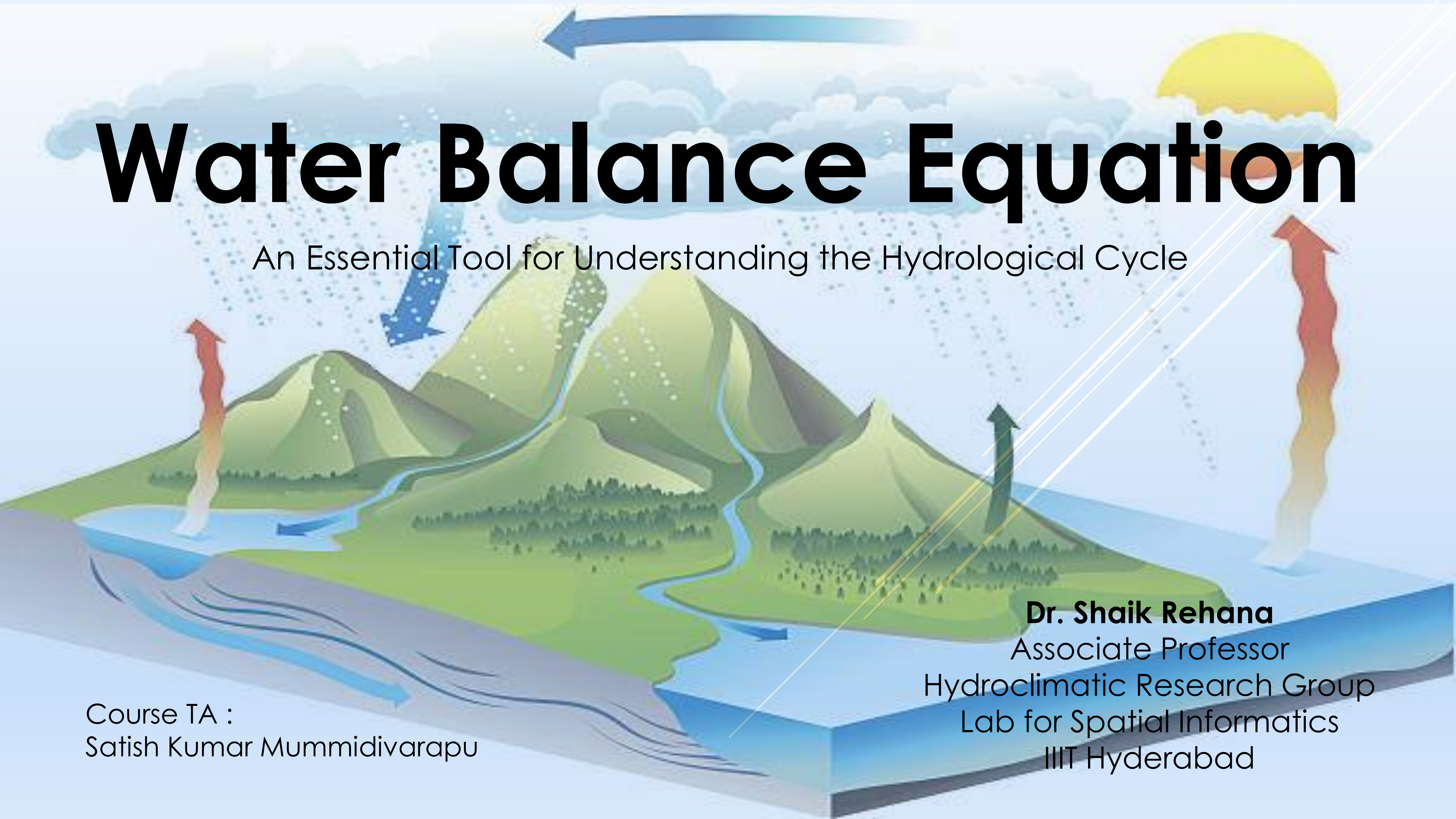

# Water Balance Equation

An Essential Tool for Understanding the Hydrological Cycle

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# Introduction to Water Balance

