

HYDROLOGY

A scenic landscape photograph featuring a mountain peak, a lake, and a rocky stream in the foreground, with the word 'HYDROLOGY' overlaid in large white letters. The scene is captured during the 'golden hour' of sunset or sunrise, with warm light filtering through the clouds and illuminating the landscape. In the foreground, a stream flows over dark, jagged rocks, creating white water rapids. The middle ground shows a calm lake reflecting the sky, nestled between rolling hills covered in green and yellow vegetation. In the background, a prominent, dark mountain peak rises sharply against a sky filled with soft, white clouds. The overall composition emphasizes the natural beauty and hydrological features of the environment.

Hydrology

- Hydrology is one of the earth sciences. It studies the waters of the earth, their occurrence, circulation and distribution, their chemical and physical properties, and their relation to living things.

Engineering Hydrology

- Engineering hydrology focusses on using knowledge about water to solve practical engineering problems.
- It studies how water varies across different places, times, and seasons to help design safe and effective water systems and structures while assessing potential risks to society.

Engineering Hydrology

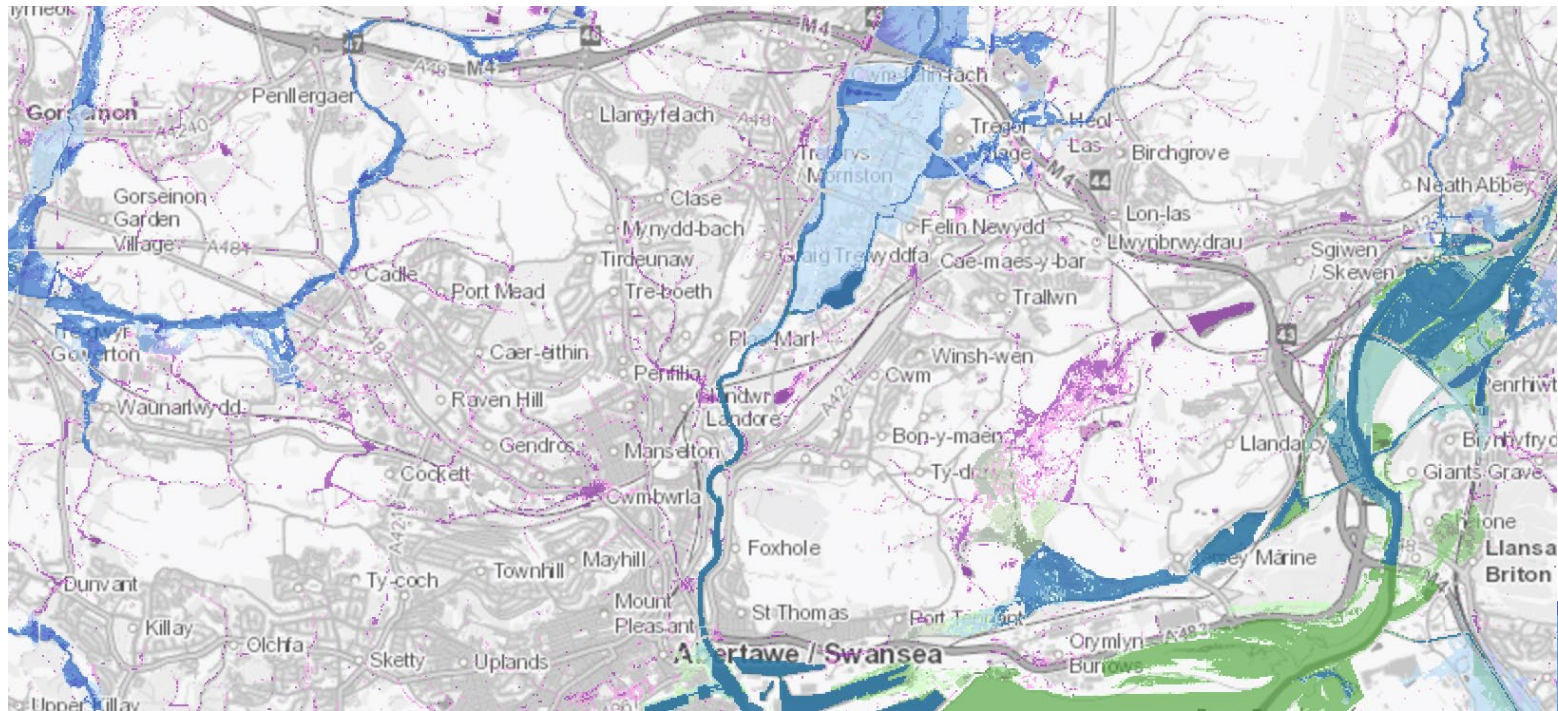
- For engineers, there are three main reasons why hydrology is important.

Water Resources Management

- Reservoir Design and Operation
- Water Supply Systems
- Irrigation Projects



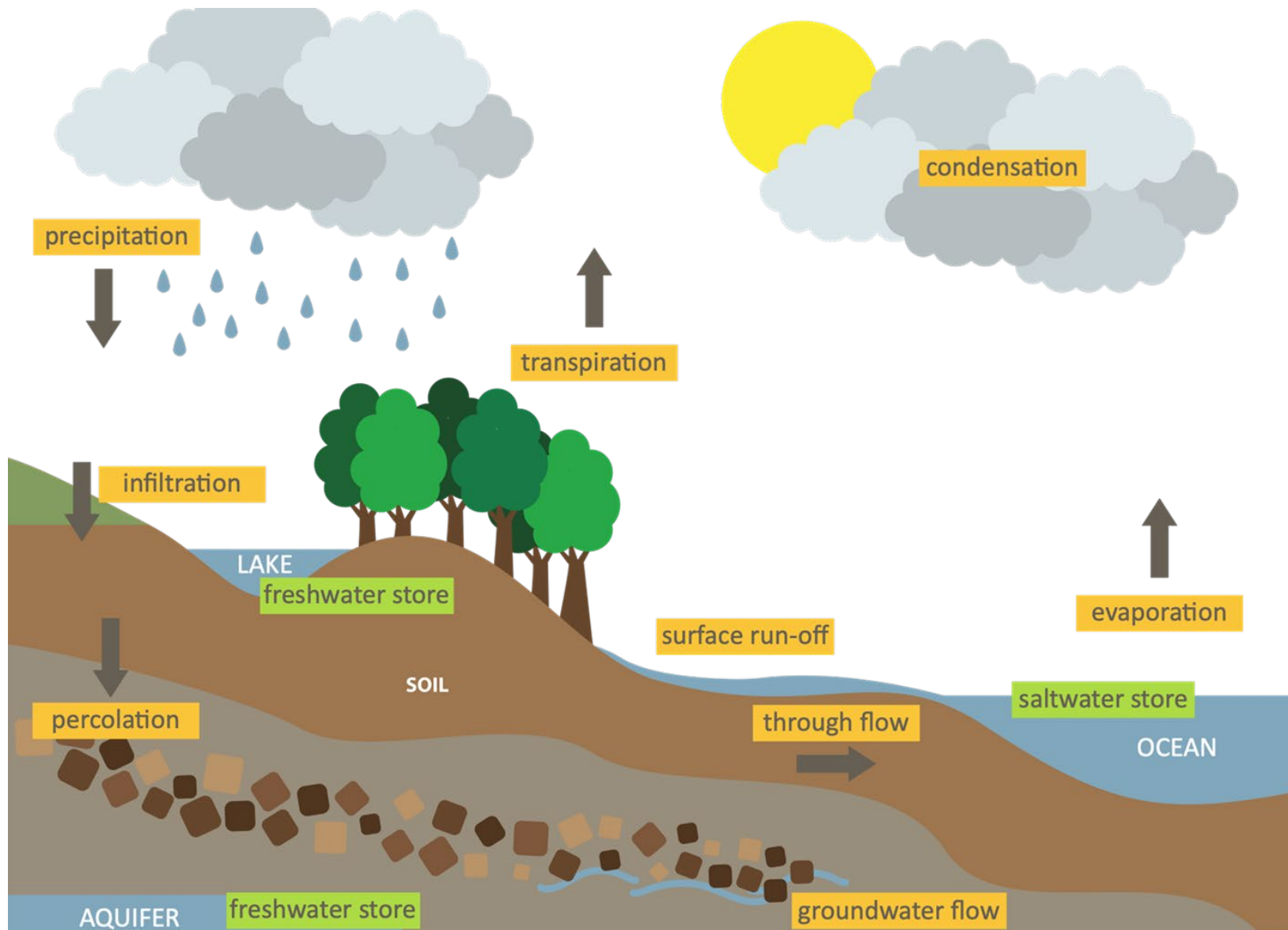
- Flood Prediction and Monitoring
- Design of Flood Control Structures
- Urban Drainage Systems



Hydraulic Structures

- Bridges
- Dams
- Culverts







Climate Change

- Increase precipitation variability



Climate Change

- Increase precipitation variability
- Rising Temperatures



Climate Change

- Increase precipitation variability
- Rising Temperatures
- Sea Level Rise



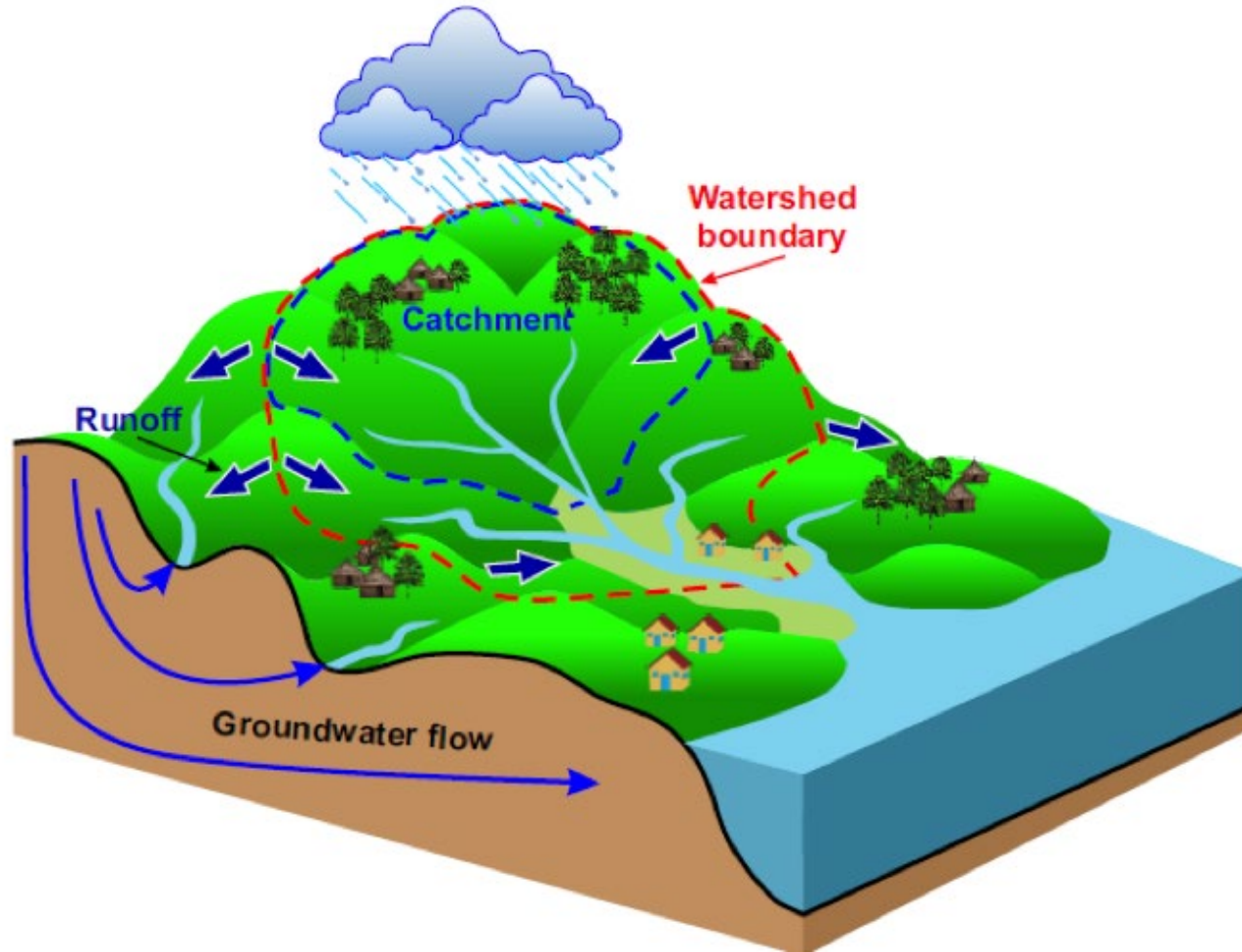
Climate Change

- Increase precipitation variability
- Rising Temperatures
- Sea Level Rise
- Altered Runoff Patterns



