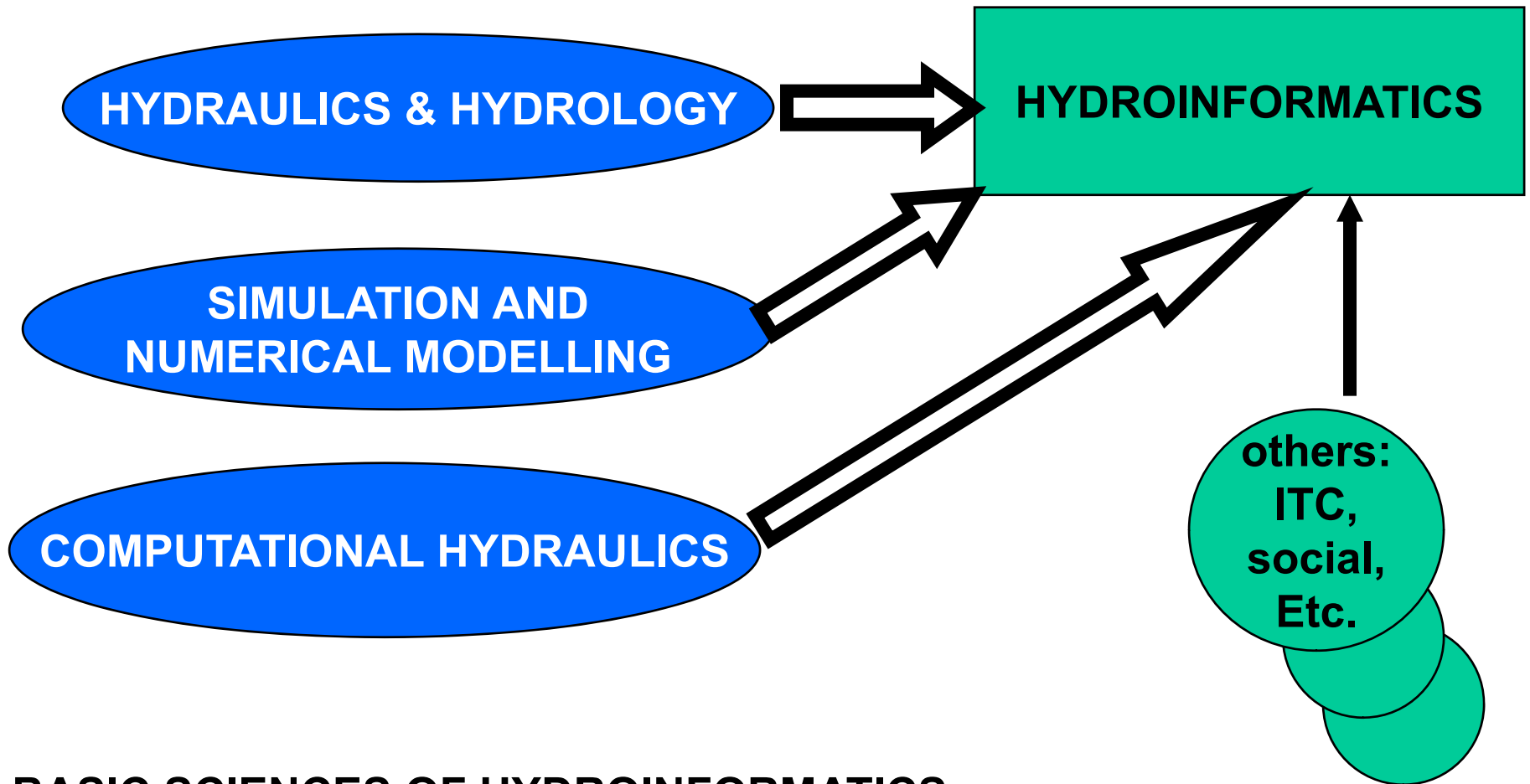


SOFTWARE , MODELS AND SIMULATION

REMINDER :

**MODELLING AND NUMERICAL SIMULATION ARE
AT THE VERY HEART OF HYDROINFORMATICS**



BASIC SCIENCES OF HYDROINFORMATICS

**NEITHER HYDROINFORMATICS NOR
HYDROINFORMATICIAN WITHOUT:**

- **FUNDAMENTAL KNOWLEDGE OF WATER SCIENCES,**
- **GOOD UNDERSTANDING OF HYDRAULICS AND HYDROLOGICAL PHYSICAL PROCESSES,**
- **GOOD UNDERSTANDING OF NUMERICAL MODELLING OF PHYSICAL PROCESSES.**

MODELS :

WHAT ARE WE TALKING ABOUT?