**Can we quantify the water in bucket ?**

**What about huge water bodies like lakes, reservoirs?**

**How ?**

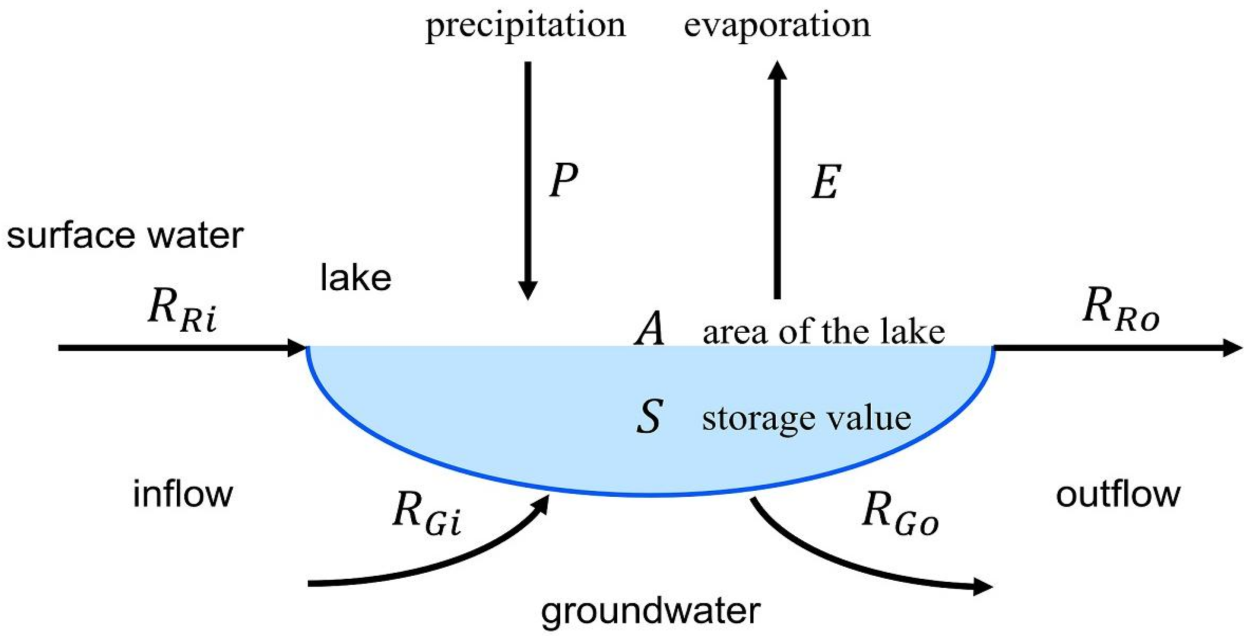
# Introduction to Water Balance

**Definition:**

- The water balance equation is a quantitative method used to describe the flow of water in and out of a system, such as a watershed or a region.

**Purpose:**

- Helps in hydrological studies, water resource management, and climate impact assessment.



# More on Water Balance

- A water balance can be established for any area of earths surface by calculating the total precipitation input and total of various outputs.
- The water balance approach allows an examination of the hydrological cycle for any period of time.
- The purpose of the water balance is to describe the various ways in which the water supply is expected.
- The water balance is a method by which we can account for the hydrological cycle of a specific area, with emphasis on plants and soil moisture.

# Water Balance Equation

- Input-output= balance
- In water balance all components of input and output are considered
- Methods vary- as:
  - Surface water balance
  - Groundwater balance
  - Soil water balance
  - Lake water balance
  - Oceanic water balance
- Input components are= rainfall, snowfall
- Output components are = Runoff, infiltration, baseflow, evapotranspiration

# Water Balance Equation

**Equation:**

$$P = ET + R + \Delta S$$

where:
P: Precipitation
ET: Evapotranspiration
R: Runoff (surface and subsurface)
ΔS: Change in storage (groundwater, soil moisture, etc.)

**Assumptions:**

- System boundaries are clearly defined.
- Units of water input and output are consistent.

# Components of the Water Balance Equation

**Precipitation (P):**

- Rainfall, snow, and other forms of atmospheric water input.

**Evapotranspiration (ET):**

- Water loss due to evaporation and plant transpiration.

**Runoff (R):**

- Surface and subsurface flow leaving the system.

**Storage Change (ΔS):**

- Groundwater recharge/discharge, soil water retention, and snowpack changes.

