Hydrology of catchments, rivers and deltas (CIE5450)

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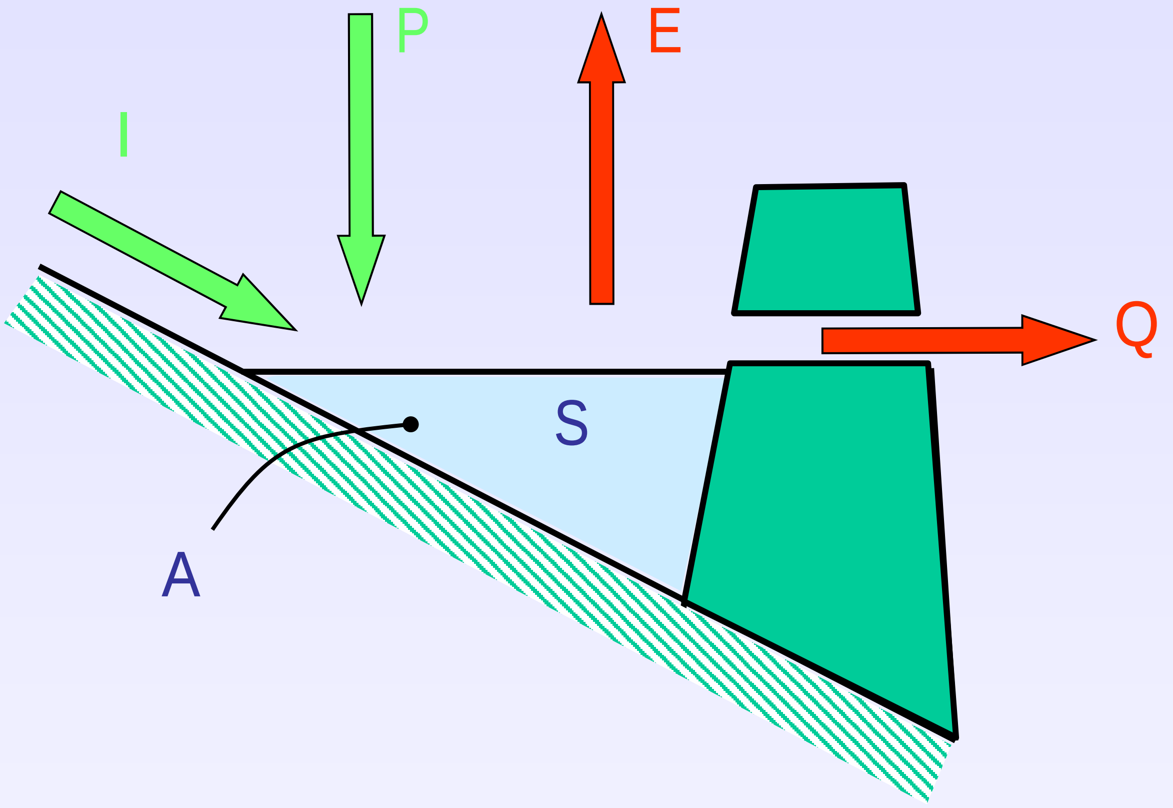
Lecture ‘Flood routing’

FLOOD PROPAGATION

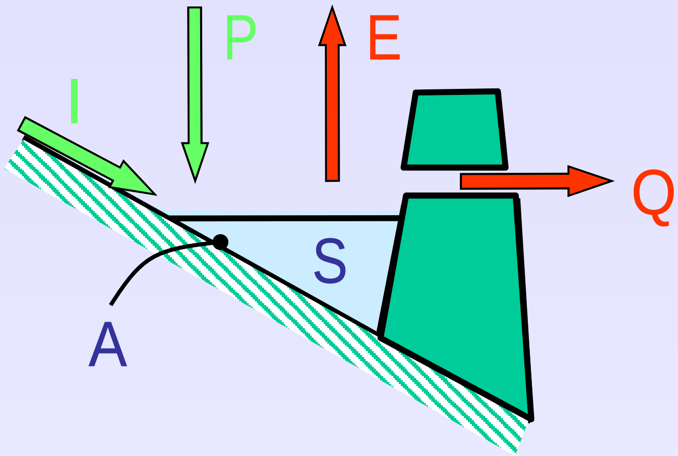
- Reservoir routing
- Flood routing in natural channels

