EXPLORING THE INCREASE OF FLOOD ATTENUATION POTENTIAL OF RESERVOIRS THROUGH SIMPLE GATES OPERATIONS

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MOTIVATION

Dams effects on flood risk assessment of large areas are sometimes disregarded.

Especially in mountainous basins, **unsupervised flood attenuation** should be systematically included in flood hazard mapping procedures.

Increased flood storage can be useful to control flood peaks (flood management practices).

INCREASED FLOOD STORAGE is possible through:

A) SEASONAL FLOOD STORAGE ALLOCATION (**STATIC**)

B) SIMPLE AND STANDARDIZED GATES OPERATIONS (**DYNAMIC**)

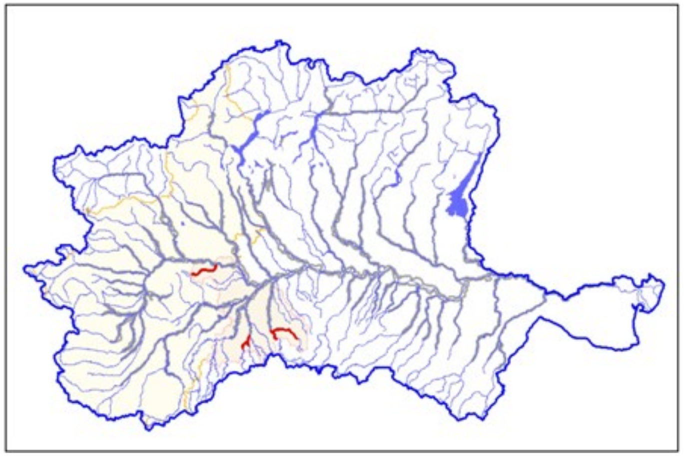
DYNAMIC STORAGE ALLOCATION POTENTIAL

PRELIMINARY SELECTION → SCHEMATIZATION OF THE DAM HYDRAULICS → **CONFIGURATIONS** FOR EFFICIENT FLOOD ATTENUATION

SYSTEMATIC APPROACH → **LARGE-SCALE** SCENARIOS → **IDENTIFY** DAMS WITH THE BEST ATTENUATION POTENTIAL

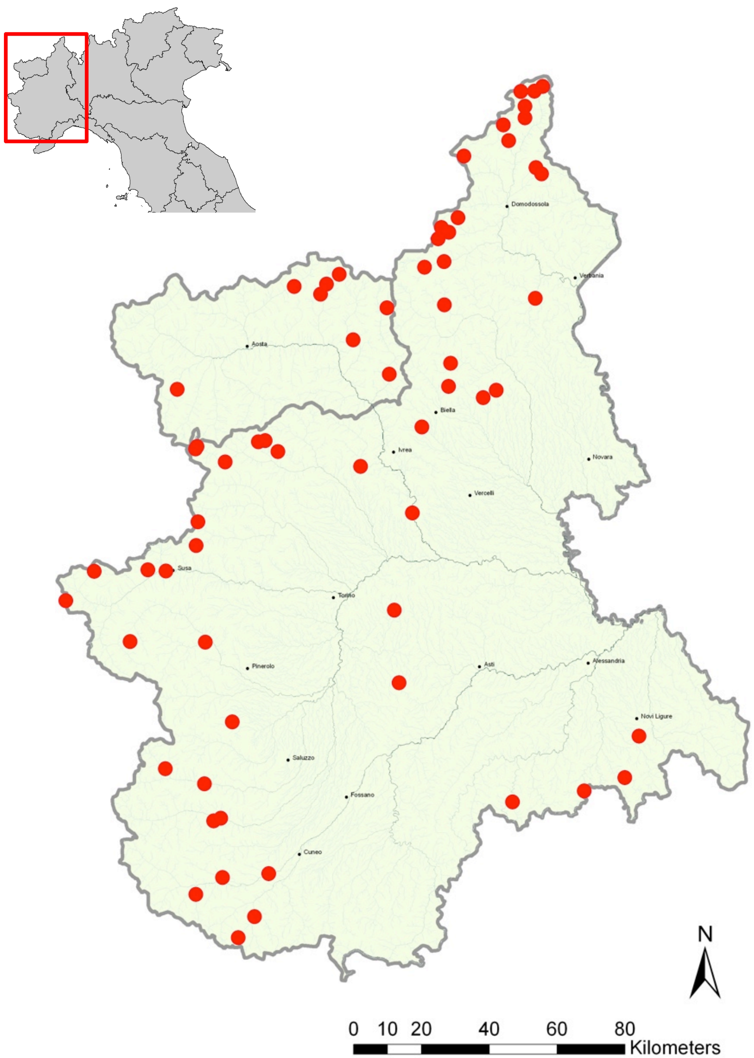
Po River basin (60’000 km^2)

