

# **Watershed Hydrology**

## **Flood Routing**

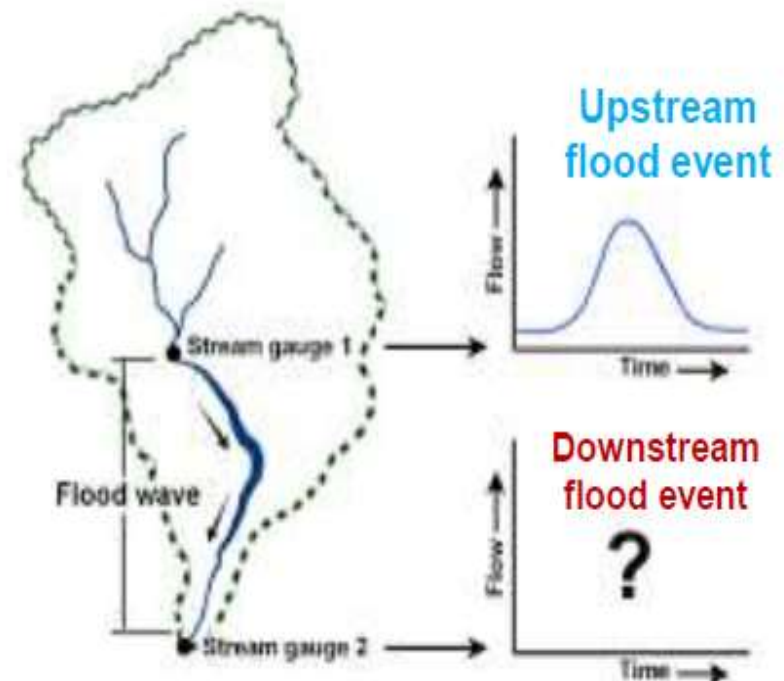
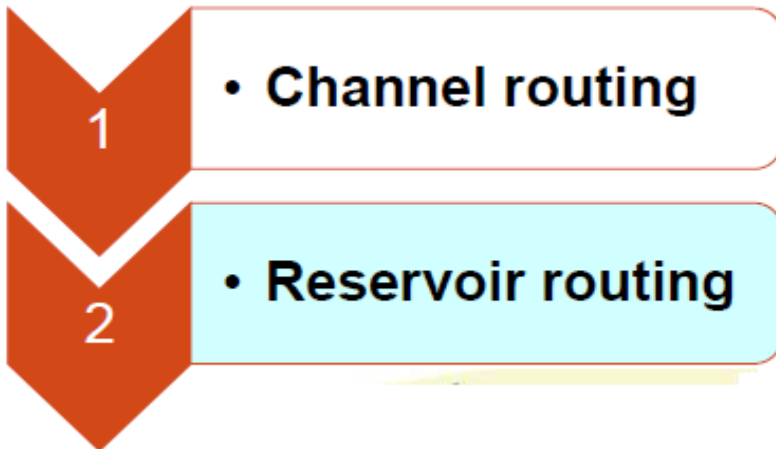
# What is Flood Routing?



It is the method to obtain the **temporal distribution** of an upstream flood event at the desired downstream section (Flood routing is the technique of determining the flood hydro graph at a section of a river by utilizing the data of flood flow at one or more upstream sections)



## Classification



# Flood Routing

## • Reservoir Routing

- In reservoir routing the effect of flood wave entering a reservoir is studied
- The variation of reservoir elevation and outflow discharge with time is studied by knowing volume elevation characteristic of the reservoir and the outflow elevation relationship for the spillway and other outlet structures in the reservoir
- In reservoir routing storage is a uniform function of outflow discharge
- It helps in
  - Design of capacity of spillways and other outlet structures
  - Location and sizing of the capacity of reservoirs to meet specific requirements

# Flood Routing

## • Channel Routing

- In channel routing the change in the shape of a hydrograph is studied as it travels down a channel
- By considering a channel reach and an input hydrograph at the upstream end, it helps to predict the flood hydrograph at various sections of the reach
- In channel routing the channel is a function of both outflow and inflow discharges
- It Helps in flood forecasting operations and flood protection works