Reservoir routing



$$\frac{dS}{dt} = I - Q + AP - AE$$

Reservoir routing



$$\frac{dS}{dt} = I - Q + A \cdot (P - E)$$

$$S_1 = S_0 + (I - Q + A(P-E)) * (t_1 - t_0)$$

$$A = A(H)$$

$$A = A_0 + a(H-H_0)^b$$

$$A = A_0 \exp(b(H-H_0))$$

$$S = \int_{H_0}^{H} A\,dH$$

$$Q = K(H-H_c)^c$$

Reservoir routing

Short term model, Flood routing:

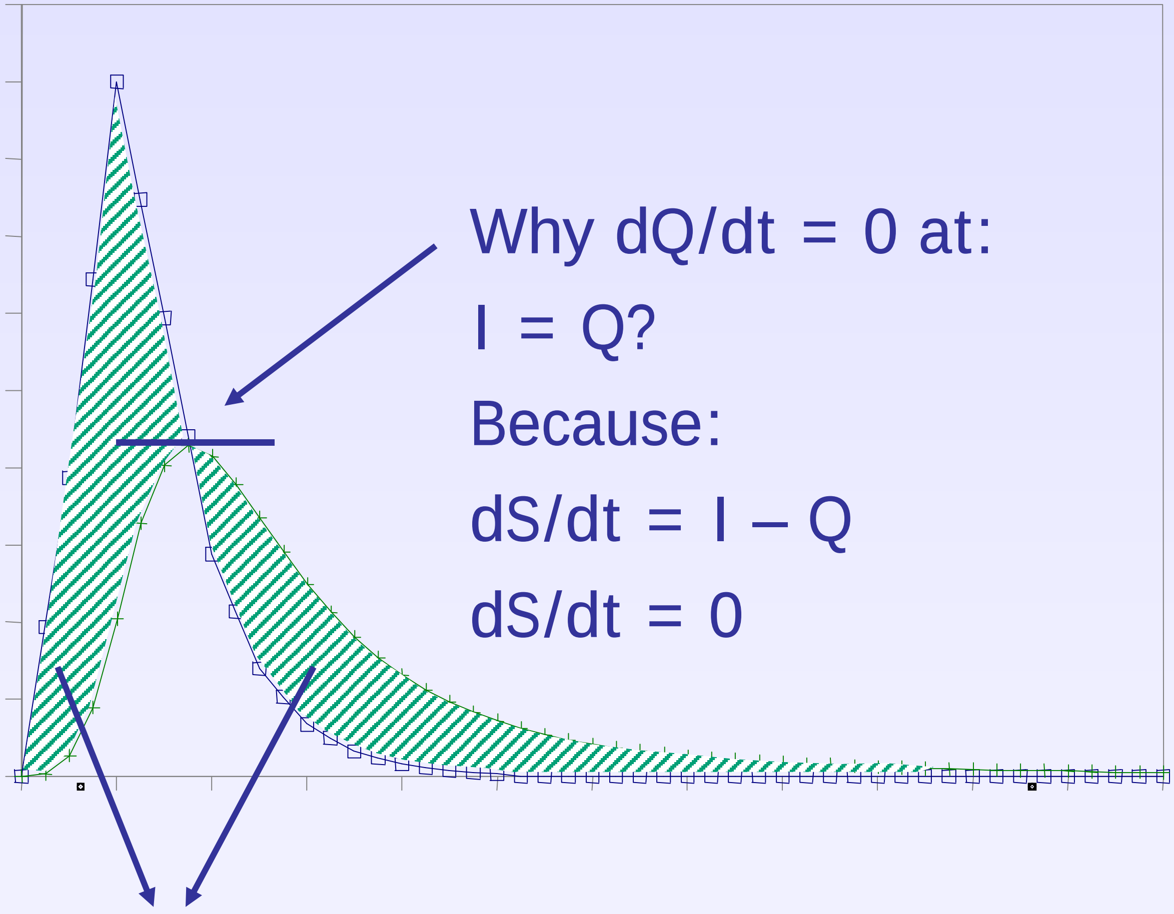
Neglect P-E

Predictor-Corrector:

