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INTERNATIONAL ATOMIC ENERGY AGENCY
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR.1065 - 19

COLLEGE ON SOIL PHYSICS
14 - 30 APRIL 1998

"Erosion Models"

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MODEL

ANSWERS

Areal Non-Point Source Watershed Environment Response Simulation

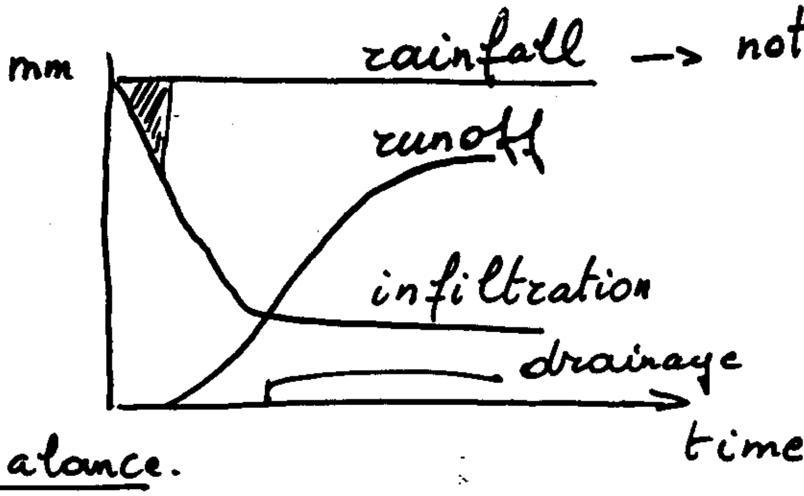
→ Agricultural Watersheds

consists of

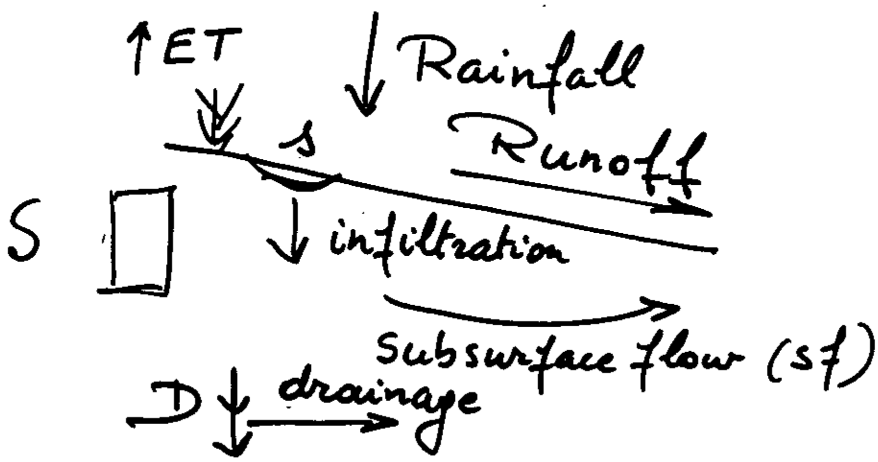
1) Hydrological model
2) Sediment Detachment / Transport model
3) components to describe movement of water
   - overland flow
   - channel flow
   - subsurface flow

→ event oriented ≠ long term

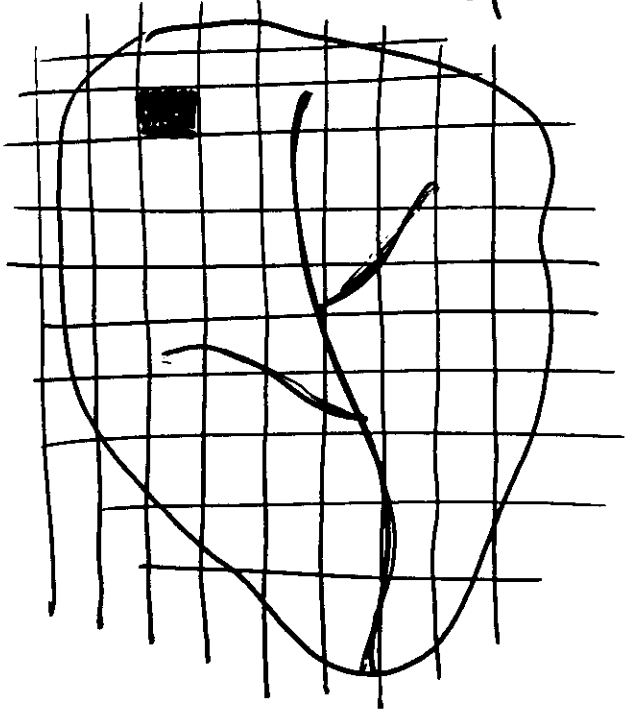
1) Hydrology model



Balance.



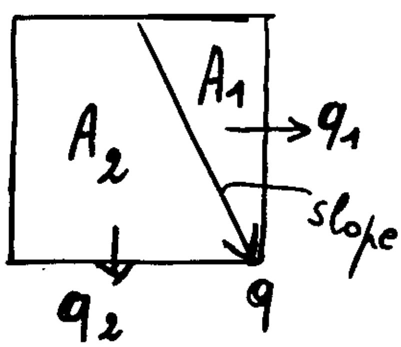
Rainfall = infiltration (I) + runoff (r)
+ soil storage (S) + drainage D
+ subsurface flow (sf)
+ surface storage + ET



$$\text{Input} - \text{Output} = \frac{dS}{dt}$$

$$q_1 = \left(\frac{A_1}{A_1 + A_2}\right) q$$

$$q_2 = \left(\frac{A_2}{A_1 + A_2}\right) q$$



COMPONENTS

Infiltration

$$f = f_c + A\left(\frac{S-F}{T_p}\right)^P$$

f: infiltration rate at a particular time
f_c: final or steady state infiltration rate
A: difference between maximum and steady state rates
S: storage potential of soil (total porosity - antecedent moisture content)
F: total volume of water infiltrated
T_p: total porosity within the control depth
P: coefficient related to decrease infiltration / increase soil moisture