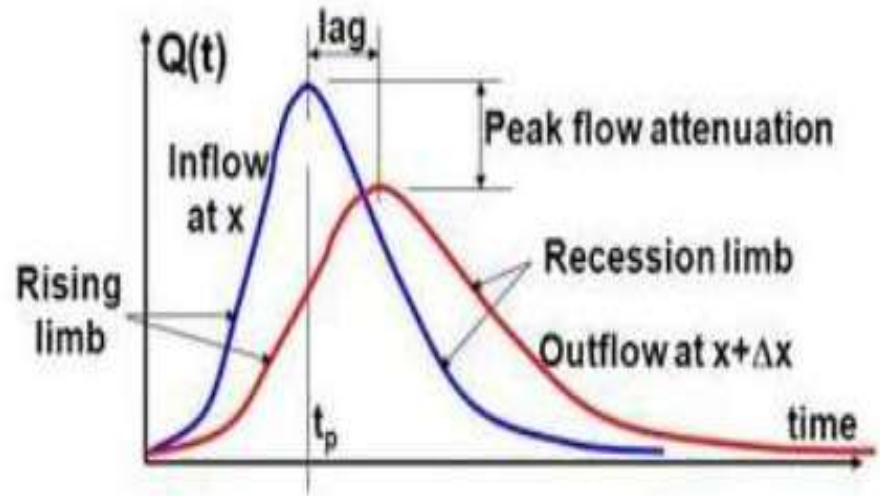
# Flood Characteristics:

**Magnitude**

(**Attenuation property**)

**Time to peak**

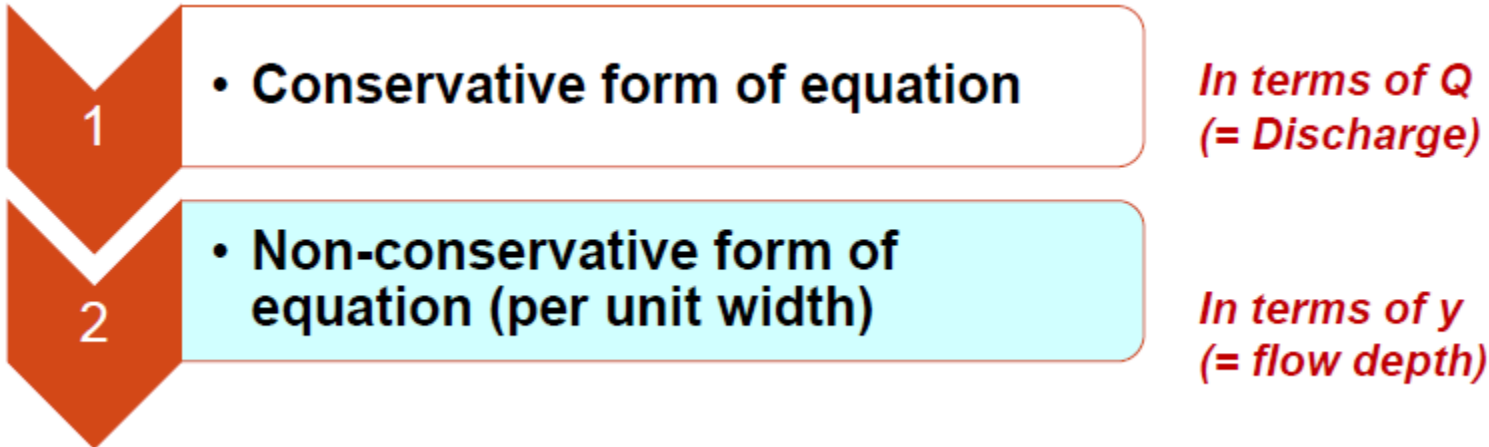
(**Translation property**)