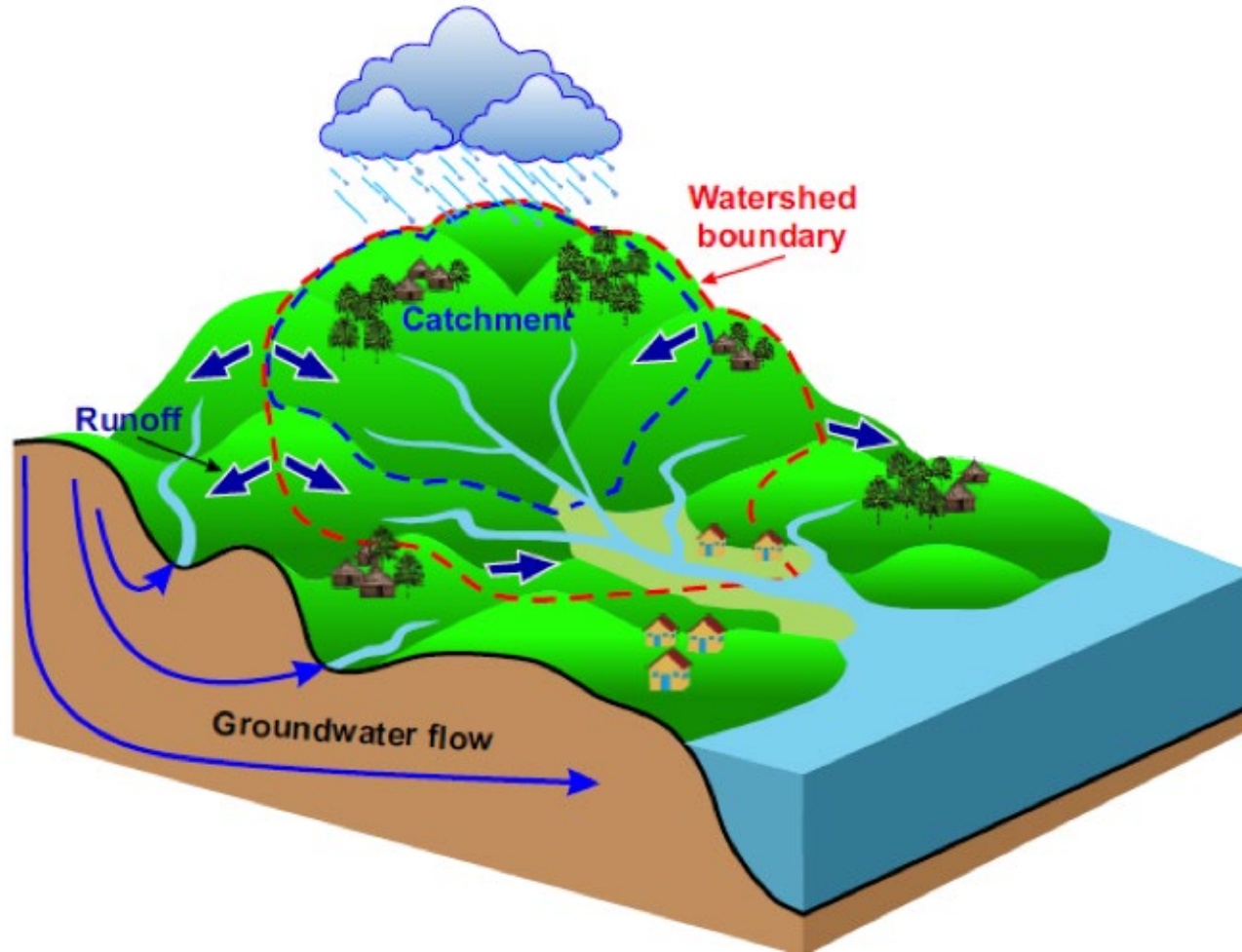
Climate Change

- Increase precipitation variability
- Rising Temperatures
- Sea Level Rise
- Altered Runoff Patterns
- Impact on Infrastructure



Catchment

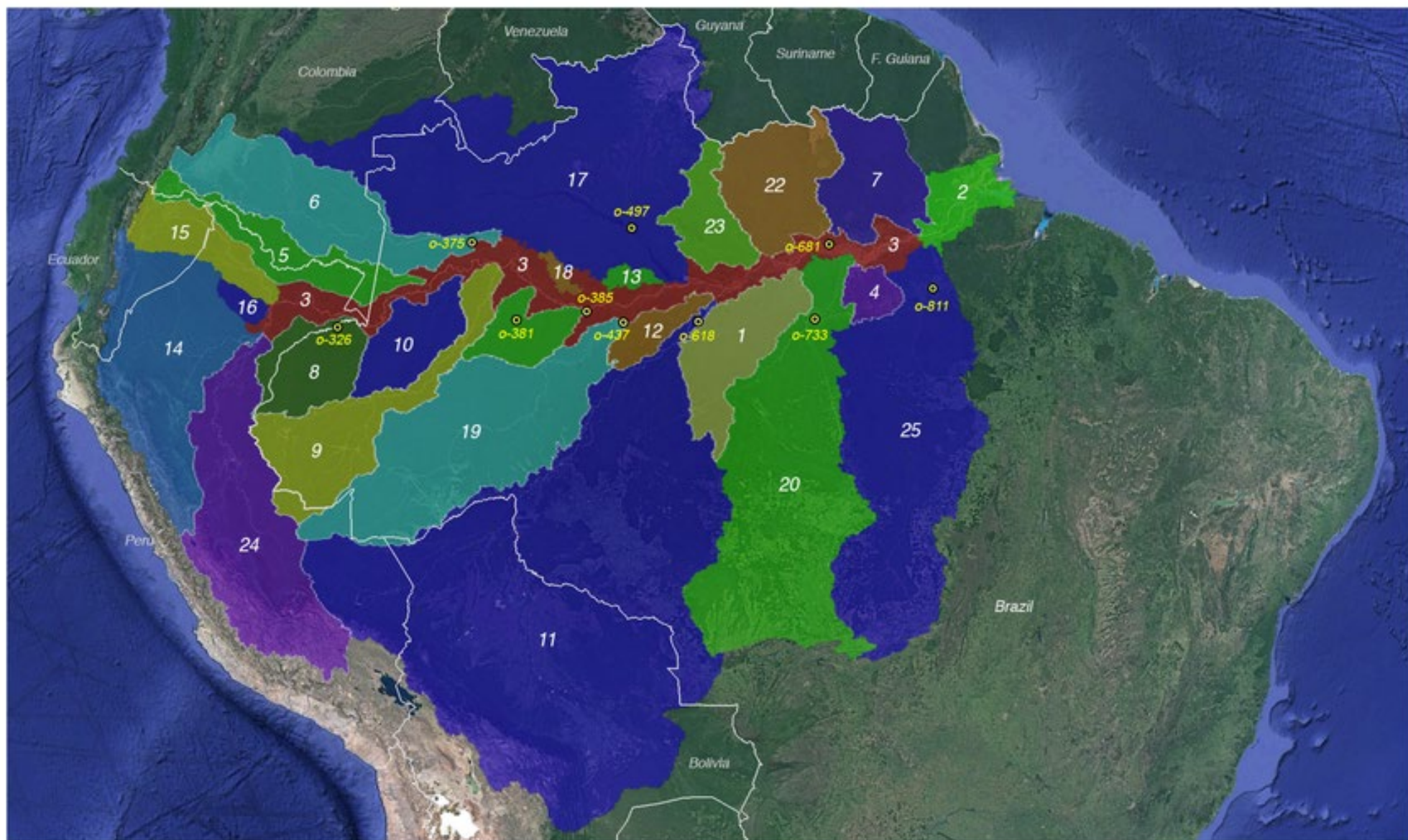
A catchment is the area where precipitation collects and drains into a specific river, lake, reservoir, or other water body.



Watershed

A watershed is a larger drainage area that collects water and directs it toward a major river, basin, or ocean.

It is usually defined by topographic boundaries (hills, ridges, or mountains) that separate it from adjacent watersheds.



Key Characteristics

- Size and Shape



Key Characteristics

- Size and Shape
- Slope and Topography



Key Characteristics

- Size and Shape
- Slope and Topography
- Soil Type and Land Use



Key Characteristics

- Size and Shape
- Slope and Topography
- Soil Type and Land Use
- Drainage Density

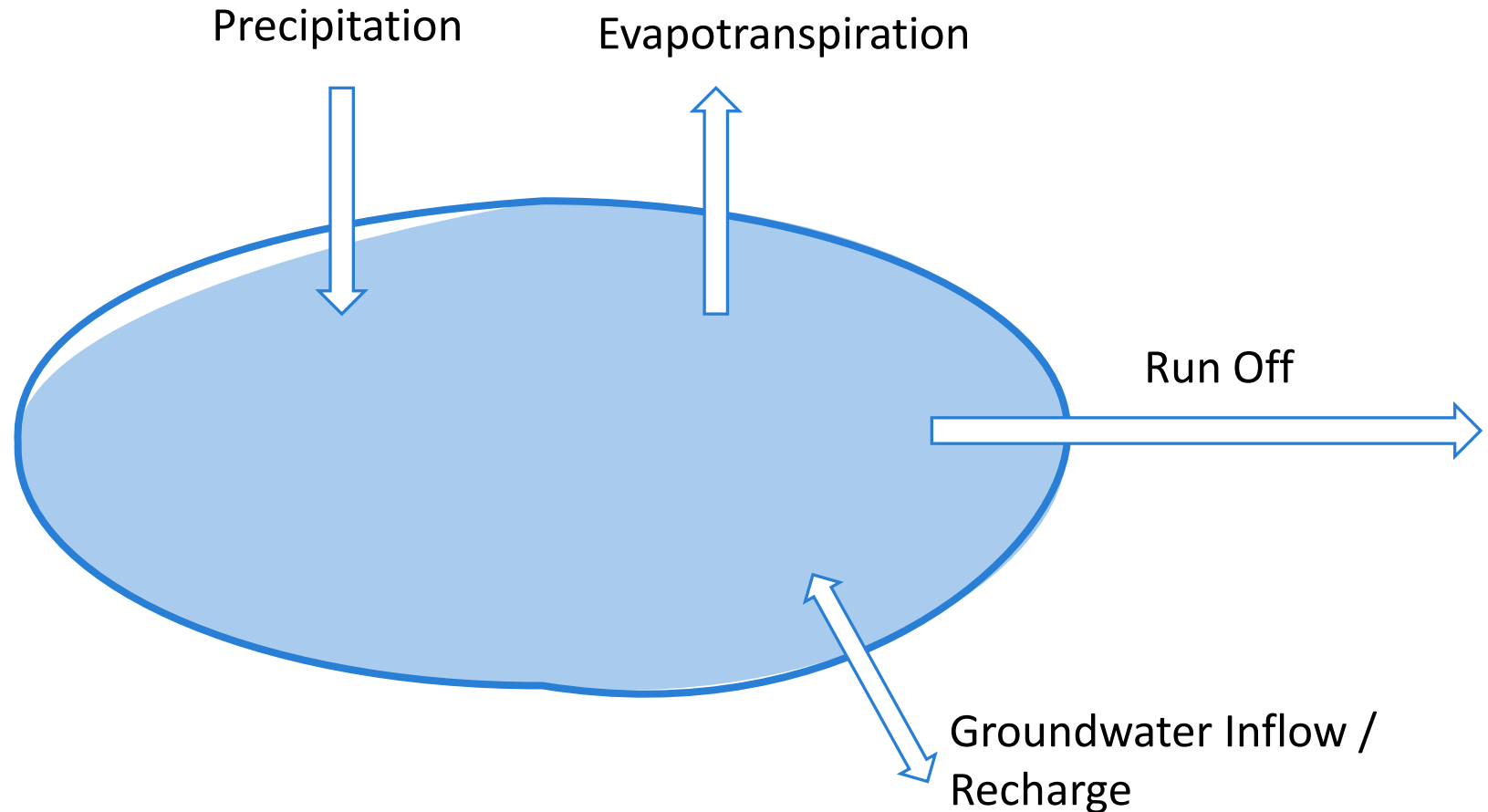


Hydrologic Budget

- The interpretation of the hydrologic cycle within the confines of a catchment leads to the concept of hydrologic budget.
- This is a quantitative assessment of inflows, outflows and storage within a defined system, such as a catchment, or a lake.
- It follows the principle of conservation on mass, ensuring the total amount of water remained balanced over time.