MODELS IN HYDRAULICS AND HYDROLOGY

VOCABULARY: «MODEL» or «SOFTWARE»

DIFFERENCE BETWEEN:

***A MODELLING SOFTWARE* also called
A SOFTWARE *CODE***

and

A MODEL

N.B.: A SCALE MODEL IS ALWAYS A MODEL

MATHEMATICAL MODELS – GENERAL CONCEPT

**MODEL = conceptualisation of reality limited
by our knowledge and our needs
= partial image of the reality**

**EXAMPLE: newtonian mechanics, as compared to
einsteinian one, is sufficient for needs of
engineering.**

TYPES OF MODELS:

**Mathematical - concepts formalised in mathematical
expressions (equations)**

**Numerical - algorithms and computer program
needed to solve equations**

MODELS IN HYDRAULICS / HYDROLOGY:

mechanistic

«black boxes»

stochastic/statistics or correlative

A MODEL – WHAT FOR?

- TO UNDERSTAND PHYSICAL PHENOMENA**
- TO PREDICT CONSEQUENCES OF EXCEPTIONNAL EVENTS AND HUMAN ACTIVITIES**

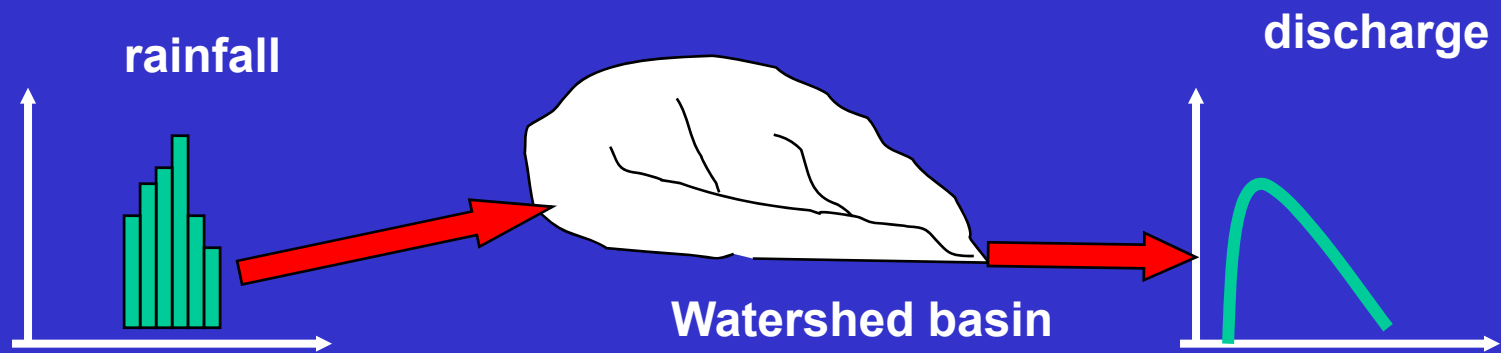
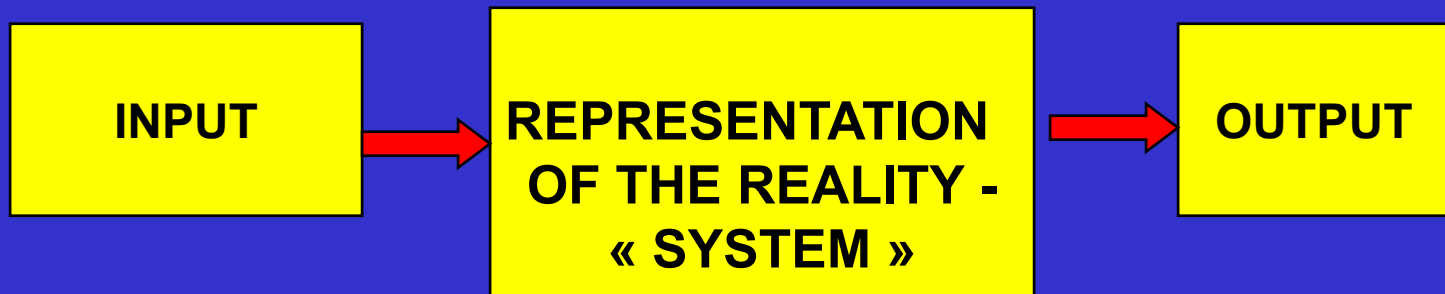
How can models help to understand physical phenomena?

Hypotheses \rightarrow model \rightarrow comparison with observed
If positive, the hypotheses **could** be right !!!