Subsurface drainage

- drainage? when soil water content > field capacity
- when soil is saturated then the subsurface drainage = steady state infiltration rate (k_s)

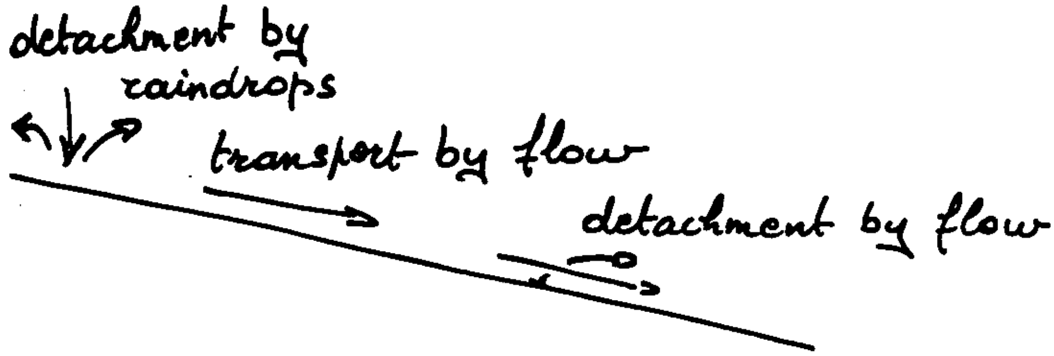
$$SDR = f_c\left(1 - \frac{PVOL}{GWC}\right)^b$$

f_c: steady infiltration rate
PVOL: unsaturated pore volume (tot. porosity - soil moisture content)
GWC: volume of gravit. water (tot. porosity - field capacity)
b: drainage coeff

FLOW in CHANNELS ??

Manning's equation
flow depth / flow rate

2) Erosion model



Sediment movement in flow

$$\frac{dG_F}{dx} = R_{DT} + D_F$$

G_F : rate of sediment movement in flow (weight per unit width per unit time)

x : distance along flow surface

R_{DT} : rainfall detachment rate (weight per unit area per unit time)

D_F : flow detachment rate (weight per unit area per unit time)

DETACHMENT OF SOIL PARTICLES by RAINDROP IMPACT

$$\boxed{D_R = 0{,}027\, C\, K\, A_I\, I^2}$$

where: D_R = rainfall impact detachment rate kg/min

C: cropping factor

K: soil erodibility factor

A_I: area increment (m^2)

I: rainfall intensity (mm/min)

or (splash erosion rate) W_s ($kg/m^2/h$)

$$W_s = 0{,}182\, K_r\, K_h\, C_m \left[2.96 (\sin\theta)^{0.79} + 0.56\right] \times \left[(1-p)\, I^{ex} + p\, C_n\, I_x^{ex}\right]$$

where: K_r: erodibility factor for splash

K_h: water depth correction factor

C_m: crop mulch factor

θ: slope gradient

p: fraction of area covered by canopy

C_n: crop canopy factor

I: rainfall intensity (cm/hr)

I_x: excess rainfall intensity

$$K_h = a \cdot e^{-h/D_{50}}$$

h: water depth (cm)

D_{50}: median drop diameter of raindrops

DETACHMENT OF SOIL PARTICLES BY OVERLAND FLOW

$$\boxed{D_F = 0.018\, C K A_I S Q}$$

where D_F: overland flow detachment rate kg/min

S: slope steepness

Q: flow rate per unit width (m^2/min)

or FLOW EROSION RATE W_F ($kg/m^2/h$)

$$W_F = 11.02\, K_f C_f \tau^{ex}$$

τ: bed shear stress (N/m^2)

$\tau = \gamma h S$ γ: specific gravity of water

S: slope gradient

h: water depth

K_f: flow erodibility factor K (USLE ??) depends rill erosion

C_f: crop factor

EROSION in CHANNELS E_{CH} ($kg/m^2/h$)

$$E_{CH} = 11.02\, c\, K_f C_f \tau^{ex}$$

c: correction factor for rill / channels / gullies

TRANSPORT CAPACITY of FLOW

$TF = 146\,(S Q^{1/2})$ for $Q < 0.046\ m^2/min$

$TF = 14600\,(S Q^2)$ for $Q > 0.046\ m^2/min$

TF: transport capacity of flow (kg/min/m)

Q: flow rate per unit width m^2/min

S: slope (m/m)

Sediment concentration/streampower relationships

$$\omega = \rho g S D_w V_w$$

$$\omega = \rho g S \, OVF_w$$

ω: streampower of overland flow ($J/s.m^2$)

S: slope

D_w: water depth

V_w: flow velocity

OVF_w: Volumetric water flux of overland flow $m^3/s.m$ (m^2/s)

Bagnold sediment transport/streampower relationship

$$\frac{i_b}{(\omega - \omega_0)} = \left[\frac{(\omega - \omega_0)}{\omega_0}\right]^{1/2} \left(\frac{y}{D}\right)^{-2/3}$$

i_b: sediment transport rate

ω: streampower of runoff

ω_0: threshold streampower

y/D: flow depth to grain size

Kirkby's sediment transport

$$G = Q^2 S$$

$$G = CP \, Q^2 \sin S \, 10^{-3}$$

G: transport capacity of overland flow

Q: overland flow discharge

CP: cover-practice factor.