Hydrologic Budget

The hydrologic budget is the annual balance between precipitation, evapotranspiration, groundwater inflow / recharge and runoff.



Hydrologic Budget

$$\Delta S = P - E \pm G - Q$$

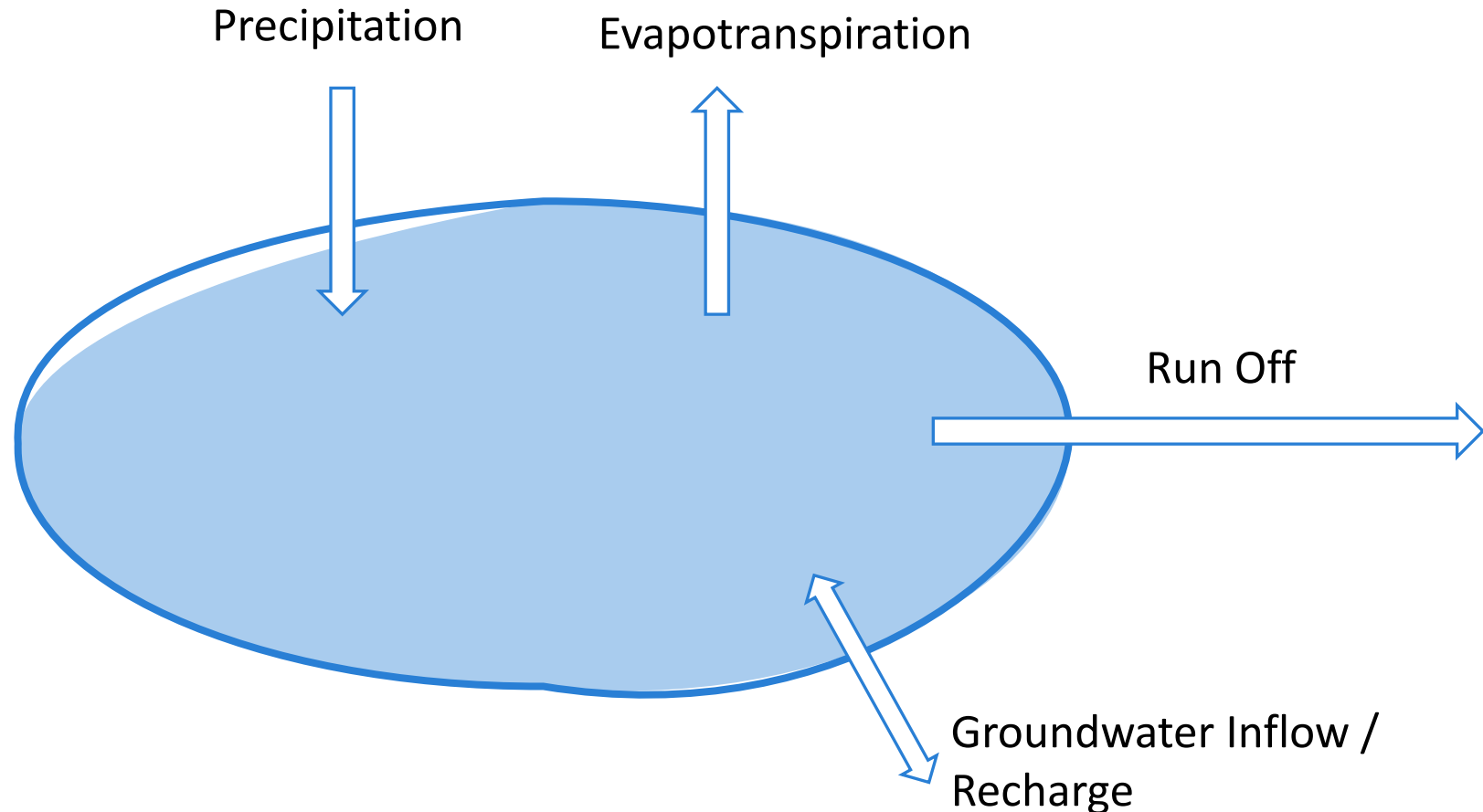
ΔS = Change in Storage

P = Precipitation

E = Evapotranspiration

G = Groundwater Inflow /
Recharge

Q = Surface Run off





Intensity-Duration-Frequency Curves

- Intense precipitation events can deliver large amounts of rain over short periods of time.
- This rain, as well as related flooding, can overwhelm storm drains, flood basements, wash out bridges and roads, and trigger landslides.
- To reduce the risk of these impacts, engineers, hydrologists, planners and other decision makers rely on accurate information about extreme rainfall events.
- IDF curves are one important source of this information

Intensity-Duration-Frequency Curves



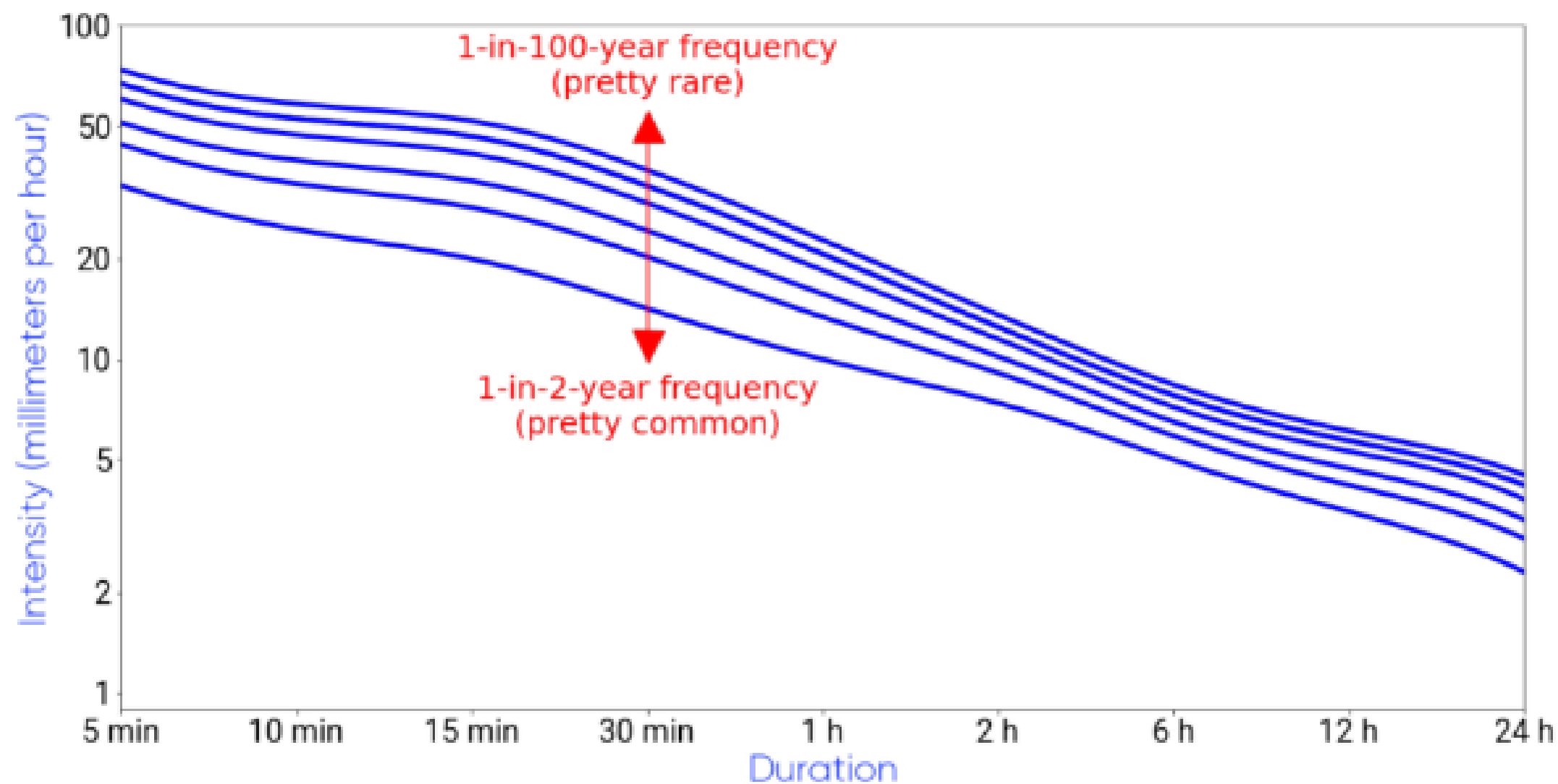
Duration: The period of time of interest

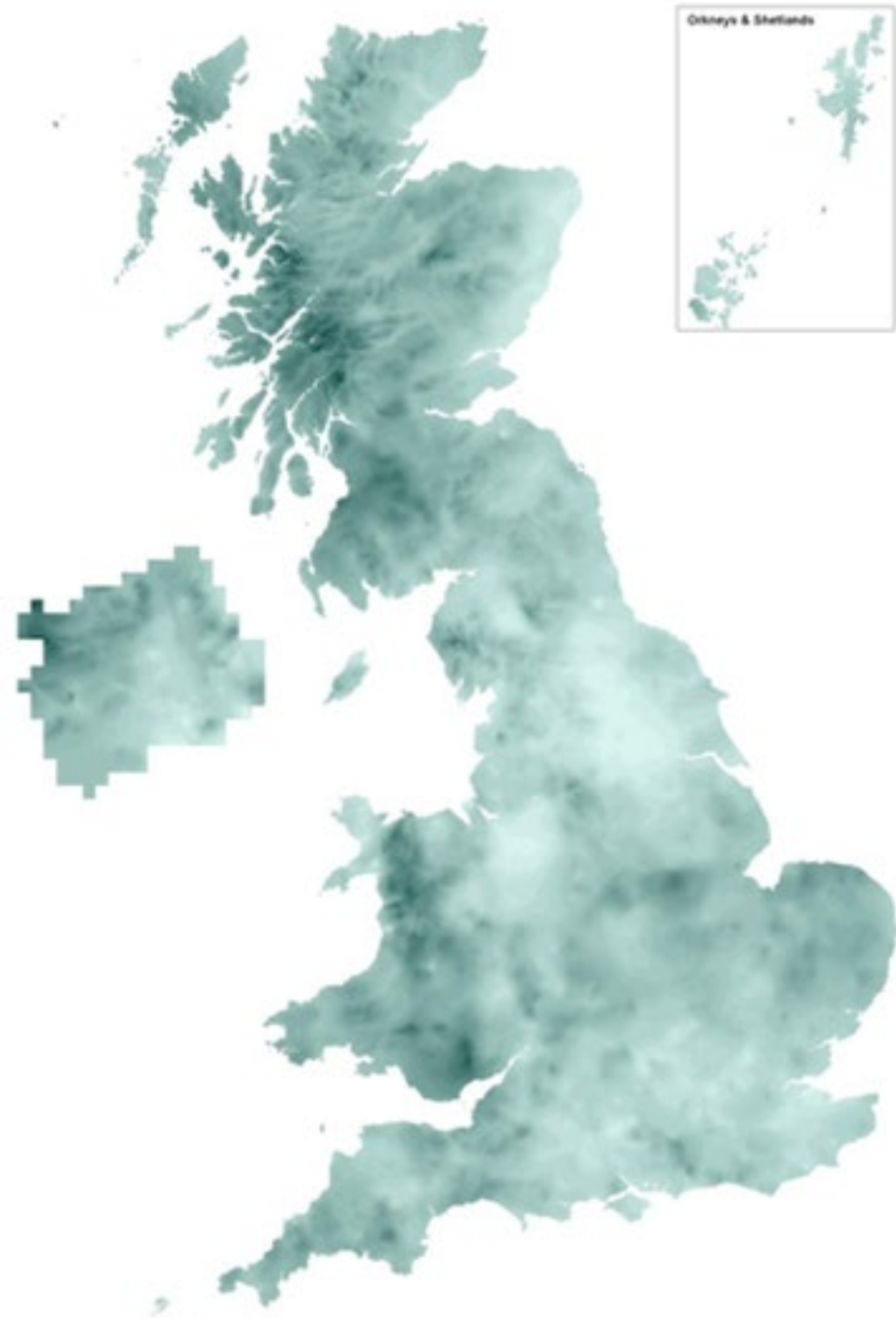


Intensity: The average rainfall over the specific duration.