Engineering:

Supposing the model is correct,
To predict consequences of events or human activities

Model concept



**TWO WAYS TO REPRESENT THE REALITY,
TWO CLASSES OF MODELS:**

- **CORRELATIVE MODELS & TRANSFER FUNCTIONS,**
- **MECHANISTIC MODELS THAT CAN SIMULATE PHYSICAL PHENOMENA**

THE CLASS OF **CORRELATIVE** MODELS & TRANSFER FUNCTIONS

MODEL =
A FUNCTION OR A PROCESS
APPROACHED BY CALIBRATION
(FITTING) OF NON-PHYSICAL
PARAMETERS

CRITERIA ARE **OBSERVED**
INPUTS & OUTPUTS



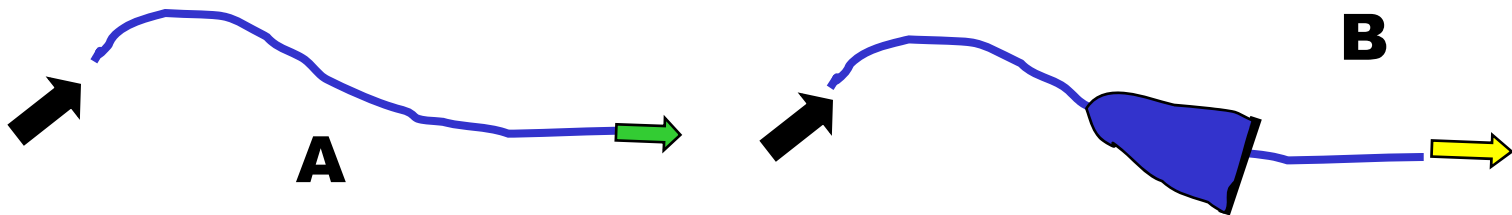
EXAMPLES:

- **Simple correlations,**
- **ARMA/ARIMA and similar,**
- **ANN – Artificial Neuron Networks,**
- **GA – Genetic Algorithms,**
- **« Black Boxes », etc.**

**IN ALL CASES TRANSFER FUNCTIONS ARE DEFINED
SOLELY UPON PAST-OBSERVED INPUT/OUTPUT DATA**

LET

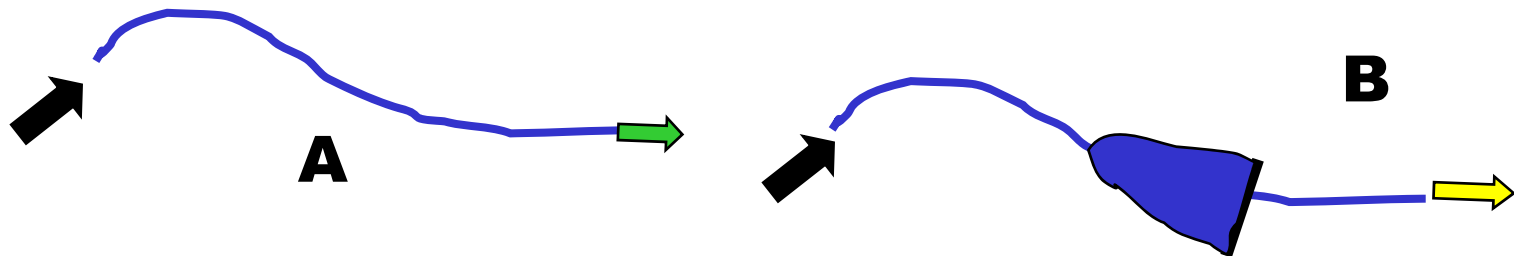
- A RIVER,
- A VERY LONG CHRONOLOGIC SERIES OF RECORDED INPUTS AND OUTPUTS (DISCHARGES) IN SITUATION **A** **BEFORE** THE DAM WAS BUILT :



**NO « DATA MINING » METHOD
(CORRELATIONS, ANN, GA, etc.)**

**CALIBRATED WITH THE DATA OF THE SITUATION
« A »**

**CAN PREDICT THE OUTPUT DISCHARGES IN THE
SITUATION « B »**



CORRELATIVE MODELS & TRANSFER FUNCTIONS

- **AVANTAGES:**

- **AUTOMATIC FITTING OF PARAMETERS**
- **STATISTICS OF QUALITY OF FITTING**
- **MODEST COMPUTER RESOURCES AND
SHORT COMPUTATIONAL TIME → REAL-
TIME APPLICATIONS**

DISADVANTAGES & LIMITATIONS:

- VALIDITY LIMITED BY THE RANGE OF INPUT/OUTPUT DATA **SAMPLE,**
- USELESS WHEN THE **REALITY IS MODIFIED =** SELDOM USEFUL FOR ENGINEERING,
- INTERPRETATION IN TERMS OF PHYSICAL PROCESSES DIFFICULT OR IMPOSSIBLE.