# Applications of the Water Balance Equation

**1. Watershed Management:**

- Estimating water availability for agriculture or urban needs.

**2. Flood and Drought Analysis:**

- Predicting extreme hydrological events.

**3. Climate Change Studies:**

- Understanding how precipitation and ET patterns are shifting.

**4. Groundwater Assessment:**

- Quantifying aquifer recharge and depletion rates.

# Limitations and Considerations

- **Spatial Scale:**
  - Equation components vary across regions.
- **Temporal Scale:**
  - Seasonal and interannual variability affects precision.
- **Measurement Challenges:**
  - Accuracy of precipitation and ET data.

# Problems on Water Balance Equation

1. A watershed receives 500 mm of precipitation annually. The annual evapotranspiration is 300 mm, and the runoff is 150 mm. Calculate the change in storage ($\Delta S$).

**Solution-1**

**Given Data:**

Precipitation (P) = 500 mm

Evapotranspiration (ET) = 300 mm

Runoff (R) = 150 mm

Use the water balance equation: $\Delta S = P - ET - R$

Substitute the given values: $\Delta S = 500 - 300 - 150$

$\Delta S = 50 mm$

# Problems on Water Balance Equation

2. During a storm event, 50 mm of rainfall occurs. If the evapotranspiration during this period is 5 mm and the runoff is 30 mm, what is the change in storage?

**Solution-2**

**Given Data:**

Precipitation (P) = 50 mm

Evapotranspiration (ET) = 5 mm

Runoff (R) = 30 mm

Use the water balance equation: $\Delta S = P - ET - R$

Substitute the given values: $\Delta S = 50 - 5 - 30$

$\Delta S = 15$ mm

# Problems on Water Balance Equation

3. In a region, the following data is recorded for a month: precipitation = 100 mm, evapotranspiration = 70 mm, runoff = 20 mm. Calculate the monthly change in storage. How would the results change if precipitation increased by 20%?

**Solution-3**

**Given Data:**

Precipitation (P) = 100 mm

Evapotranspiration (ET) = 70 mm

Runoff (R) = 20 mm

Use the water balance equation: $\Delta S = P - ET - R$

Substitute the given values: $\Delta S = 100 - 70 - 20$

Perform the subtraction: $\Delta S = 10$ mm

**With a 20% Increase in Precipitation:**

Adjust precipitation: $P = 100 + (100 \times 0.2) = 120$ mm

Use the water balance equation with the adjusted P: $\Delta S = 120 - 70 - 20$

Perform the subtraction: $\Delta S = 30$ mm

Original: $\Delta S = 10$ mm

Adjusted: $\Delta S = 30$ mm

# Problems on Water Balance Equation

4. For a watershed, the following data is recorded over two seasons:
Wet season: $P=800$ mm, $ET=400$ mm, $R=300$ mm; Dry season: $P=200$ mm, $ET=250$ mm, $R=50$
Calculate the annual change in storage.

**Solution-4**

**Given Data:**

Wet Season:

Precipitation (P) = 800 mm

Evapotranspiration (ET) = 400 mm

Runoff (R) = 300 mm

Dry Season:

Precipitation (P) = 200 mm

Evapotranspiration (ET) = 250 mm

Runoff (R) = 50 mm

**Wet Season:**

Use the water balance equation: $\Delta S=P-ET-R$

Substitute wet season values: $\Delta S=800-400-300$

Perform the subtraction: $\Delta S=100$ mm

**Dry Season:**

Use the same equation: $\Delta S=P-ET-R$

Substitute dry season values: $\Delta S=200-250-5050$

Perform the subtraction: $\Delta S=-100$ mm

# Problems on Water Balance Equation

4. For a watershed, the following data is recorded over two seasons:
Wet season: $P=800$ mm, $ET=400$ mm, $R=300$ mm; Dry season: $P=200$ mm, $ET=250$ mm, $R=50$
Calculate the annual change in storage.

**Solution-4 Continued…**

**Annual Change:**

Add the wet and dry season storage changes: $\Delta S$ annual$=100+(-100)$

$$\Delta S \text{ annual} = 0 \text{ mm}$$

Therefore:

Wet Season: $\Delta S=100$mm,

Dry Season: $\Delta S=-100$mm,

Annual: $\Delta S=0$mm

# Problems on Water Balance Equation

5. A basin receives 600 mm of precipitation annually. Evapotranspiration accounts for 320 mm, and runoff contributes 150 mm. If the initial groundwater storage is 200 mm, calculate the final groundwater storage at the end of the year.