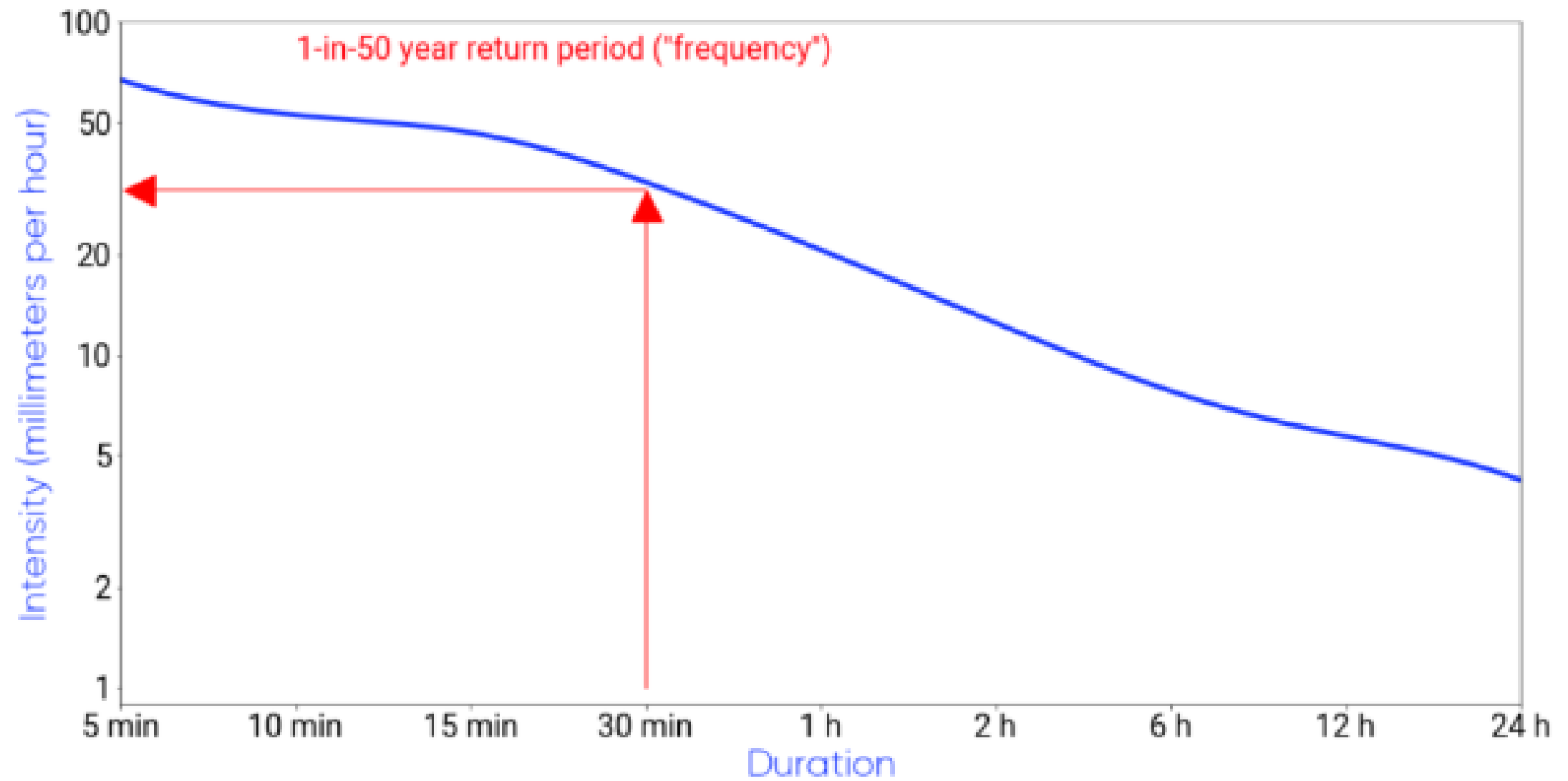
Frequency: To plan for extreme events, it matters how often such event occur.

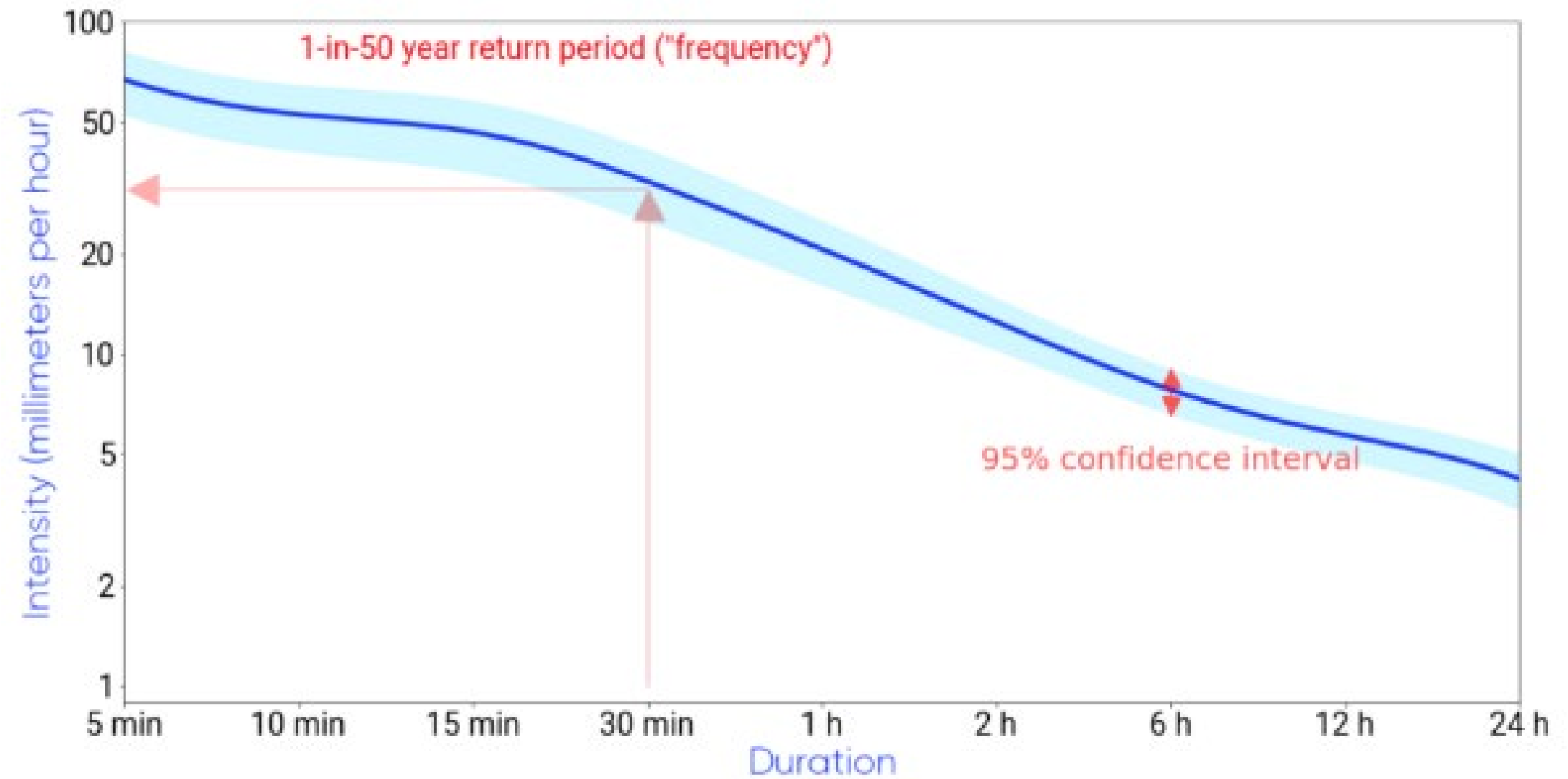




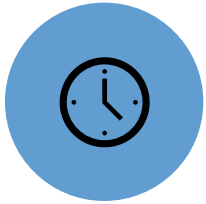
Return Period

- This is often described as a return period, which is defined as how often, on average, the event is expected to occur.
- Frequency can also be thought of in terms of probability or likelihood.
- For example, an event with a 1-in-20 year return period will occur on average once every 20 years, and therefore has a 1-in-20, or 5%, chance of occurring each year.

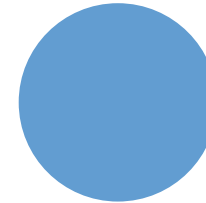
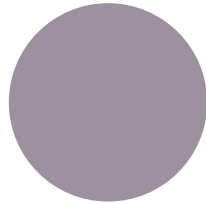
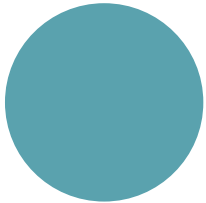
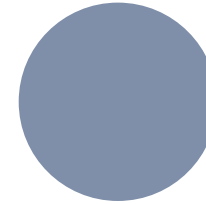
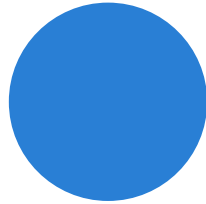




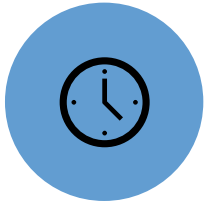
Best Practice



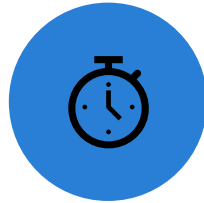
Appropriate Return
Period



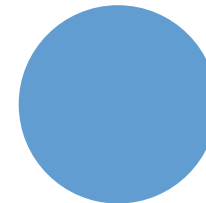
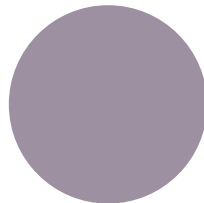
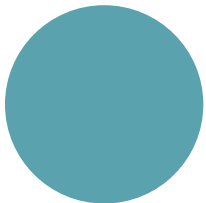
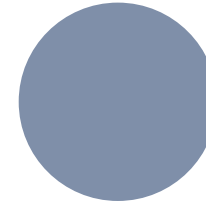
Best Practice



Appropriate Return
Period

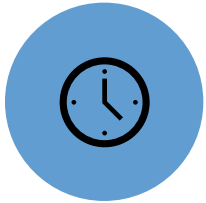


Appropriate Storm
Duration

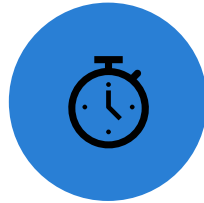




Best Practice



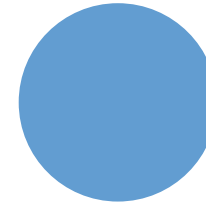
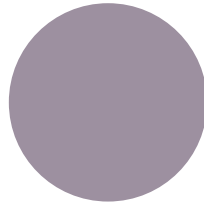
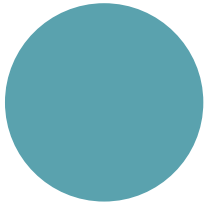
Appropriate Return
Period



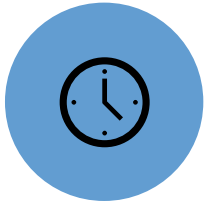
Appropriate Storm
Duration



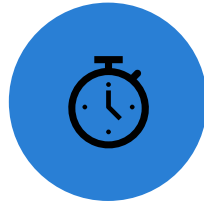
Understand
hydrologic
processes



Best Practice



Appropriate Return
Period



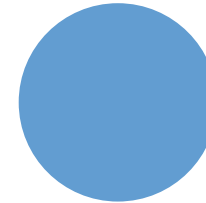
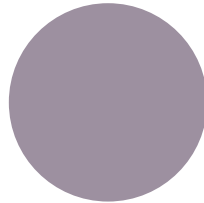
Appropriate Storm
Duration