- ~ 150 reservoirs
- Dams built since 1930.
- Many urbanized flood prone areas



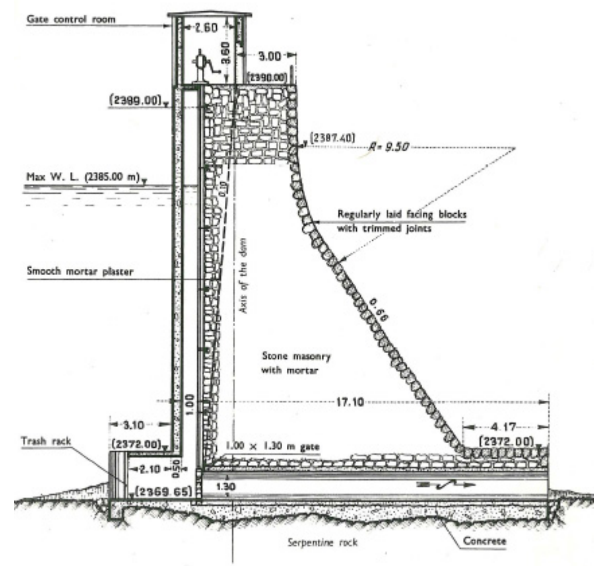
DAMS DATASET

63 reservoirs located in the Northwestern part of Italy.