1. Initial condition: $H_0 = H_c$
2. Predictor: $S_1^* = S_0 + \left(I - Q(H_0)\right)\Delta t$
3. $H_1^* = H(S_1^*)$ -> $Q^* = K\left(\dfrac{H_1^* + H_0}{2} - H_c\right)$
4. Corrector: $S_1 = S_0 + \left(I - Q^*\right)\Delta t$
5. $H_1 = H(S_1)$
6. Possible iteration
7. Next time step

Reservoir routing

When at t=0 water level is at the spillway crest:



Why dQ/dt = 0 at:

I = Q?

Because:

dS/dt = I – Q

dS/dt = 0

Surfaces are equal

Reservoir routing

What happens when water level is NOT at the spillway crest ?

Reservoir routing

Long term model, Reservoir yield analysis:

$$S_1 = S_0 + (I - Q + A(P-E)) * (t_1 - t_0)$$

Q is draft (regulated) and flood discharge (unregulated)

Main questions:

What is the safe yield?

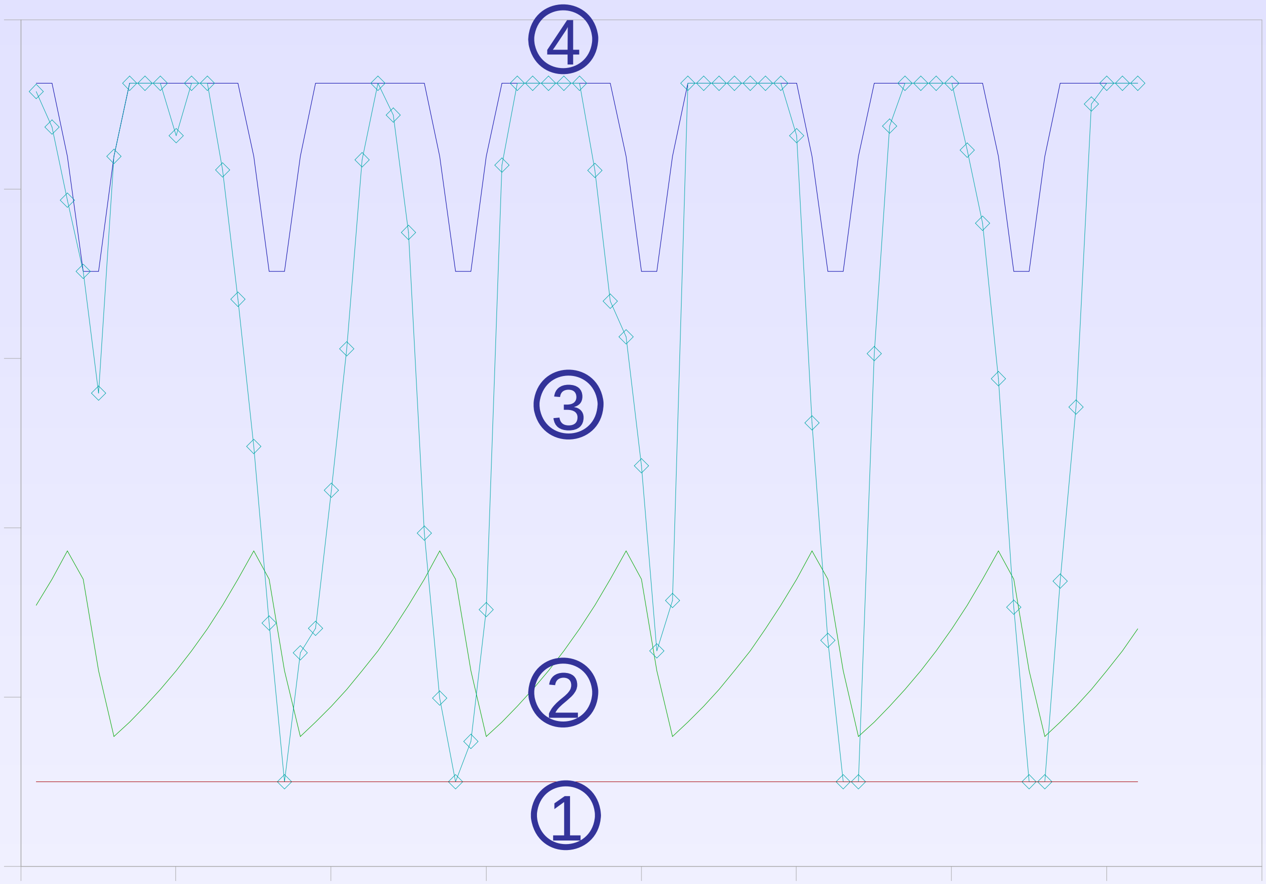
Reservoir routing – yield analysis

FRC

4 zones

URC

DSC



FRC = Flood Rule Curve

URC = Utility Rule Curve

DSC = Dead Storage Curve

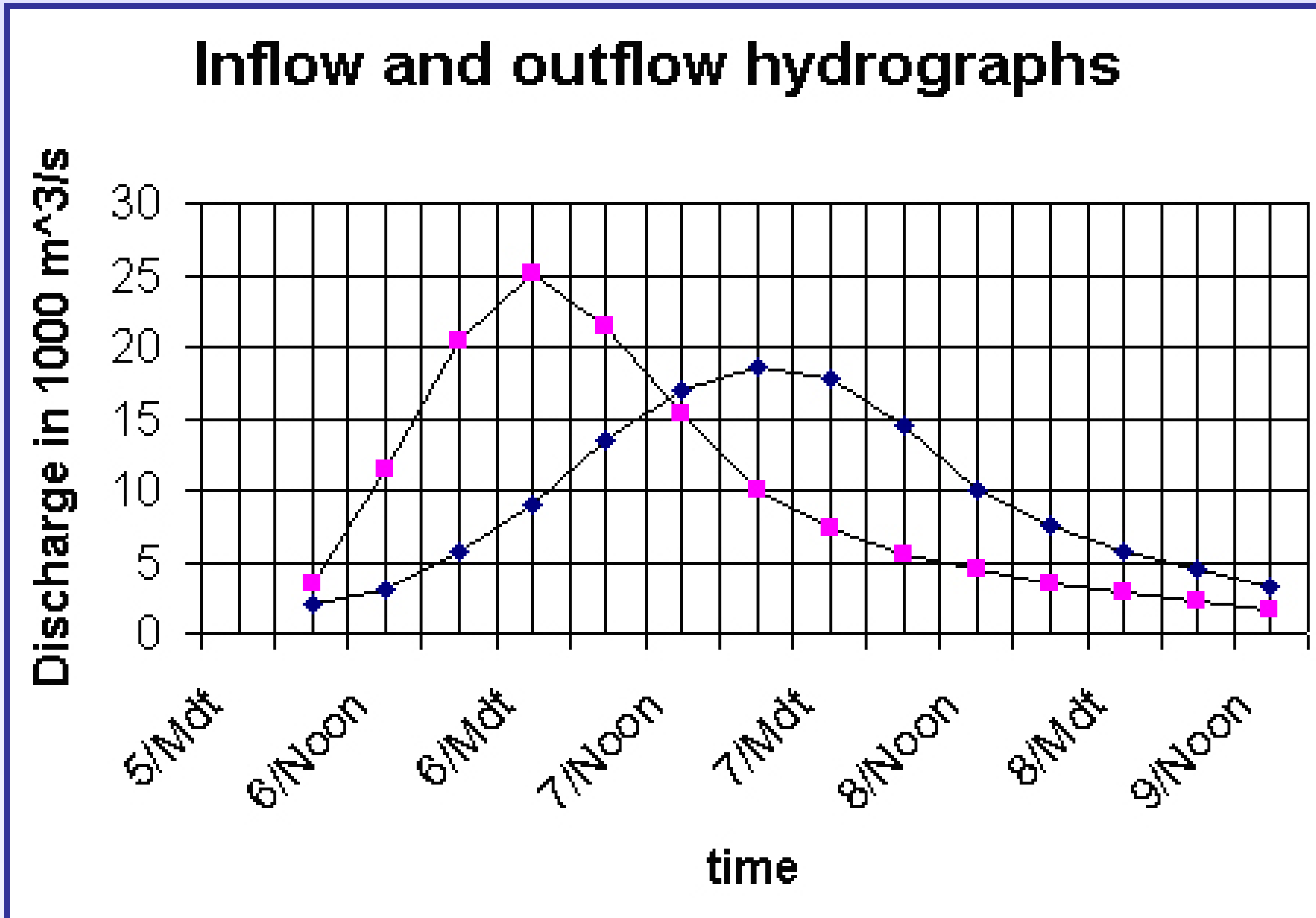
Reservoir routing – yield analysis

$$S_1 = S_0 + (I - Q + A(P-E)) * (t_1 - t_0)$$

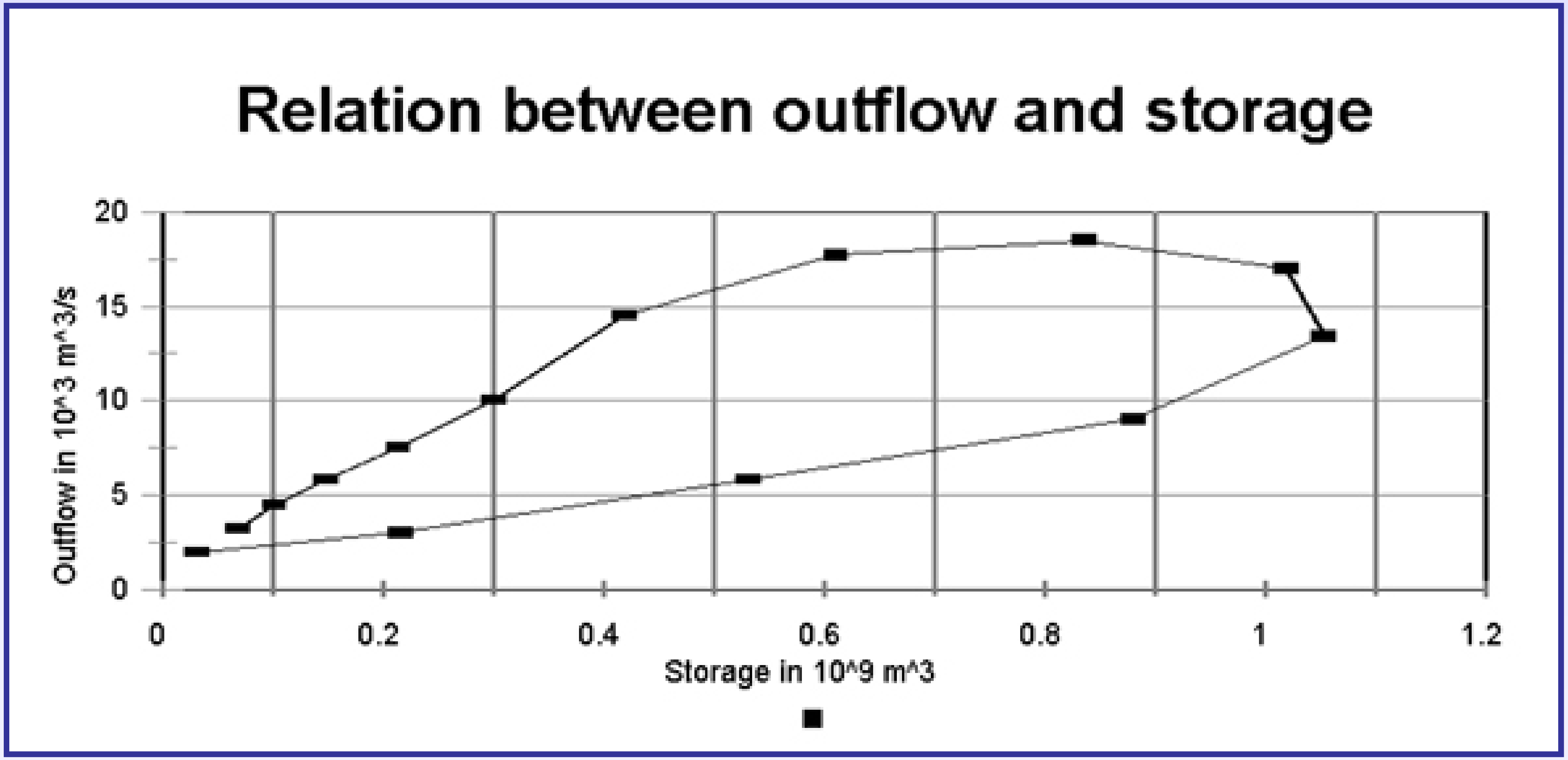
Use operating rules:

1. Assume Q=D
2. Apply water balance with $A(H_0)$
3. Check rule curves
4. Redo water balance, if rule curves apply
5. Next time step

Flood routing in natural channels



Flood routing in natural channels



So here there is no unequivocal relation between Q and S

Flood routing in natural channels

Muskingum equation:

$S = K[x\,I + (1-x)Q]$

Because dS/dt = I-Q:

$$I - Q = \frac{dS}{dt} = K\left[x\frac{dI}{dt} + (1-x)\frac{dQ}{dt}\right]$$

If I = Q, then:

$$x = \frac{dQ/dt}{dQ/dt - dI/dt}$$

Flood routing in natural channels

Muskingum-Cunge equations:

$$K = \frac{\Delta x}{c}$$

$$c = \frac{\mathrm{d}q}{\mathrm{d}h} \approx 1.67\bar{v}$$

$$x = 0.5\left(1 - \frac{q}{S_b c \Delta x}\right) \approx 0.5\left(1 - 0.6\frac{h}{S_b \Delta x}\right)$$

Flood routing in natural channels

Conditions:

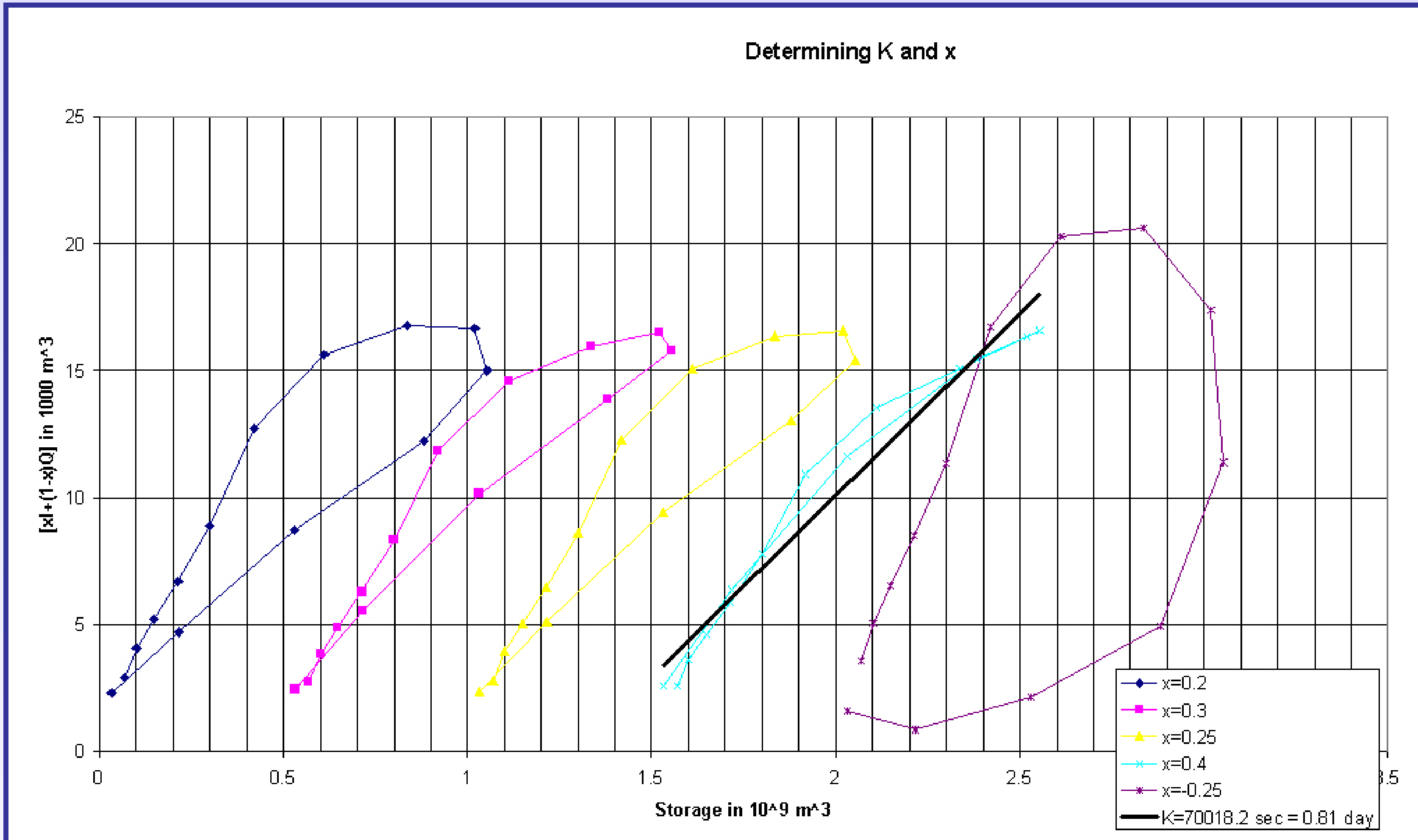
Courant number

$$C = \frac{c\Delta t}{\Delta x} = \frac{\Delta t}{K} \leq 1$$

Physical boundaries of x

$$0 \leq x \leq 0.5$$

Flood routing in natural channels



Flood routing in natural channels

Muskingum routing equation:

$$Q_2 = c_0 I_2 + c_1 I_1 + c_2 Q_1$$

