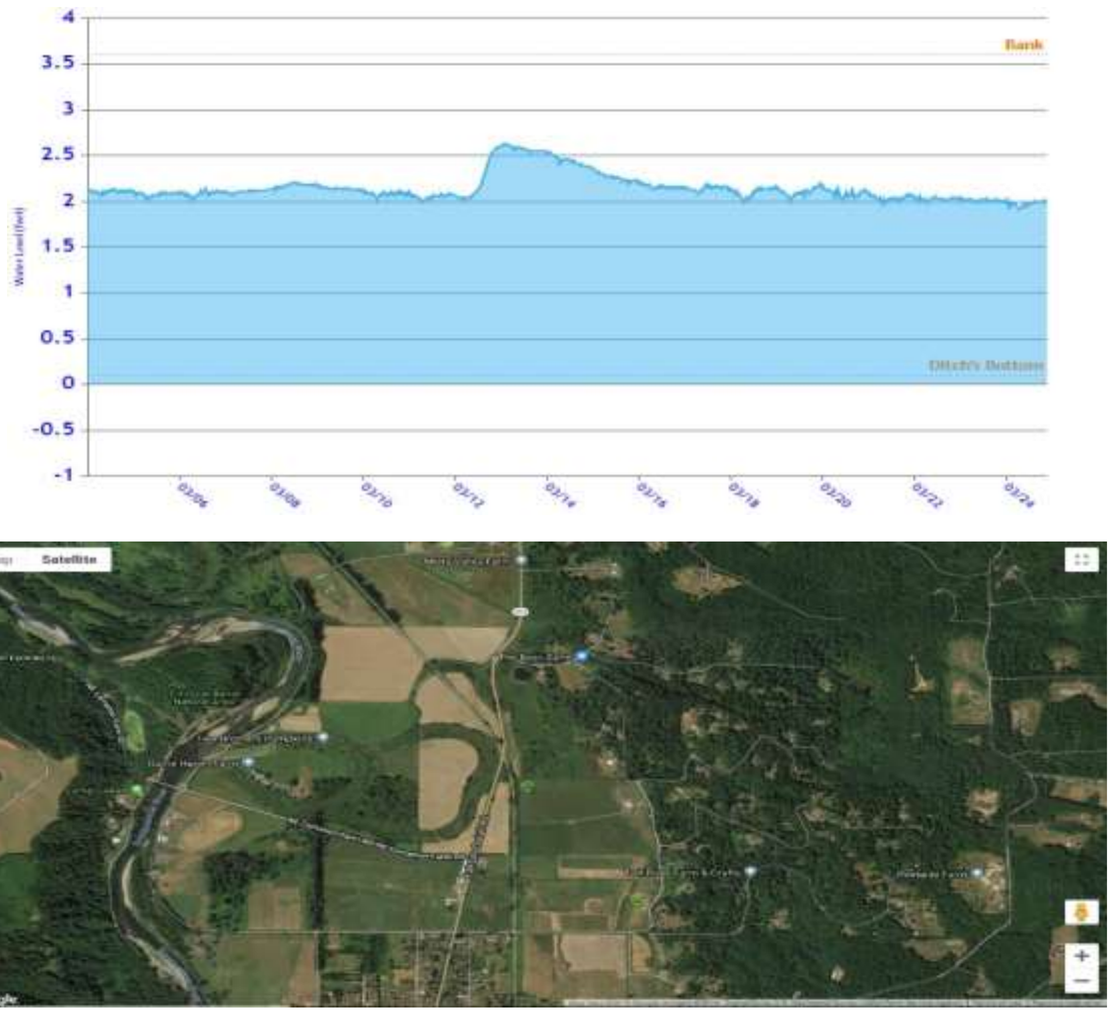

Figure 9 hydrological data of Phill Hammonds ditch in Washington, USA.

This is twenty days hydrological data of Phill Hammonds ditch in Washington, USA.

First break down the hydrograph.

- There is only one rainfall event during that time period.
- The peak has a broader base.
- No flooding has occurred as the water level is way below the channel capacity.

Reasoning

The peaks are not pointy and very low as compared to the previous example and as we look beyond the peak flow the recession limb is relatively broader.

There might be several reasons for that;

- As we see in the map, most of the watershed is covered with vegetation which is the basic reason for a low peak.
- There is also less urbanization nearby so the runoff will not directly contribute to the stream as it will infiltrate in the soil.
- The rainfall might be of lower intensity.

1.8. Glossary

Antecedent soil moisture: Moisture already present in the soil

Base Flow: Flow during normal days/Flow during no rainfall

Catchment Area: the area from which rainfall flows into a river, lake, or reservoir.

Direct Runoff: Surface Flow of storm water.

Discharge: Volumetric Flowrate of water through a cross sectional area

Drainage Basin: A larger catchment area

Embankment: a wall or bank of earth or stone built to prevent a river flooding an area

Evaporation: Vaporization of a liquid into gas by heat; particularly the sun

Evapotranspiration: Evaporation from earth surface and from plant leaves.

Gauging Station: Location of water in monitoring

Heterogeneity: The quality or state of being diverse in character or content

Infiltration: Absorbtion/entering of surface water by the soil

Peak Runoff: Maximum flow of water in the channel

Point of Inflection: a point of a curve at which a change in the direction of curvature occurs

Precipitation: Rainfall

Runoff: the draining away of water from the surface of an area of land

Stage: Height of waterflow in the channel

Tributaries: a river or stream flowing into a larger river or lake.

Watershed: Small catchment area

1.9.References

[1]. Sharp, J. J., & Sawden, P. G. (2013). *BASIC hydrology*. Elsevier.

[2]. Mays, L. W., & Tung, Y. K. (2002). *Hydrosystems engineering and management*. Water Resources Publication.

[3]. Viessman Jr, W., & Lewis, G. L. (1996). Introduction to Hydrology, Harper Collins College Publishers. New York.

[4]. Raghunath, H. M. (2006). Hydrology: principles, analysis and design. New Age International.

[5]. Haan, C. T., Barfield, B. J., & Hayes, J. C. (1994). Rainfall-runoff estimation in stormwater computations. Design hydrology and sedimentology for small catchments, 37-103.

[6]. Fleischmann, A. S., Collischonn, W., & Paiva, R. C. D. D. (2019). Estimating design hydrographs at the basin scale: from event-based to continuous hydrological simulation. RBRH, 24.

[7]. Sherman, L. K. (1932). The relation of hydrographs of runoff to size and character of drainage-basins. Eos, Transactions American Geophysical Union, 13(1), 332-339.

[8]. Link, O., Henríquez, S., & Ettmer, B. (2018). Physical scale modelling of scour around bridge piers. Journal of Hydraulic Research, 1-11.