many Old Hydropower Dams,

1920-1940 and 1950-1970



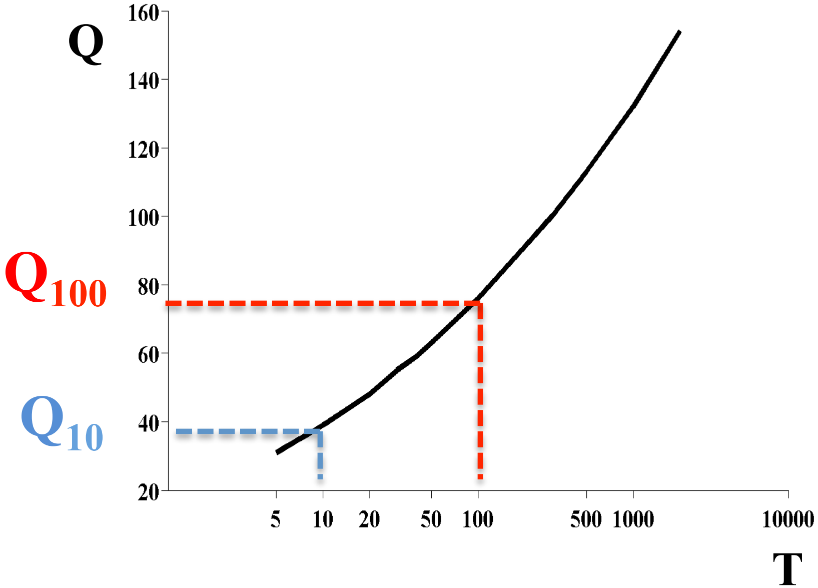
FLOOD DATA

OFTEN UNAVAILABLE @ DAMS

STATISTICAL REGIONALIZATION METHOD
Laio et al, 2011

→ **FLOOD FREQUENCY CURVES**

Morpho-climatic catchment descriptors



Use of
L-moments statistics

$$Q_T = Q_{ind} \cdot \mathcal{P}(T, L_{CV}, L_{CA})$$

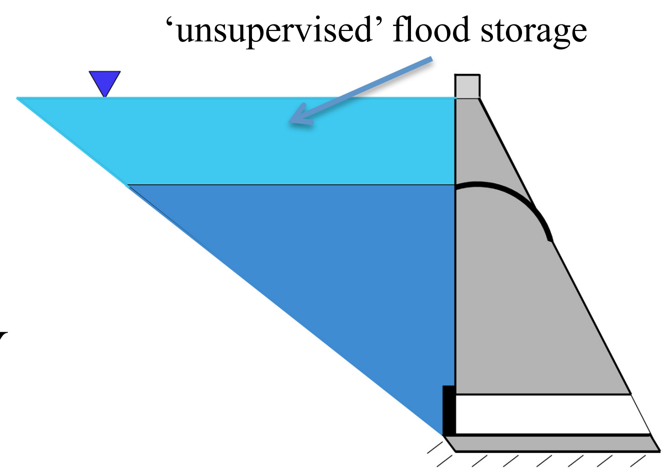
- Q_{ind} → Scale (index flow)
- L_{CV} → dispersion
- L_{CA} → skewness

UNSUPERVISED ATTENUATION

Continuity equation

$$q_i(t) - q_o\big(H(t)\big) = \frac{dV\big(H(t)\big)}{dt}$$

→ η_0



- STANDARDIZED FLOOD SHAPE
- NO GATES OPERATION

← FLOOD FREQUENCY ANALYSIS

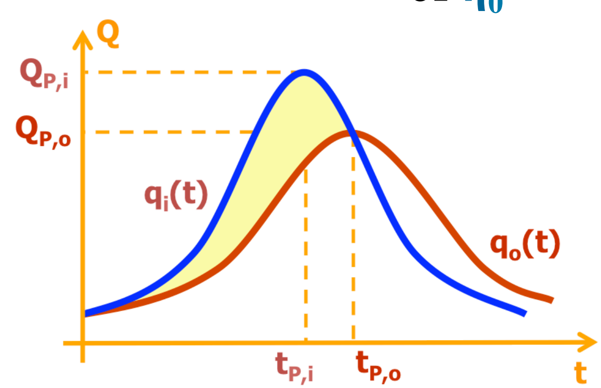
SFA (*Miotto et al.*, 2007) **S**ynthetic **F**lood **A**ttenuation index.

Derived solving the continuity equation (simplified assumptions) → Same dimensions of η_0

$$SFA = \frac{1}{R} \cdot \left(\frac{R}{R+1}\right)^{R+1} \qquad R = 100 \cdot \frac{A_L}{L \cdot \sqrt{A_B}}$$

Governing parameters:

- **L**, spillway crest length
- $\mathbf{A_L}$, lake area
- $\mathbf{A_B}$, basin area