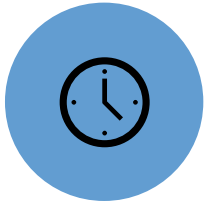
Understand
hydrologic
processes



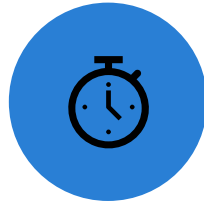
Understand
weather events



Best Practice



Appropriate Return
Period



Appropriate Storm
Duration



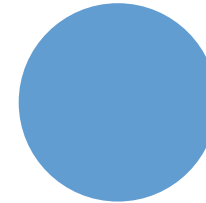
Understand
hydrologic
processes



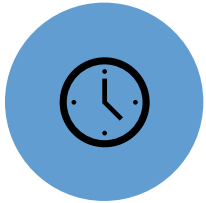
Understand
weather events



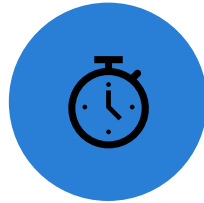
Long data records



Best Practice



Appropriate Return
Period



Appropriate Storm
Duration



Understand
hydrologic
processes



Understand
weather events



Long data records



Specific locations



River Flow

Discharge, the flow of water through a river per unit of time, is an essential parameter in hydrology and civil engineering.

$$Q = A \times V$$

Q = Discharge (m^3/s)

A = Cross-sectional area of the flow (m^2)

V = Average Flow Velocity (m/s)

Discharge – Measurement Methods

Velocity – Area Method

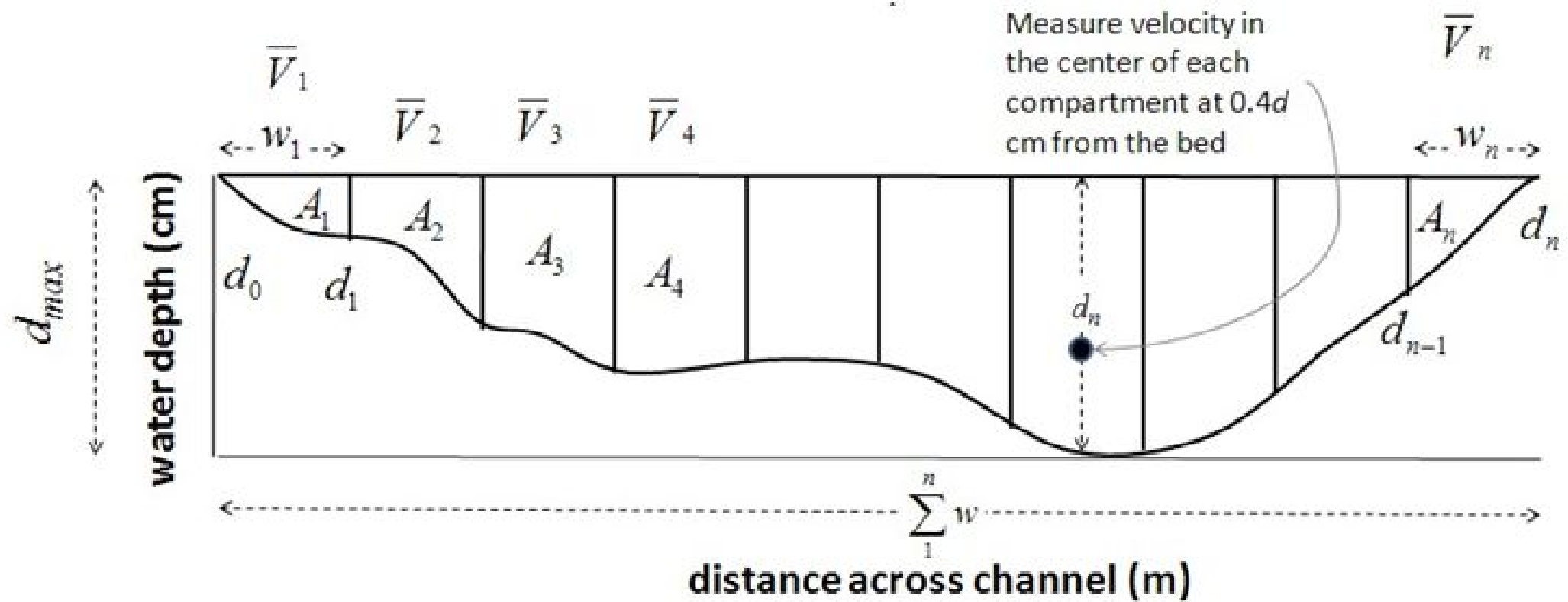
This method calculates discharge by measuring flow velocity at various points across a river cross-section and then multiplying by the cross-sectional area.

Discharge – Measurement Methods

Velocity – Area Method

Steps:

1. Divide the river cross-section into segments.
2. Measure the flow velocity at different points in each segment.
3. Multiply the velocity by the cross-sectional area of each segment.
4. Sum the values to estimate the total discharge.



Discharge – Measurement Methods

Weirs

To calculate discharge (flow rate) using a weir, you need to use a formula that relates the height of the water above the weir (known as the head) to the flow rate.

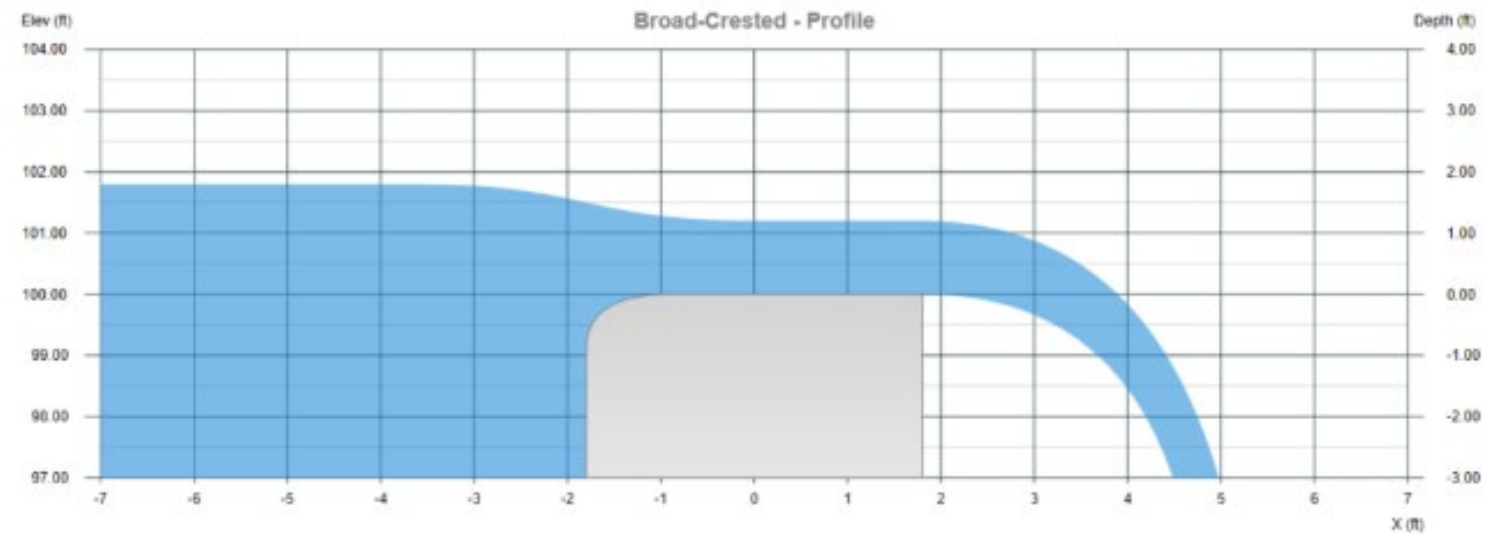
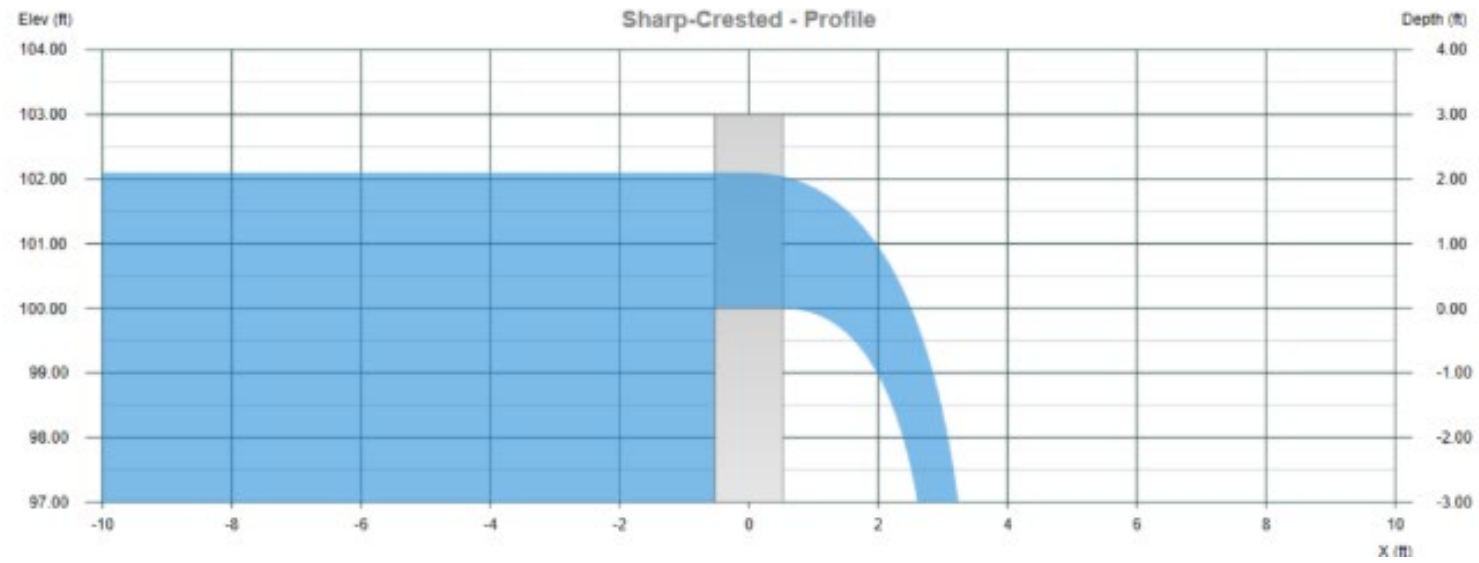
The calculation depends on the type of weir, the shape of the weir crest, and the characteristics of the water flow.

Discharge – Measurement Methods

Weirs

Steps:

1. Measure the head (H)



Discharge – Measurement Methods

Weirs

Steps:

1. Measure the head (H)
2. Determine the Weir Type



Discharge – Measurement Methods

Weirs

Steps:

1. Measure the head (H)
2. Determine the Weir Type
3. Apply the appropriate formula

Rectangular Weir

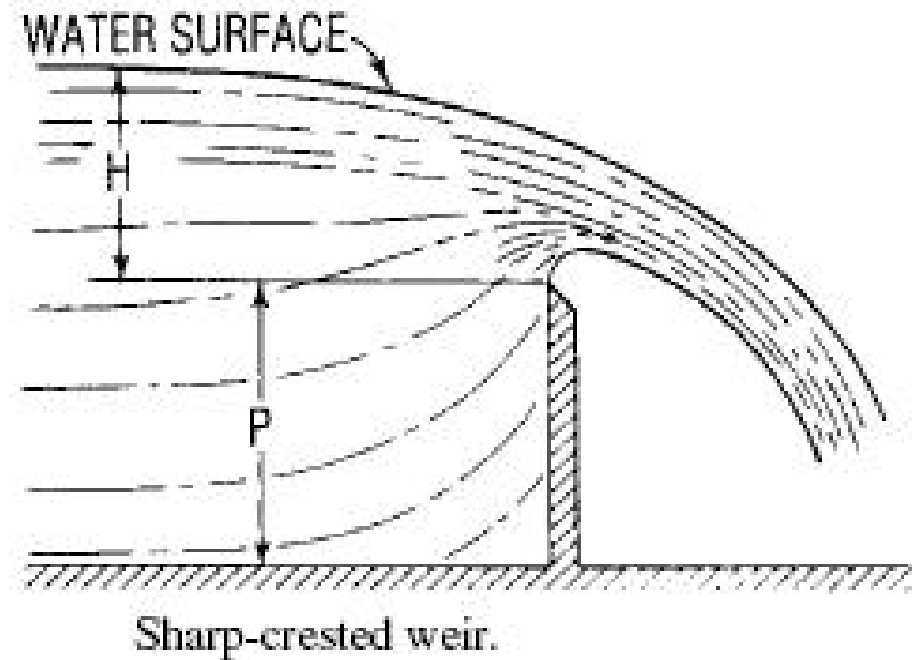
$$Q = C_d b H^{1.5}$$

Q = Discharge (m^3/s)