**Solution-5**

**Given Data:**

Precipitation (P) = 600 mm

Evapotranspiration (ET) = 320 mm

Runoff (R) = 150 mm

Initial Groundwater Storage = 200 mm

Use the water balance equation: $\Delta S = P - ET - R$

Substitute the given values: $\Delta S = 600 - 320 - 150$

$\Delta S = 130$ mm

# Problems on Water Balance Equation

5. A basin receives 600 mm of precipitation annually. Evapotranspiration accounts for 320 mm, and runoff contributes 150 mm. If the initial groundwater storage is 200 mm, calculate the final groundwater storage at the end of the year.

**Solution-5 Continued…**

**Final Groundwater Storage:**

Add $\Delta S$ to the initial storage: Final Storage=Initial Storage+$\Delta S$

Final Storage=Initial Storage+$\Delta S$

Final Storage=200+130

Final Storage=330 mm

# Problems on Water Balance Equation

6. An urban watershed receives an annual precipitation of 1200 mm. Out of this: 40% of the precipitation becomes surface runoff. 25% is lost to evapotranspiration. The remainder infiltrates and contributes to groundwater storage. Additionally, groundwater abstraction for urban water supply amounts to 100 mm per year.

Calculate the following:

i. The amount of water that contributes to surface runoff.

ii. The evapotranspiration.

iii. The net groundwater recharge, considering the abstraction.

# Problems on Water Balance Equation

**Solution-6**

**1. Surface Runoff Contribution:**

Calculate 40% of precipitation:

$R=0.4\times P=0.4\times 1200=480mm$

**2. Evapotranspiration Contribution:**

Calculate 25% of precipitation:

$ET=0.25\times P=0.25\times 1200=300$ mm

**3. Groundwater Recharge:**

Calculate the remaining water after runoff and evapotranspiration: $\Delta S=P-R-ET=1200-480-300=420$ mm

Subtract the groundwater abstraction:
Net Groundwater Recharge $=\Delta S-\text{Abstraction}=420-100=320$ mm

Surface runoff: $R=480$ mm
Evapotranspiration: $ET=300$ mm
Net groundwater recharge: 320 mm

# Problems on Water Balance Equation

7. A river basin receives precipitation during two seasons: wet and dry. The following data is recorded:

**Wet Season:**

Precipitation (P) = 900 mm
Evapotranspiration (ET) = 450 mm
Runoff (R) = 350 mm

**Dry Season:**

Precipitation (P) = 150 mm
Evapotranspiration (ET) = 180 mm
Runoff (R) = 30 mm

Groundwater storage at the start of the year is 500 mm.

**Question:**

Calculate the storage change (ΔS) for each season.

Determine the total annual storage change and the final groundwater storage at the end of the year.

# Problems on Water Balance Equation

**Solution-7**

**1. Wet Season Storage Change:**

Use the water balance equation: $\Delta S\ wet = P - ET - R$

$$\Delta S\ wet = 900 - 450 - 350 = 100\ mm$$

**2. Dry Season Storage Change:**

Use the same equation: $\Delta S\ dry = P - ET - R$

$$\Delta S\ dry = 150 - 180 - 30 = -60\ mm$$

**3. Total Annual Storage Change:**

Add the storage changes from both seasons:

$$\Delta S\ annual = \Delta S\ wet + \Delta S\ dry$$

$$\Delta S\ annual = 100 + (-60) = 40\ mm$$

# Problems on Water Balance Equation

**Solution-7 Continued..**

**Final Groundwater Storage:**

Add the annual storage change to the initial groundwater storage:

$$\text{Final Storage} = \text{Initial Storage} + \Delta S \text{ annual}$$

$$\text{Final Storage} = 500 + 40 = 540 \text{ mm}$$

Wet season storage change: $\Delta S$ wet$=100$ mm
Dry season storage change: $\Delta S$ dry$=-60$ mm
Total annual storage change: $\Delta S$ annual$=40$ mm
Final groundwater storage: 540 mm