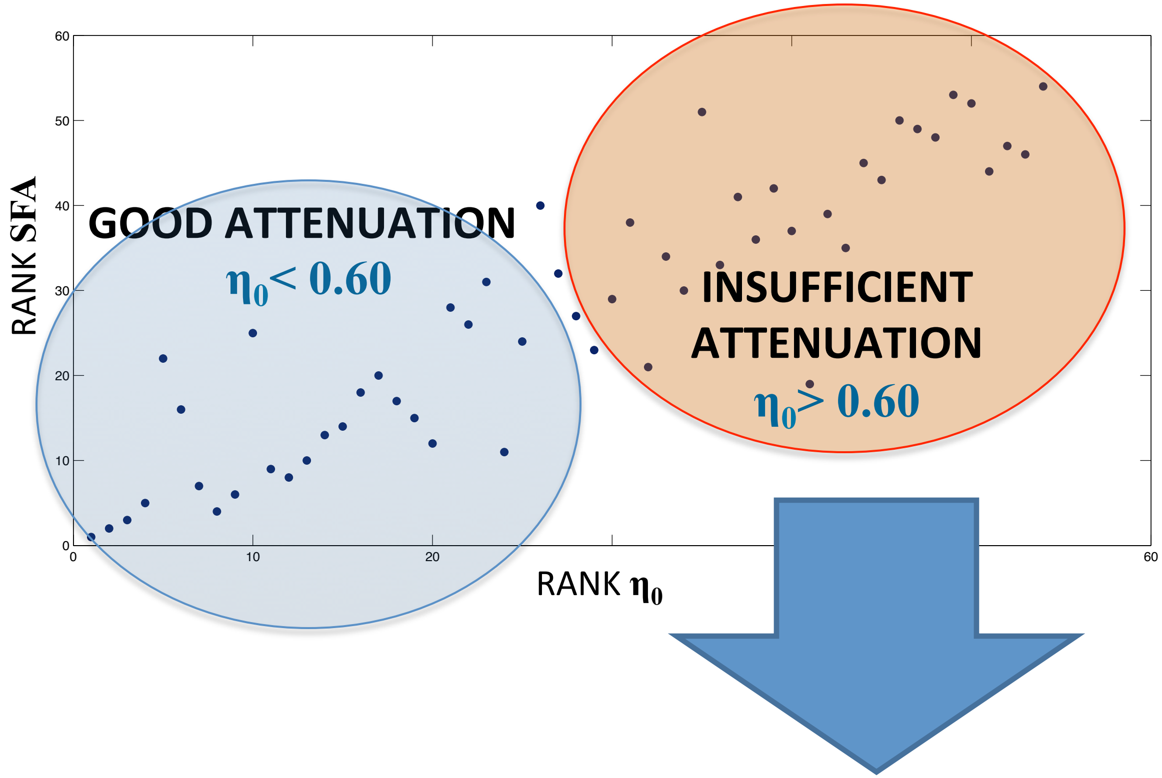


UNSUPERVISED ATTENUATION

34 dams already have a good (unsupervised) attenuation potential

SFA and η_0 :

comparable **RANK**



PREEMPTIVE DRAWDOWN

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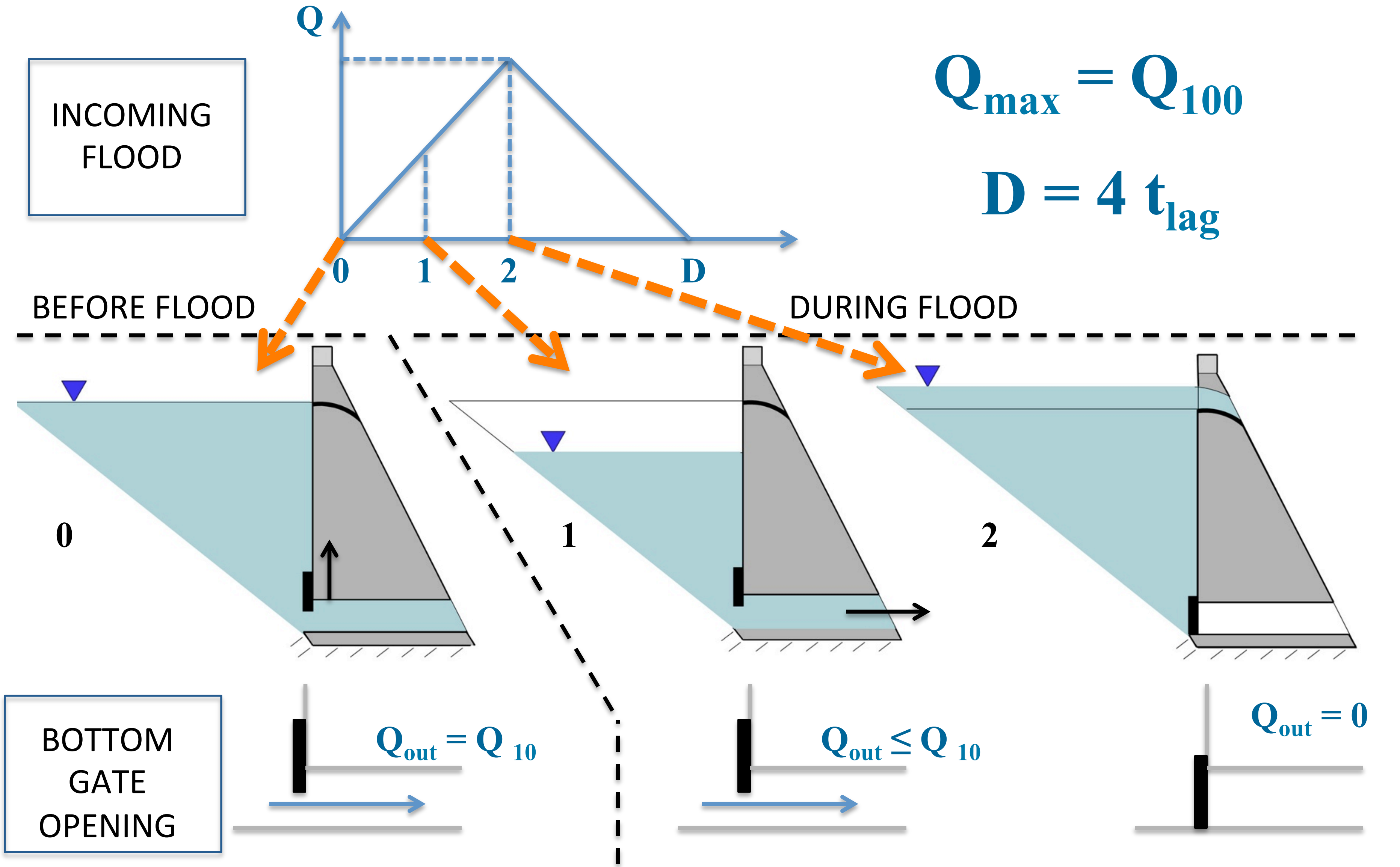