C_d = Weir Discharge Coefficient

b = Weir Crest Length (m)

H = Head (m)



V-Notch Weir

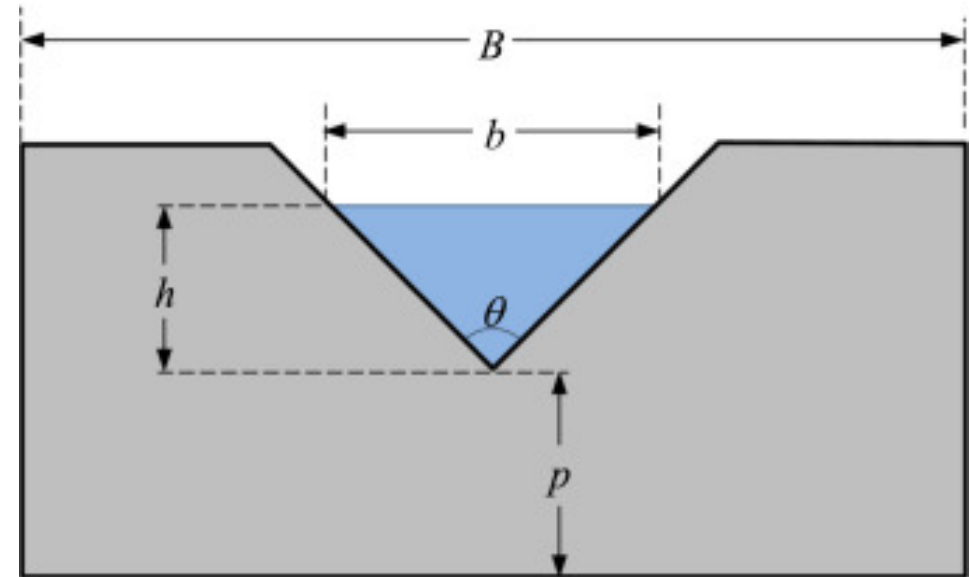
$$Q = \frac{8}{15} C_d \tan \frac{\theta}{2} \sqrt{2g} H^{2.5}$$

Q = Discharge (m^3/s)

C_d = Weir Discharge Coefficient

θ = Internal Angle of Notch ($^\circ$)

H = Head (m)



Broad-Crested Weir

$$Q = C_d L \sqrt{2g} (H_1 - H_2)^{1.5}$$

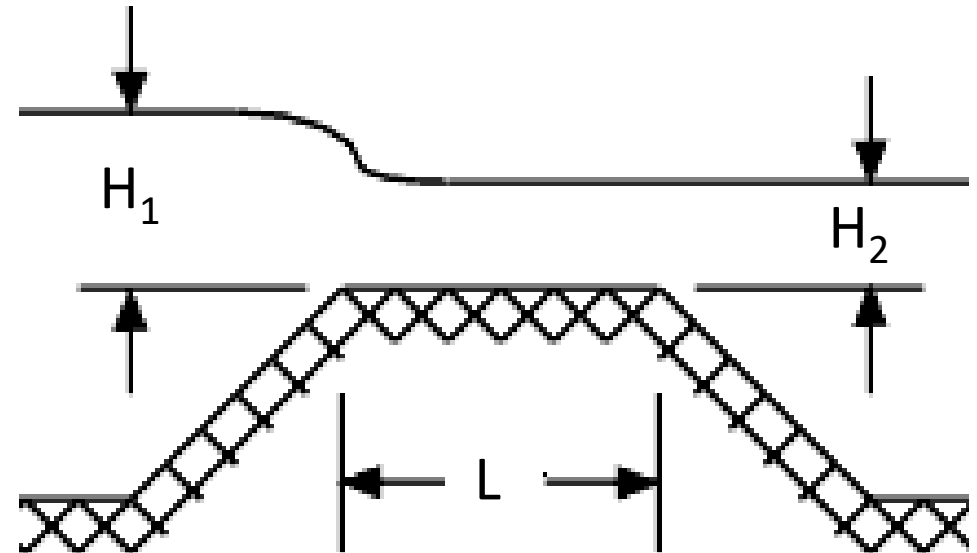
Q = Discharge (m^3/s)

C_d = Weir Discharge Coefficient

L = Width of weir crest (m)

H_1 = Upstream Head (m)

H_2 = Downstream Head (m)



Broad-Crested Weir

A broad-crested submerged weir is installed in a river to regulate and measure flow. The width of the weir crest is 4.5 metres, and the upstream head (H_1) is 1.2 metres. The downstream head (H_2) is 0.8 metre. The discharge coefficient C_d for this weir is 2.8.

Discharge – Measurement Methods

Acoustic Doppler Devices

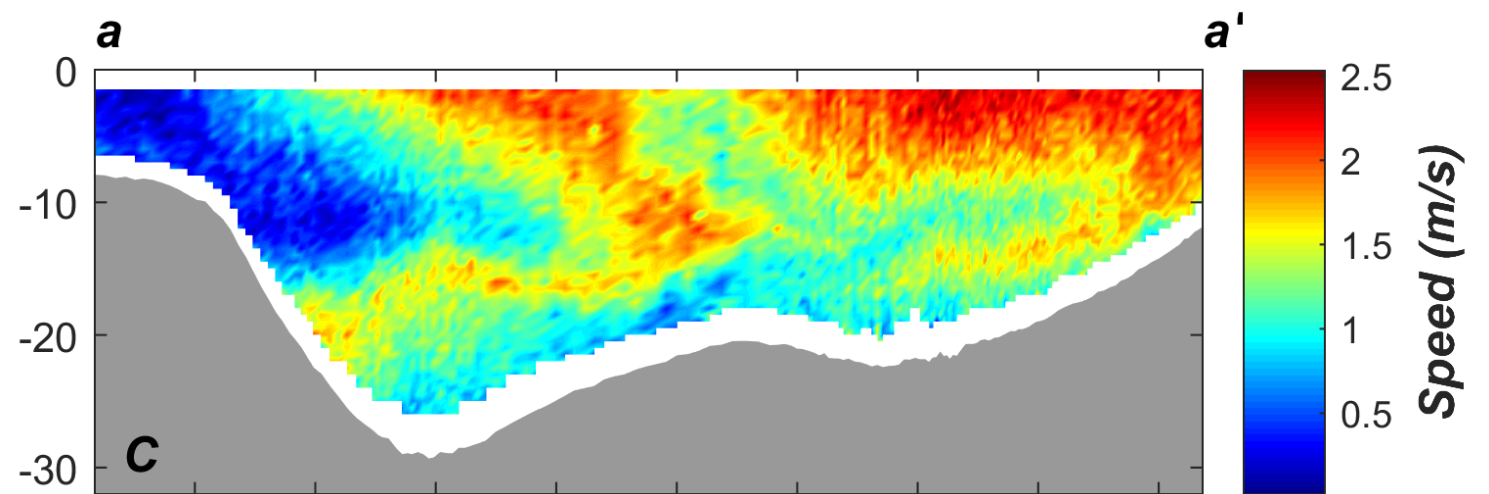
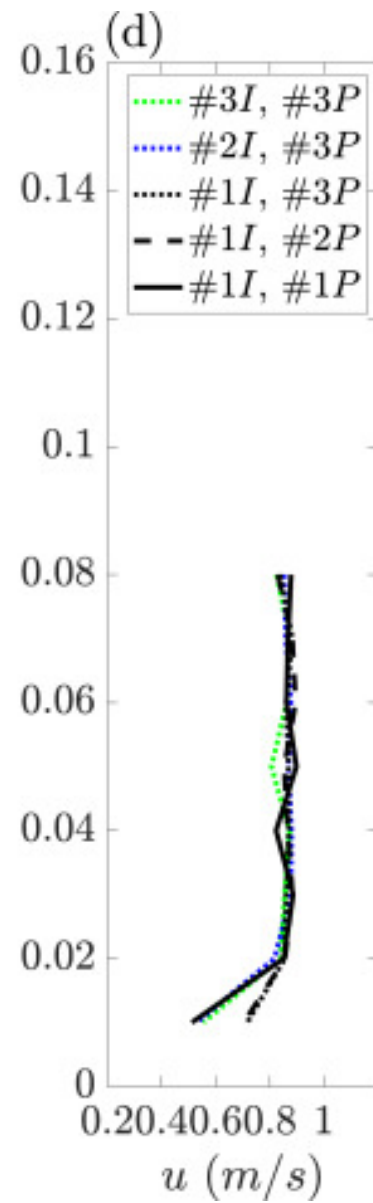
Uses the Doppler effect to measure water velocity by bouncing sound waves off moving particles in the water.

Discharge – Measurement Methods

Acoustic Doppler Devices

- Acoustic Doppler Velocity Profiler (ADVP): Measures flow velocity at specific points across the river.
- Acoustic Doppler Current Profiler (ADCP): Measures water velocity over a large vertical range and cross-sectional area.





Discharge – Measurement Methods

Remote Sensing and Satellite Data

Uses satellite images, radar, and other remote sensing technologies to monitor river discharge over large areas.



Discharge – Measurement Methods

Remote Sensing and Satellite Data

- Satellite Altimetry: Measures water level changes over time
- Radar-based Remote Sensing: Measures surface flow velocities or water levels.

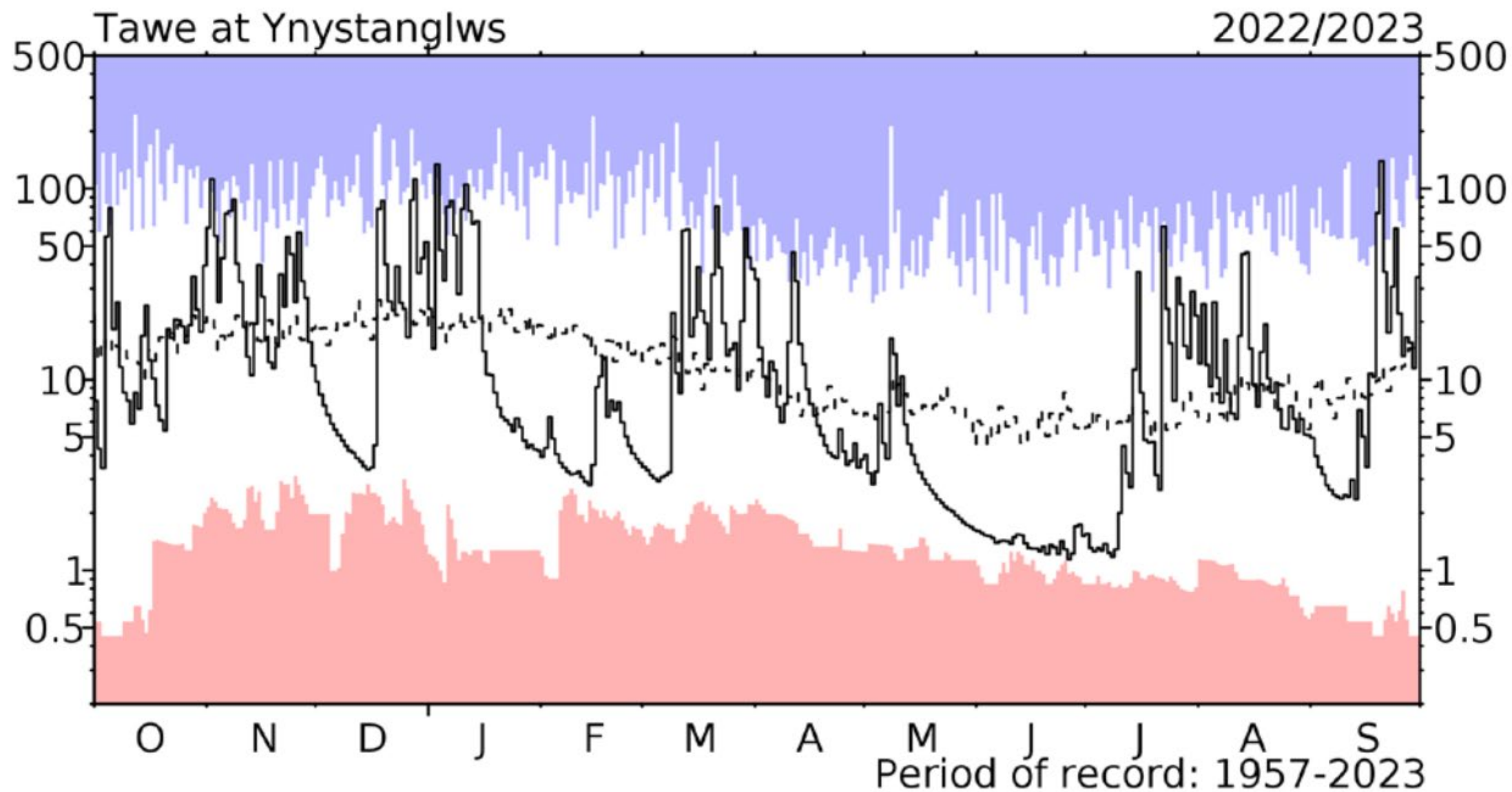
Hydrographs

Hydrographs are graphical representations of river discharge or streamflow over time.