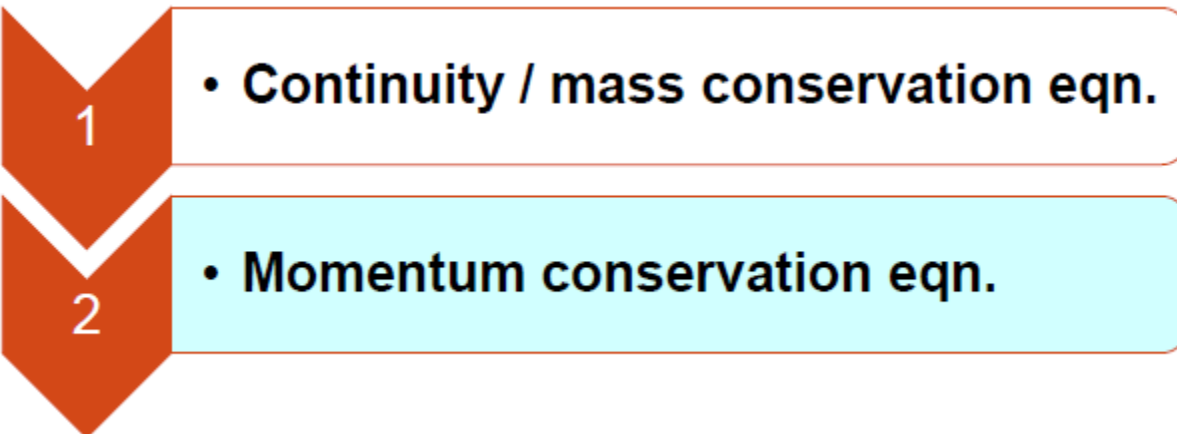
## **Application**

The hydrologic analysis of problems such as flood forecasting, flood protection, reservoir design and spillway design invariably include flood routing

# Flow Routing Equation



## Governing flow equations: **de Saint Venant's Eqs.**



# Continuity / mass conservation eqn.

## Conservative form

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

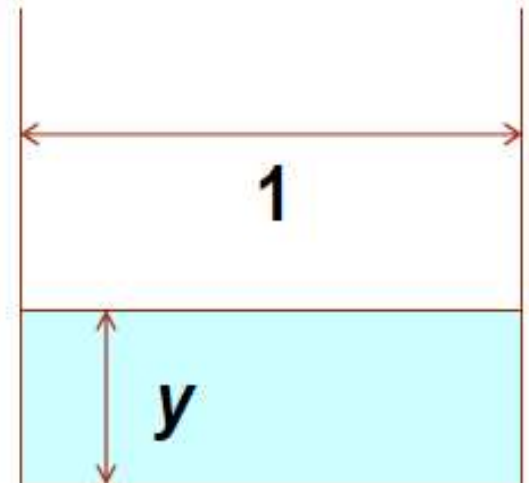
## Non-Conservative form

(For rectangular channel with unit width)

$$Q = A \cdot v = y \times 1 \times v = vy$$

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \quad \blacktriangleright \quad \frac{\partial(vy)}{\partial x} + \frac{\partial y}{\partial t} = 0$$

$$\blacktriangleright \quad v \cdot \frac{\partial y}{\partial x} + y \cdot \frac{\partial v}{\partial x} + \frac{\partial y}{\partial t} = 0$$



# Momentum conservation eqn.

Conservative form

$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{1}{Ag} \cdot \frac{\partial Q}{\partial t} - \frac{1}{Ag} \cdot \frac{\partial}{\partial x} \left( \frac{Q^2}{A} \right)$$

Non-Conservative form

$$Q = A \cdot v = y \times 1 \times v = vy$$

$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{1}{gy} \cdot \frac{\partial(vy)}{\partial t} - \frac{1}{gy} \cdot \frac{\partial}{\partial x} \left( \frac{v^2 y^2}{y} \right)$$

▶ 
$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{y}{gy} \cdot \frac{\partial v}{\partial t} - \frac{v}{gy} \cdot \frac{\partial y}{\partial t} - \frac{y}{gy} \cdot \frac{\partial v^2}{\partial x} - \frac{v^2}{gy} \cdot \frac{\partial y}{\partial x}$$

▶ 
$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{1}{g} \cdot \frac{\partial v}{\partial t} - \frac{2v}{g} \cdot \frac{\partial v}{\partial x} - \frac{v}{gy} \cdot \frac{\partial y}{\partial t} - \frac{v^2}{gy} \cdot \frac{\partial y}{\partial x}$$

▶ 
$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{1}{g} \cdot \frac{\partial v}{\partial t} - \frac{v}{g} \cdot \frac{\partial v}{\partial x} - \frac{v}{g} \left( \frac{\partial v}{\partial x} + \frac{1}{y} \cdot \frac{\partial y}{\partial t} + \frac{v}{y} \cdot \frac{\partial y}{\partial x} \right)$$

$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{1}{g} \cdot \frac{\partial v}{\partial t} - \frac{v}{g} \cdot \frac{\partial v}{\partial x}$$

= 0



## Simplification of Saint-Venant (SV) Eqn.

$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{1}{Ag} \cdot \frac{\partial Q}{\partial t} - \frac{1}{Ag} \cdot \frac{\partial}{\partial x} \left( \frac{Q^2}{A} \right)$$