THESE MODELS ARE NOT PREDICTIVE !!!

MECHANISTIC (or PHYSICAL or SIMULATION)
MODELS:

DIFFERENTIAL OR INTEGRAL EQUATIONS THAT ARE
FORMULATION OF PHYSICAL LAWS GOVERNING
MODELLED REALITY

plus

ALGOIRITHMS NECESSARY TO SOLVE NUMERICALLY THE
EQUATIONS

and

REPRESENTATION OF THE TOPOGRAPHY, OF THE
GEOMETRY, OF HYDRAULIC PARAMETERS, OF
HYDRAULIC STRUCTURES AND THEIR OPERATIONS
RULES, OF THE LAND OCCUPATION, etc.

MECHANISTIC MODELS

AVANTAGES:

THESE MODELS DESCRIBE IN DETERMINISTIC WAY THE EVOLUTION OF HYDRAULICS AND HYDROLOGY PHENOMENA.

THE DESCRIPTION (SIMULATION) IS CONFORM TO PHYSICAL LAWS (EQUATIONS) .

THESE MODELS ARE **PREDICTIVE** AND ALLOW FOR STUDYING OF CONSEQUENCES OF ENGINEERING PROJECTS.

MECHANISTIC MODELS

TYPICAL DISADVANTAGES :

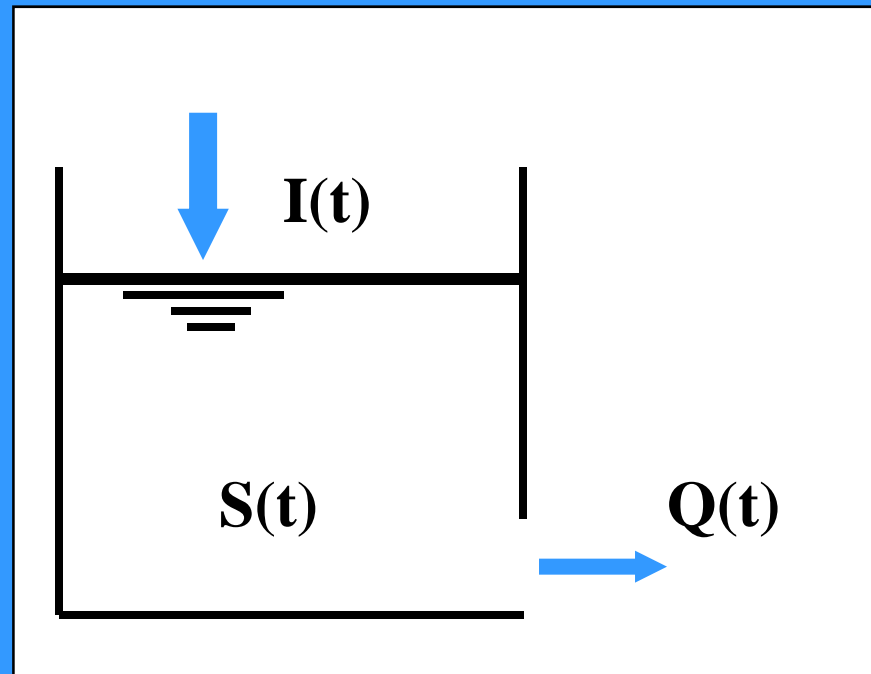
- the effort needed to set up a model,
- computational efforts can be important,
- quality and accuracy of the results depend upon the accuracy and how detailed are topography and hydraulics data,
- simulation software is to be acquired on the market and education effort to apply it is an important investment.