They are essential tools in hydrology as they provide insights into how water flows through a watershed, illustrating the relationship between rainfall events, runoff, and river response.

Understanding hydrographs helps in predicting flood events and managing water resources effectively.



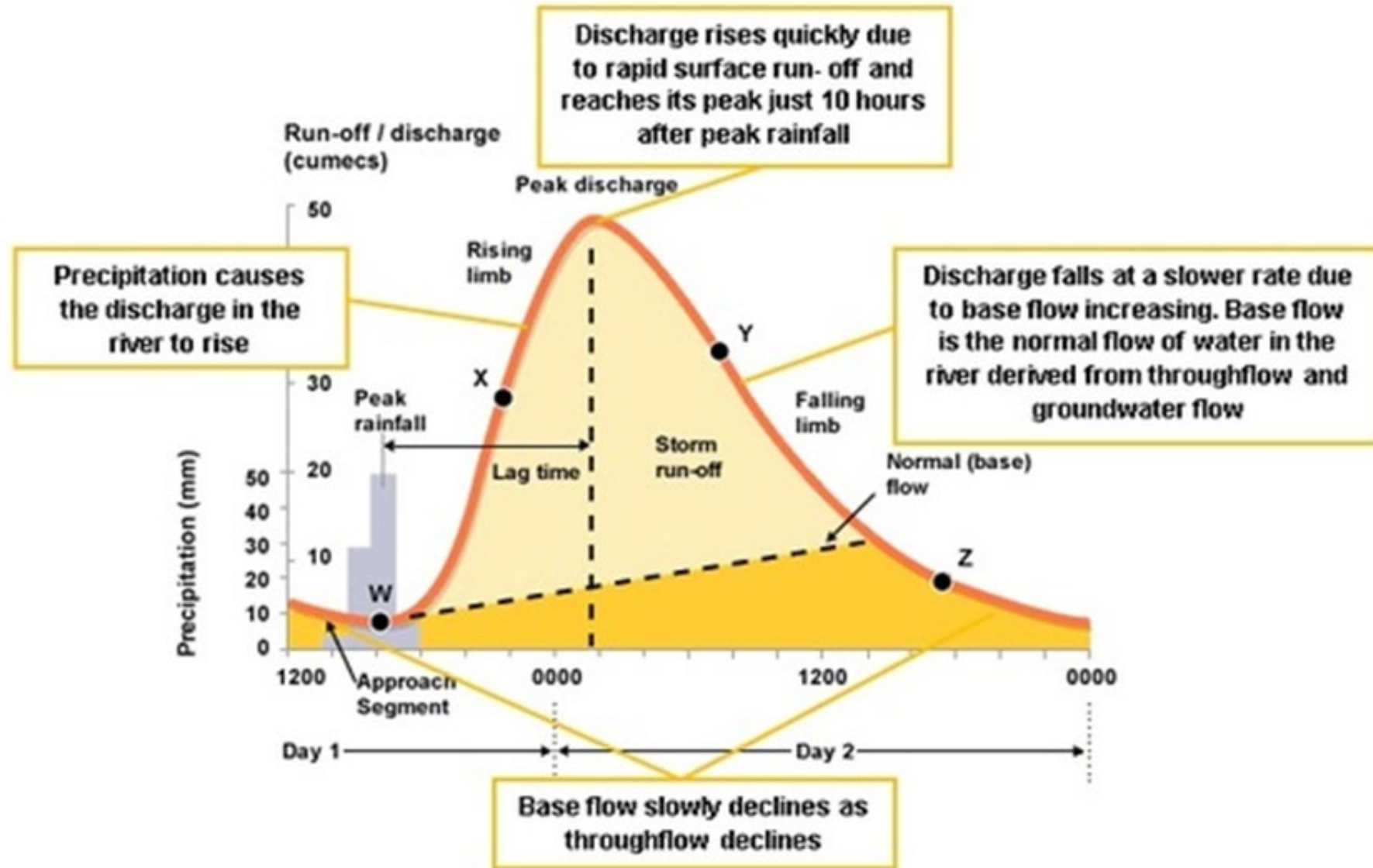


Storm Hydrographs

We often need to know about much shorter-term responses of a catchment to a large amount of rainfall, to make flooding predictions.

For these flood or storm hydrographs, information on rainfall and flow are presented with time intervals of hours, rather than months.





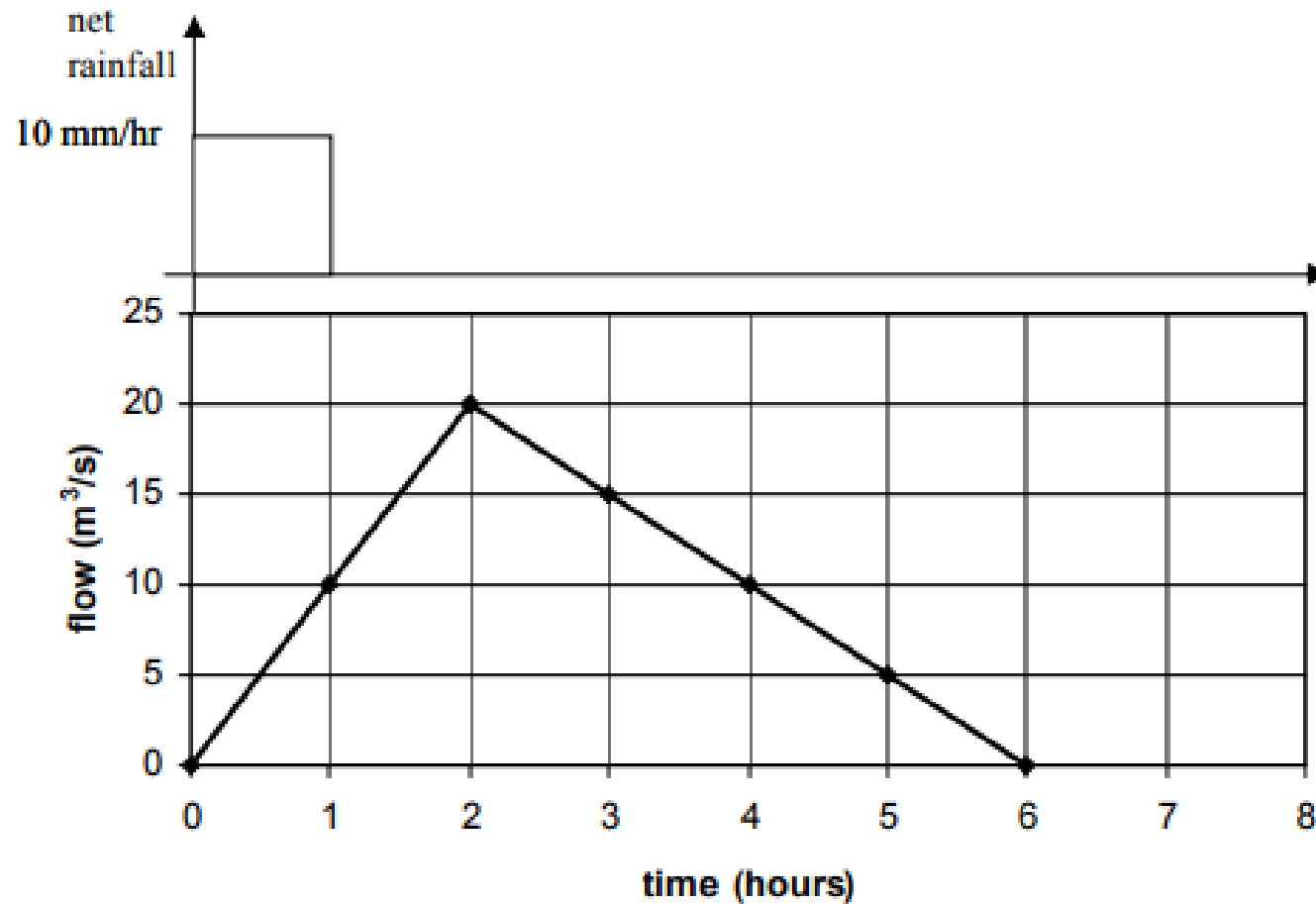
Unit Hydrographs

For flood predictions, we need a method of deriving the (extra) runoff that results from a given storm event, with a given (net) rainfall.



Unit Hydrographs

The unit hydrograph (UH) is the response of a catchment to 10mm of rain falling over a given period.



Unit Hydrographs

We assume that there is a linear relation between the net rainfall and the runoff.

Unit Hydrographs

For a Unit Hydrograph to be valid, certain assumptions are made:

1. Linear Response

Unit Hydrographs

For a Unit Hydrograph to be valid, certain assumptions are made:

1. Linear Response
2. Time Invariance

Unit Hydrographs

For a Unit Hydrograph to be valid, certain assumptions are made:

1. Linear Response
2. Time Invariance
3. Uniform Distribution

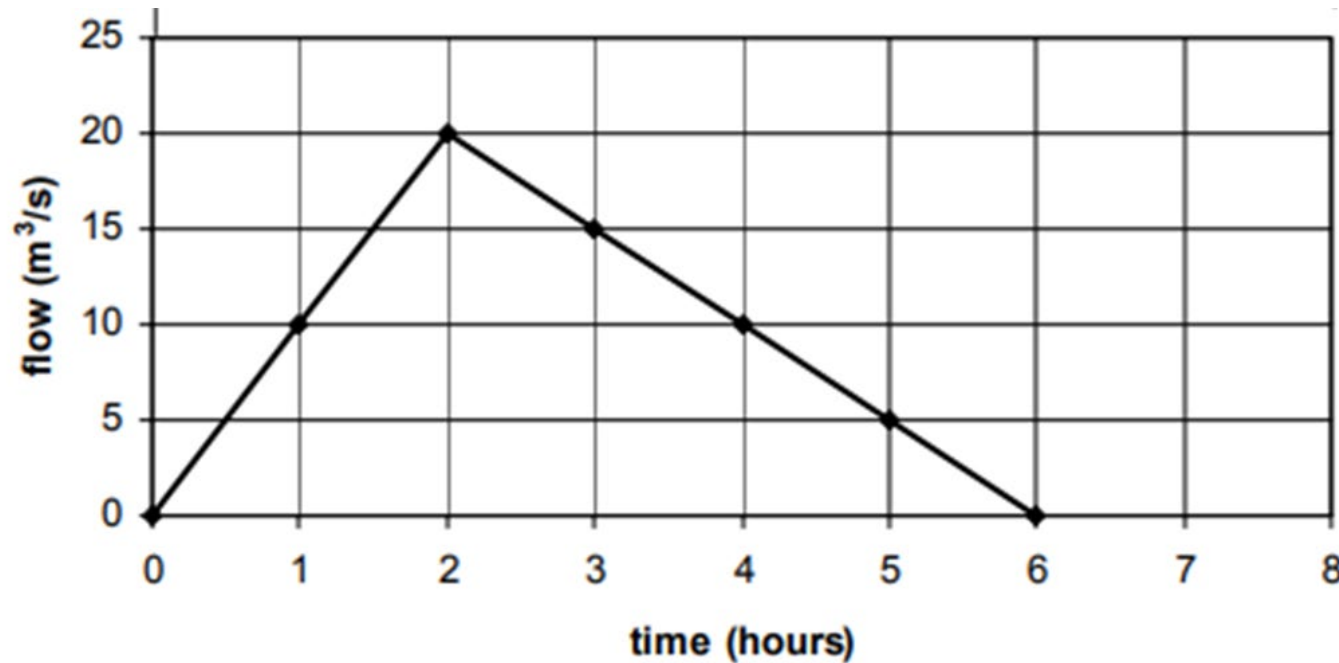
Unit Hydrographs

For a Unit Hydrograph to be valid, certain assumptions are made:

1. Linear Response
2. Time Invariance
3. Uniform Distribution
4. Superposition

Unit Hydrographs

Using this one-hour unit hydrograph, calculate the runoff from a storm where the hourly rainfall was 15 mm in the first hour, 25 mm in the second, 20 mm in the third and 5 mm in the fourth.