Friction  
force  
term

Gravity  
force  
term

Pressure  
force  
term

Local  
acceleration  
term

Convective  
acceleration  
term

# Hydrologic Channel Routing

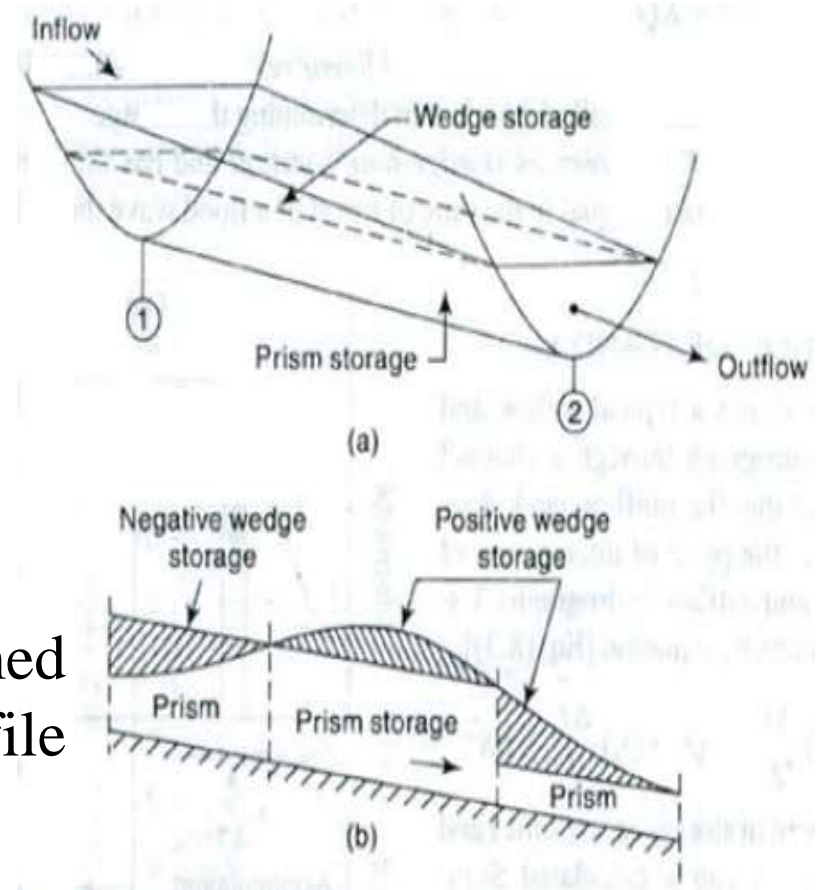
## Prism Storage

It is the volume that would exist if the uniform flow occurred at the downstream depth, i.e. the volume formed by an imaginary plane parallel to the channel bottom drawn at the outflow section water surface.

## Wedge Storage

It is the wedge like volume formed between the actual water surface profile and the top surface of the prism storage.

At a fixed depth at a downstream section of a river reach, the prism storage is constant while wedge storage changes from a +ve value at advancing flood to -ve value at receding flood

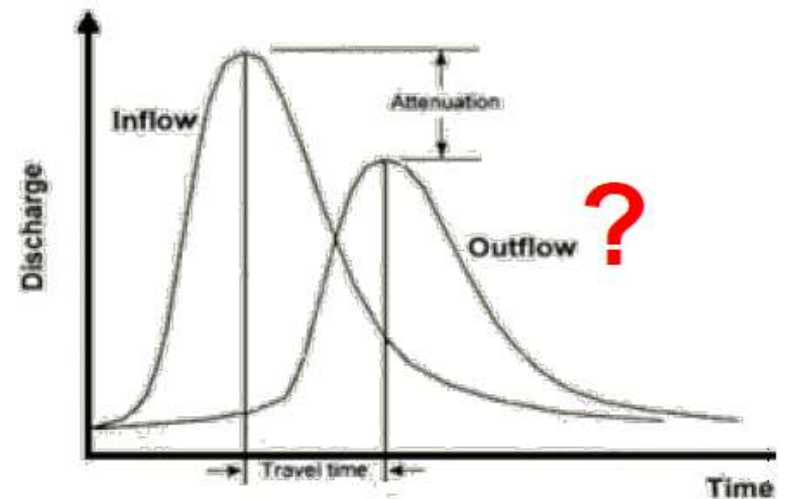


# What is Reservoir Routing?

It is the technique by which the outflow hydrograph is computed at the downstream of a reservoir with the known inflow hydrograph