Lake and Dam Geometry

relation between dam levels and storage volume sometimes difficult to find → **HALF-PYRAMIDAL** geometric model

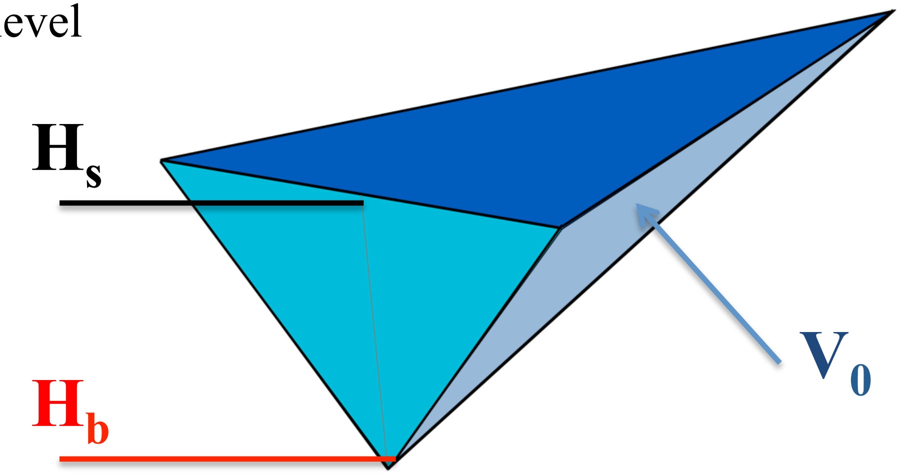
CONSIDERING TWO MAIN OUTLETS:

- **One only** spillway at a higher level;
- **One only** outlet structure at the bottom level.

V_0 : Reservoir volume at Spillway crest level

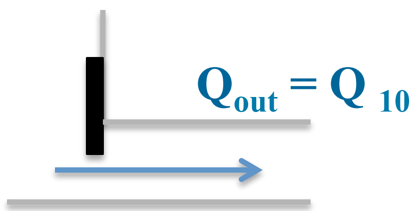
H_s : Spillway crest level

H_b : bottom outlet low level

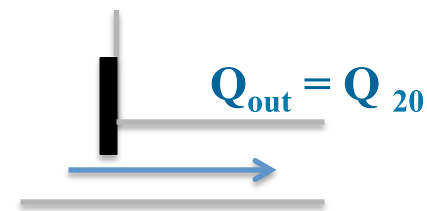


DRAWDOWN OPERATIONS

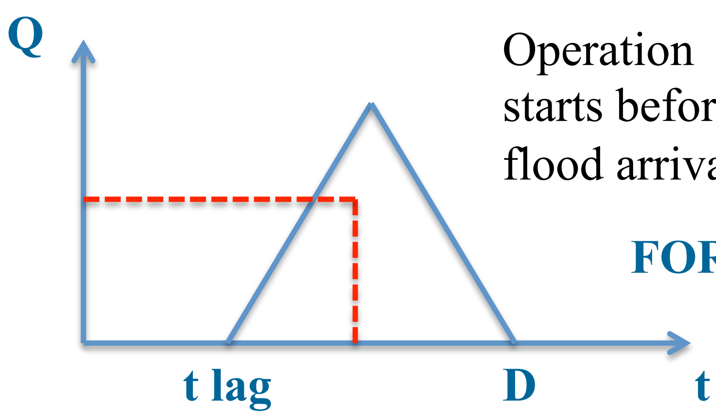
a) NORMAL RELEASE



b) HIGHER RELEASE



c) ANTICIPATE OPENING



Operation starts before flood arrival

FORECAST NEEDED

OTHER GATES POSSIBILITY

- Release Qmax > Q(T=20)
- Open gated spillways.