Unit Hydrographs

[illegible]

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15								
2	25		0								
3	20										
4	5										
Total		0	15								

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30							
2	25		0	25							
3	20										
4	5										
Total		0	15	55							

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5						
2	25		0	25	50						
3	20			0	20						
4	5				0						
Total		0	15	55	92.5						

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5	15					
2	25		0	25	50	37.5					
3	20			0	20	40					
4	5				0	5					
Total		0	15	55	92.5	97.5					

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5	15	7.5				
2	25		0	25	50	37.5	25				
3	20			0	20	40	30				
4	5				0	5	10				
Total		0	15	55	92.5	97.5	72.5				

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5	15	7.5	0			
2	25		0	25	50	37.5	25	12.5			
3	20			0	20	40	30	20			
4	5				0	5	10	7.5			
Total		0	15	55	92.5	97.5	72.5	40			

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5	15	7.5	0			
2	25		0	25	50	37.5	25	12.5	0		
3	20			0	20	40	30	20	10		
4	5				0	5	10	7.5	5		
Total		0	15	55	92.5	97.5	72.5	40	15		

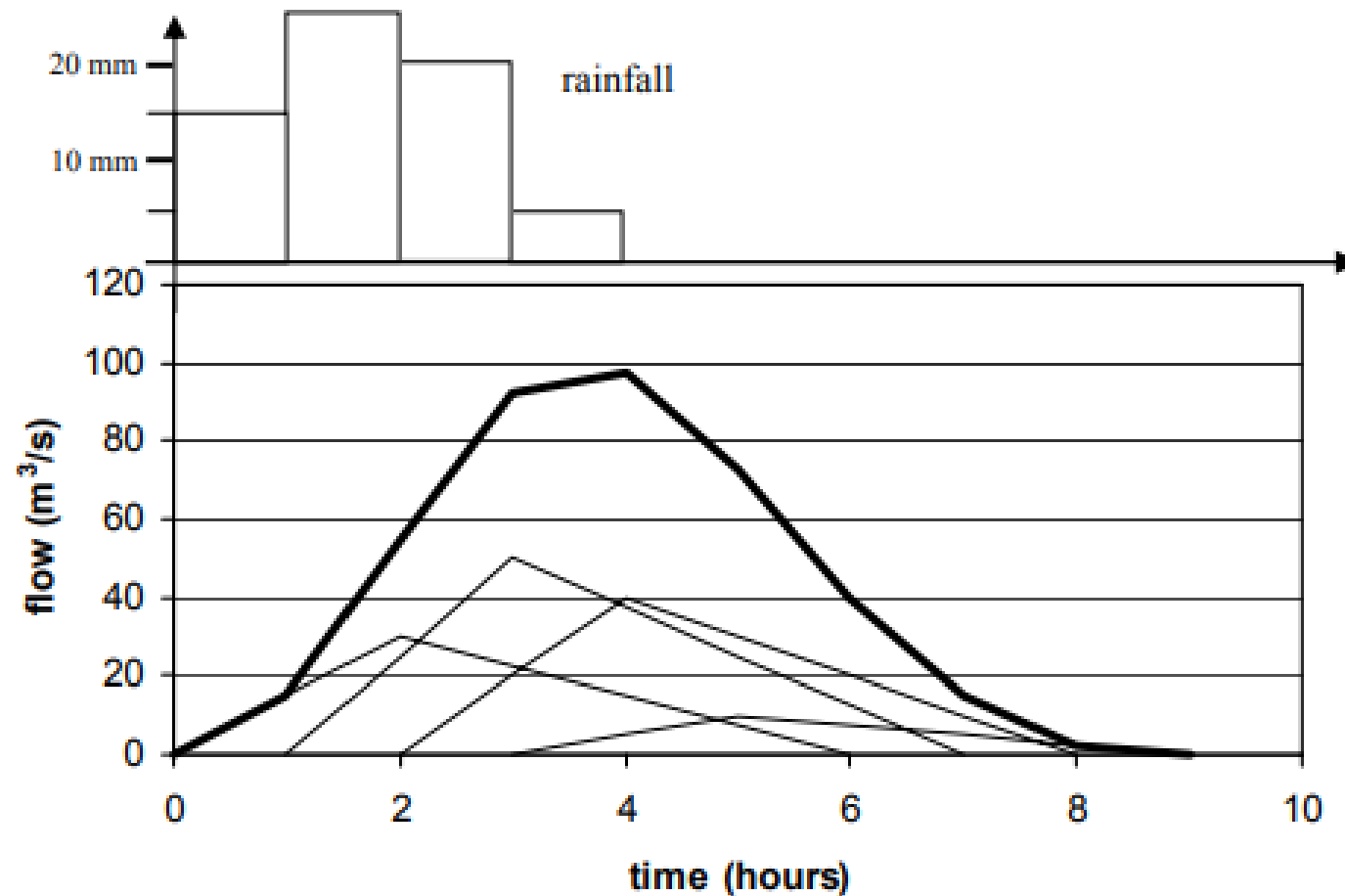
Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5	15	7.5	0			
2	25		0	25	50	37.5	25	12.5	0		
3	20			0	20	40	30	20	10	0	
4	5				0	5	10	7.5	5	2.5	
Total		0	15	55	92.5	97.5	72.5	40	15	2.5	

Unit Hydrographs

	t	0	1	2	3	4	5	6	7	8	9
	UH	0	10	20	15	10	5	0			
Hour	Rainfall										
1	15	0	15	30	22.5	15	7.5	0			
2	25		0	25	50	37.5	25	12.5	0		
3	20			0	20	40	30	20	10	0	
4	5				0	5	10	7.5	5	2.5	0
Total		0	15	55	92.5	97.5	72.5	40	15	2.5	0

Unit Hydrographs



Rational Method

The Rational Method is one of the simplest and most widely used techniques for estimating peak discharge from small watersheds. It is especially suited for urban drainage design due to its straightforward assumptions.

Rational Method

$$Q = 2.78 \times C \times i \times A$$

Where:

Q = peak discharge (l/s)

C = runoff coefficient (dimensionless, 0–1)

i = rainfall intensity (mm/h)

A = area (hectares)

Rational Method

Runoff Coefficient (C)

Represents the fraction of rainfall that becomes runoff.

Depends on:

- Land use (pavement, grassland, forest, etc.)
- Soil type and infiltration capacity
- Slope and surface condition

Rational Method

Runoff Coefficient (C)

Typical values:

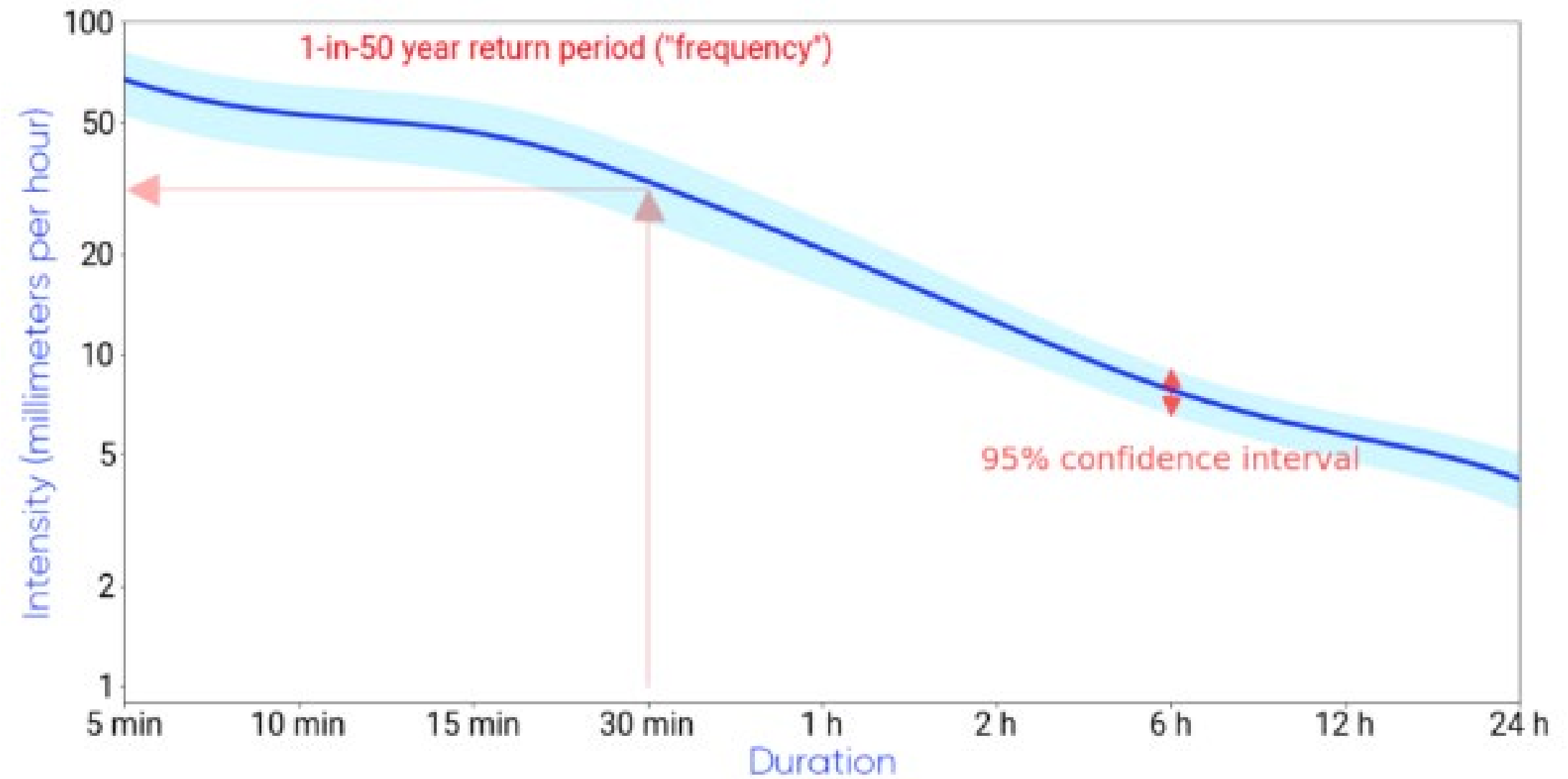
0.9–1.0 — fully impervious areas

0.3–0.6 — residential areas

0.1–0.3 — parks, pervious soils

Rational Method

Rainfall Intensity (i) is the average rate at which rain falls over a given duration.



Rational Method

Calculate the peak runoff for a 1.1 hectare site using the following values:

$C = 0.9$

$i = 23.3\text{mm/h}$ (1 in 2)



Rational Method

Calculate the peak runoff for a 1.1 hectare site using the following values:

$C = 0.9$

$i = 50.7\text{mm/h}$ (1 in 30)



Rational Method

Calculate the peak runoff for a 1.1 hectare site using the following values:

$C = 0.75$

$i = 50.7\text{mm/h}$ (1 in 30)



Flow in a Pipe

Manning's Equation can be used to work out flow in a pipe:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Q = Flow rate (m³/s)

n = Manning's roughness coefficient

A = cross-sectional area (m²)

R = hydraulic radius = A/P (m), where P is the wetted perimeter (m)

S = Slope (m/m)

<u>Channel Surface</u>	<u>Manning Roughness Coefficient, n</u>
Asbestos cement	0.011
Brass	0.011
Brick	0.015
Cast-iron, new	0.012
Concrete, steel forms	0.011
Concrete, wooden forms	0.015
Concrete, centrifugally spun	0.013
Copper	0.011
Corrugated metal	0.022
Galvanized Iron	0.016
Lead	0.011
Plastic	0.009
Steel - Coal-tar enamel	0.01
Steel - New unlined	0.011
Steel - Riveted	0.019
Wood stave	0.012