

Solution: Sediment Concentration Estimation (Varshney's Formula)

1 Objective

To estimate the sediment concentration in a Nepalese river using the provided empirical formulas (Varshney's and Khosla's).

2 Given Data

- **Catchment Area (A):** 160 km^2
- **Mean Monsoon Discharge (Q):** $1.90 \text{ m}^3/\text{s}$
- **Monsoon Duration (T):** 3 months (assumed to be 90 days)

3 Formulas

The problem provides the following formulas:

1. **Varshney's Formula (c):** For areas greater than 130 km^2

$$Q_s = 1.534 \times A^{-0.264}$$

2. **Khosla's Formula:**

$$Q_s = 0.323 \times A^{-0.28}$$

Where Q_s is the sediment load in million m^3 per 100 km^2 per year. We will use Varshney's formula (c) as the catchment area $A = 160 \text{ km}^2$, which is greater than 130 km^2 .

4 Step-by-Step Solution

4.1 Step 1: Calculate Annual Sediment Load (Q_s)

Using Varshney's formula:

$$Q_s = 1.534 \times (160)^{-0.264}$$

$$Q_s = 1.534 \times (0.2925)$$

$$Q_s = 0.4487 \text{ million m}^3 / 100 \text{ km}^2 / \text{year}$$

4.2 Step 2: Calculate Total Annual Sediment Volume (V_s)

The value Q_s is "per 100 km²". We must scale it to our 160 km² catchment.

$$V_s = Q_s \times \left(\frac{\text{Catchment Area}}{100 \text{ km}^2} \right)$$

$$V_s = (0.4487 \text{ million m}^3) \times \left(\frac{160 \text{ km}^2}{100 \text{ km}^2} \right)$$

$$V_s = 0.7179 \text{ million m}^3 / \text{year}$$

$$V_s = 717,900 \text{ m}^3 / \text{year}$$

4.3 Step 3: Estimate Sediment Mass (M_s)

We must state our assumptions to convert sediment volume to mass.

- **Sediment Bulk Density (ρ_s):** Assume a standard value of 1.5 tons/m³.
- **Monsoon Transport:** Assume 90% of the annual sediment load is transported during the 3-month monsoon.

First, find the total annual mass:

$$M_s(\text{annual}) = V_s \times \rho_s$$

$$M_s(\text{annual}) = 717,900 \text{ m}^3 \times 1.5 \text{ tons/m}^3$$

$$M_s(\text{annual}) = 1,076,850 \text{ tons/year}$$

Next, find the monsoon sediment mass:

$$M_s(\text{monsoon}) = 1,076,850 \text{ tons} \times 0.90$$

$$M_s(\text{monsoon}) = 969,165 \text{ tons}$$

4.4 Step 4: Calculate Total Water Volume (V_w)

First, find the total time in seconds:

$$T = 90 \text{ days} \times 24 \text{ hr/day} \times 3600 \text{ s/hr} = 7,776,000 \text{ s}$$

Next, find the total water volume:

$$V_w = Q \times T$$

$$V_w = 1.90 \text{ m}^3/\text{s} \times 7,776,000 \text{ s}$$

$$V_w = 14,774,400 \text{ m}^3$$

4.5 Step 5: Calculate Sediment Concentration (C_s)

Divide the sediment mass by the water volume.

$$C_s = \frac{M_s(\text{monsoon})}{V_w}$$

$$C_s = \frac{969,165 \text{ tons}}{14,774,400 \text{ m}^3}$$

$$C_s = 0.0656 \text{ tons/m}^3$$

Finally, convert to g/L (noting that $1 \text{ ton/m}^3 = 1000 \text{ g/L}$):

$$C_s \text{ (in g/L)} = 0.0656 \times 1000$$

$$C_s = 65.6 \text{ g/L}$$

5 Final Answer

Using Varshney's empirical formula, the estimated mean sediment concentration is **65.6 g/L** (or 65,600 mg/L).