$$c_0 = -\frac{Kx - 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

$$c_1 = \frac{Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

$$c_2 = \frac{K - Kx - 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

$$c_0 + c_1 + c_2 = 1$$

Flood routing in natural channels

Date	Hour	I, m^3/s	c_0I_2	c_1I_1	c_2O_1	O, m^3/s
4/9	6 a.m.	1000	...	...	...	1000
	Noon	2400	*-408*	*530*	*640*	*762*
	6 p.m.	3900	*-663*	*1272*	*488*	*1097*
	Midnight	5000	*-850*	*2067*	*702*	*1919*
4/10	6 a.m.	4900	*-833*	*2650*	*1228*	*3045*
	Noon	4000	*-680*	*2597*	*1949*	*3866*

C_0 =-0.17; c_1 = 0.53; c_2 = 0.64

Flood routing in natural channels

Local Inflow:

Four-point method:

$$Q_2 = c_0 I_2 + c_1 I_1 + c_2 Q_1 + c_3 Q_L$$

$$c_3 = \frac{2\Delta t / K}{2(1-x) + \Delta t / K}$$

is sum of c_0 and c_1

Three parameter Muskingum method:

$$\frac{\mathrm{d}S}{\mathrm{d}t} = I(1+\alpha) - Q$$

$$S = K\left[x(1+\alpha)I + (1-x)Q\right]$$

Flood routing in natural channels

Kinematic routing:

- Continuity equation

$$Q = I - L\frac{\Delta A}{\Delta t}$$

- Manning equation

$$Q = KAR^{2/3}S^{1/2}$$