## Purpose:

Flood moderation



# 1. Modified Pul's method (Storage based)

## Purpose:

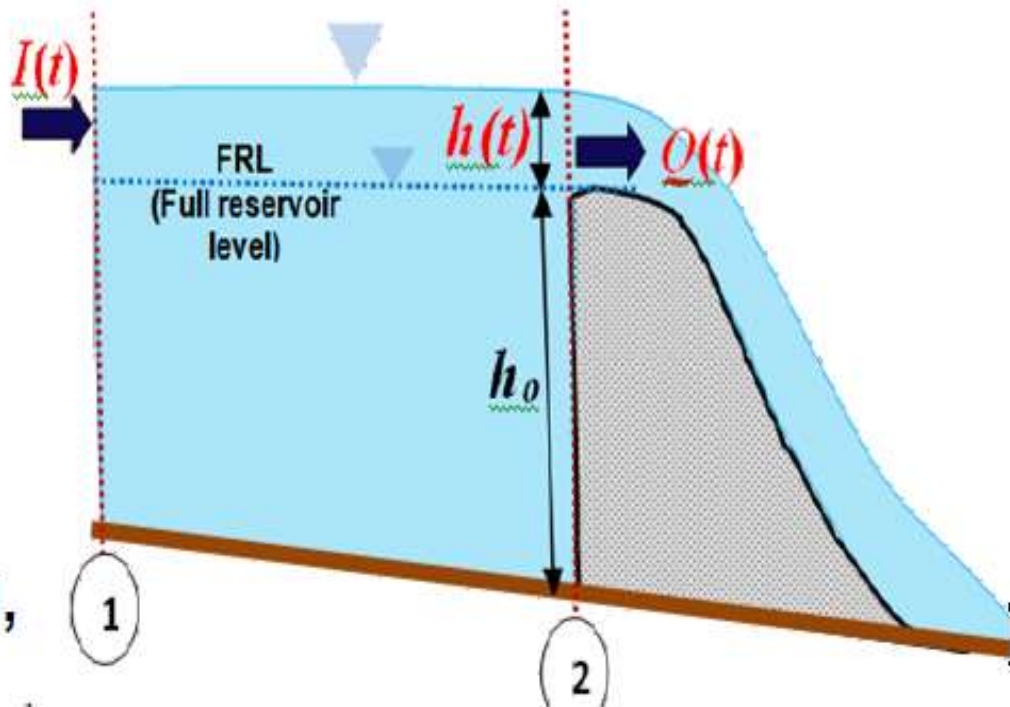
To compute  $Q-t$  &  $h-t$  relationships from known  $I-t$  relationship

## Known:

$h-Q$  &  $h-S$

relationships of the reservoir

Initial reservoir level,  $h_0$





## 2. Goodrich method (Discharge based)

### Purpose:

To compute  $Q-t$  &  $h-t$  relationships from known  $I-t$  relationship

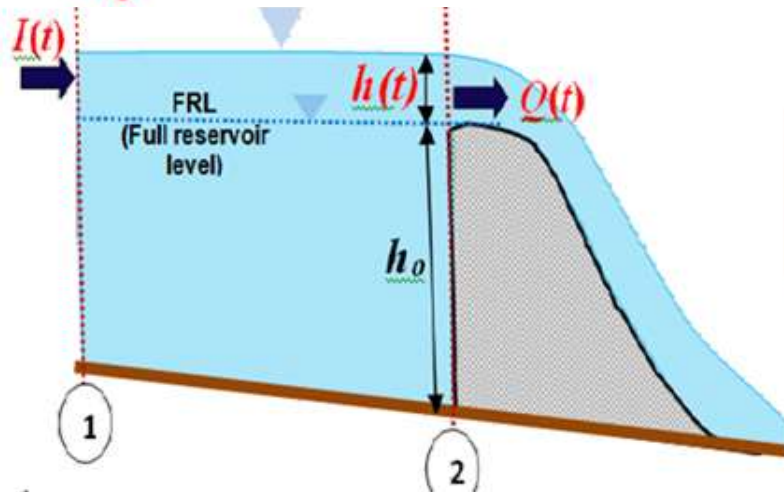
### Known:

#### $h-Q$ & $h-S$

relationships of the reservoir

Initial reservoir level,

$h_0$



$$\Delta S = (\bar{I} - \bar{Q}) \times \Delta t$$

$$S_2 - S_1 = \left( \frac{I_1 + I_2}{2} - \frac{Q_1 + Q_2}{2} \right) \times \Delta t$$

$$\frac{2S_2}{\Delta t} + Q_2 = (I_1 + I_2) + \frac{2S_1}{\Delta t} - Q_1$$

$$\left( \frac{2S}{\Delta t} + Q \right)_2 = (I_1 + I_2) + \left( \frac{2S}{\Delta t} - Q \right)_1$$

(Discharge based)