ALTERNATIVE HYDROGRAPHS

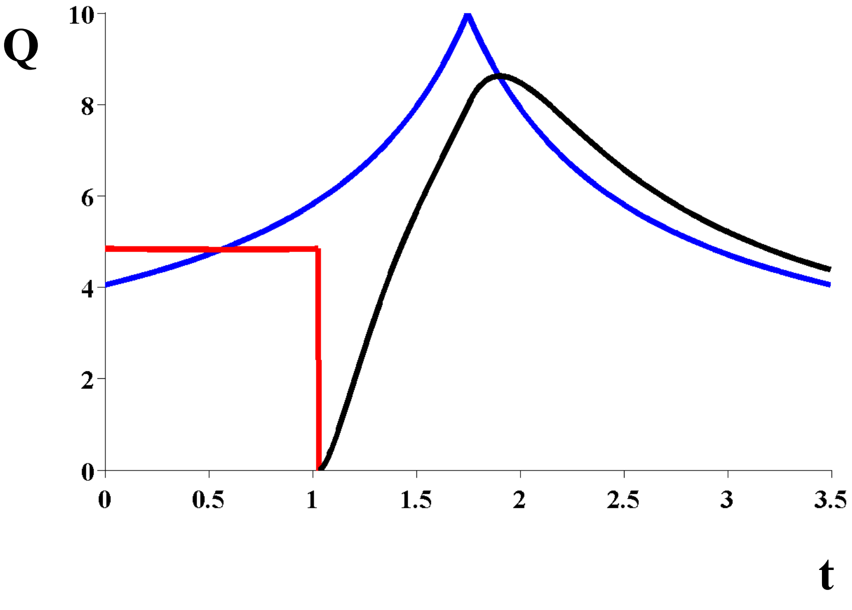
d) *POWER LAW HYDROGRAPH SHAPE*

NERC, 1975

$$q_e(t) = Q_T \cdot (\varepsilon_t + t \cdot \varepsilon'_D)$$

$$\varepsilon_D = (1 + b \cdot D)^{-c}$$

$$b = \frac{1}{2 \cdot t_{LAG}} \qquad c = 1 - n$$



RESULTS SIGNIFICANTLY DIFFERENT

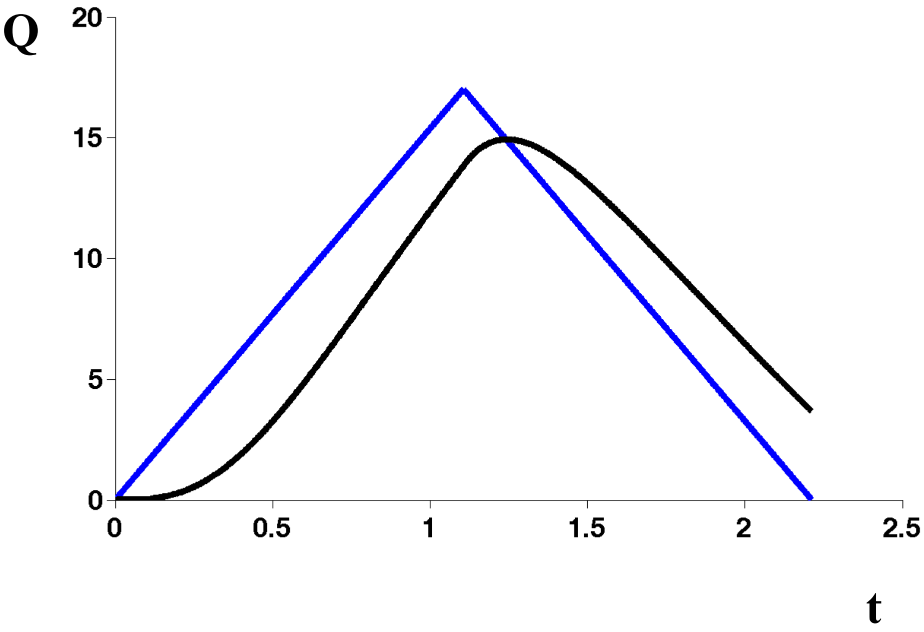
STRONG DEPENDENCY FROM HYDROGRAPH **SHAPE**

GROSSLY BUT **SYSTEMATIC APPROACH** (AS IN SFA)

SEARCHING FOR CLASSIFICATION, NOT FOR BEST INDIVIDUAL DAM RULES

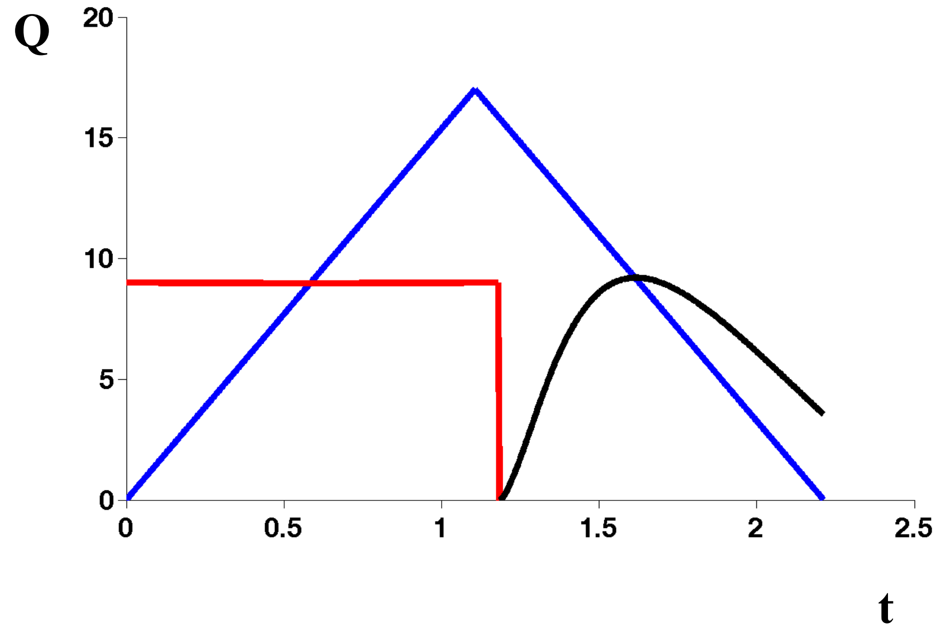
CASE A

NATURAL ATTENUATION



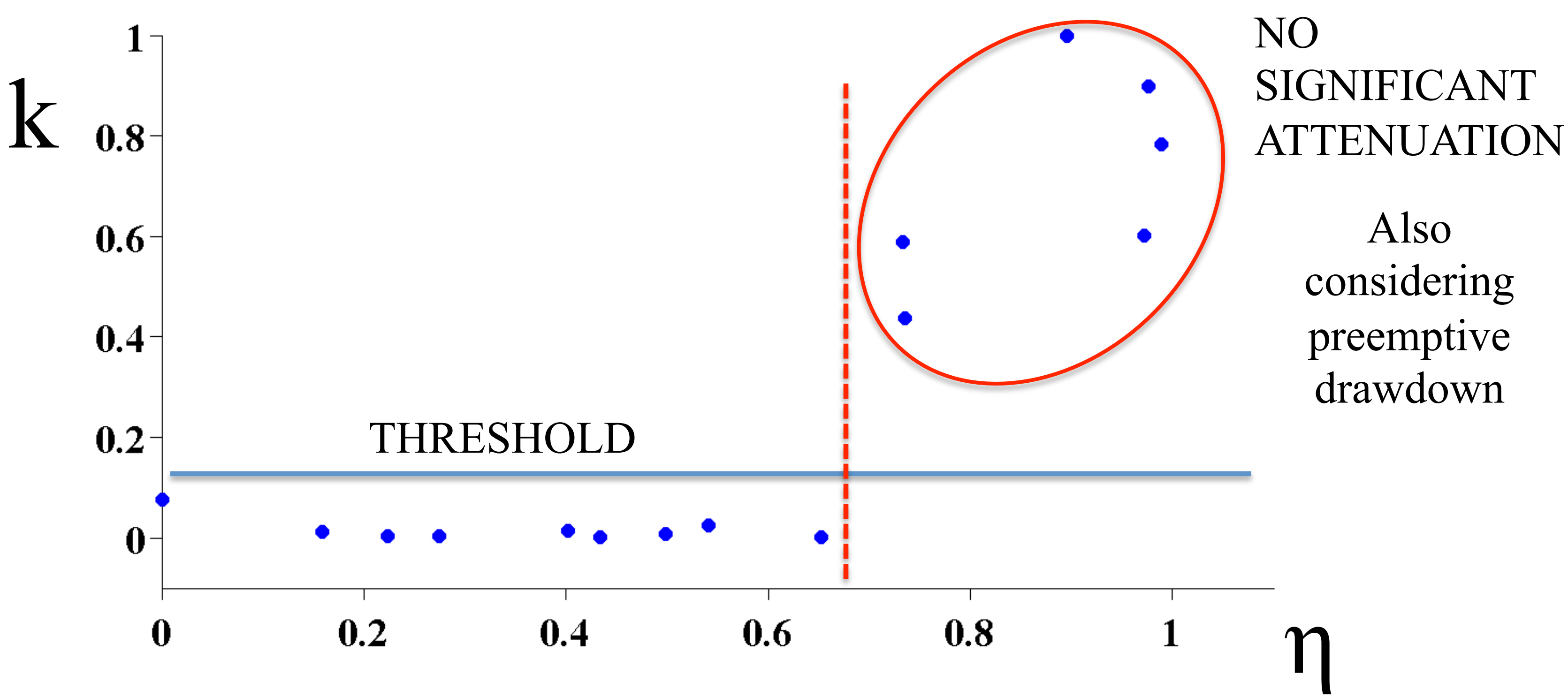
$\eta_0 = 0.88$

PREEMPTIVE DRAWDOWN



$\eta_1 = 0.54$

ANALYSIS OF RESULTS



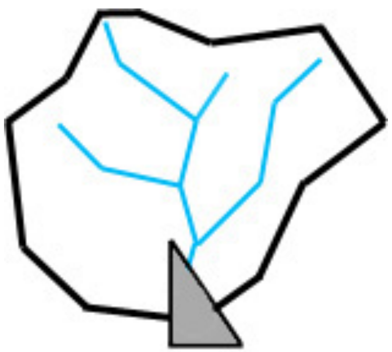
$$k_i = \frac{f_i}{f_{max}} \qquad f = \frac{A_{basin}}{V_{reservoir}}$$

There is a strong dependency on η_0 values.

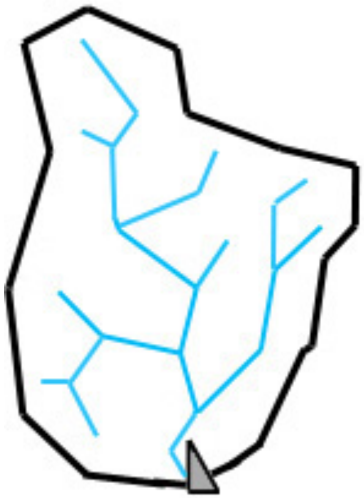
FOR SUBSEQUENT EVALUATIONS

EFFICIENCY CATEGORIES

GOOD DECREASE OF η **CASE A**	DECREASE AT B-C CONDITIONS	NO SIGNIFICANT DECREASE



Depends on spillway length and/or bottom outlet Q_{max}



CASE STUDY

$k < 0.15$		$k > 0.4$
12 dams	**3 dams**	**6 dams**

CONCLUSIONS

UNSUPERVISED ATTENUATION → WELL DESCRIBED BY SFA, FUNCTION OF **SPILLWAY LENGTH**, **LAKE AREA** BUT NOT OF **DAM VOLUME**

PREEMPTIVE DRAWDOWN → INCREASE IN ATTENUATION POTENTIAL FOR DAMS WITH LOW RATIO BETWEEN **BASIN AREA** AND **STORAGE VOLUME**

Further investigation:

- Basin Lag time influence on the real feasibility of operations
- Additional variables and non-dimensional indices to better qualify dams which benefit from Preemptive Drawdown.