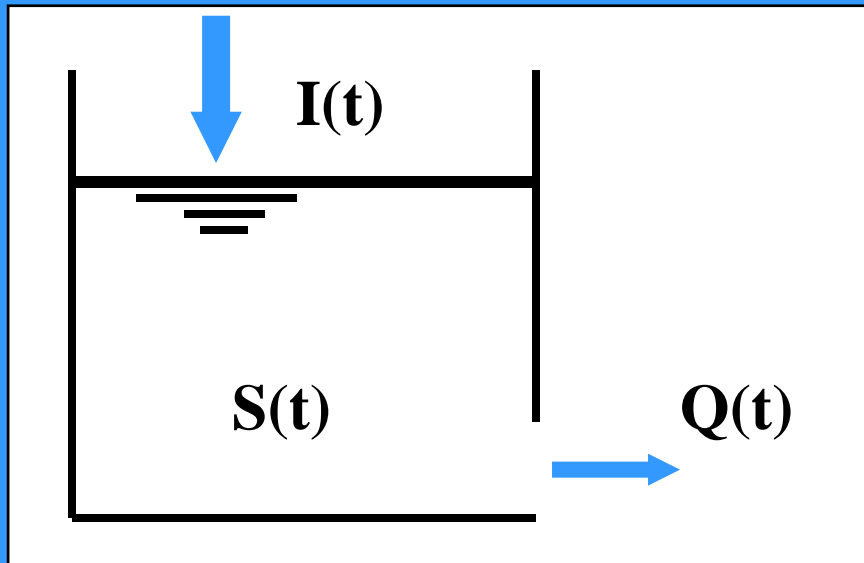
**MECHANISTIC
MODELS: *ARE BASED
ON PHYSICAL LAWS***

**EXAMPLE:
RAINFALL/DISCHARGE
TRANSFORMATION,**

Nash model:

**« RESERVOIR » MODEL
OF A WATERSHED
BASIN**





CONTINUITY LAW:

$$dS/dt = I(t) - Q(t)$$

CONCEPTUALISATION:

$$S = k Q, \quad dQ/dt = (I - Q)/k$$

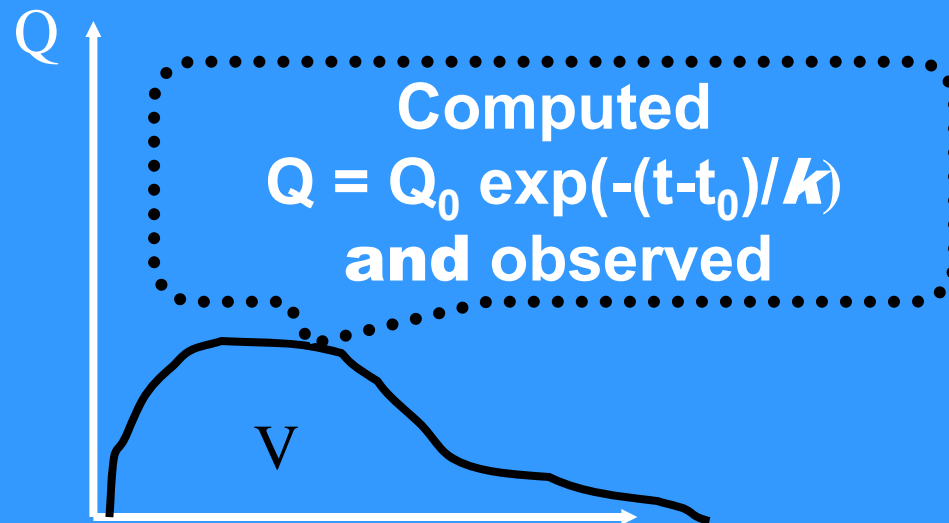
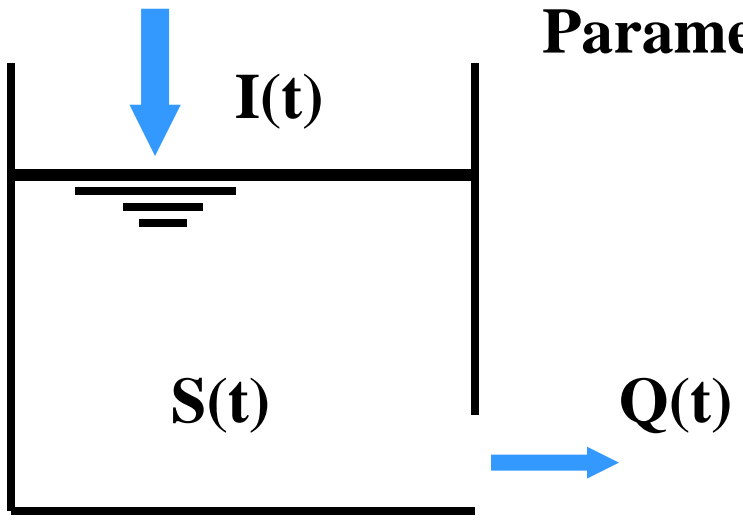
ONLY ONE PARAMETER k !!!

**IF CALIBRATED, WILL THE
MODEL BE PREDICTIVE ?**

SOLUTION:

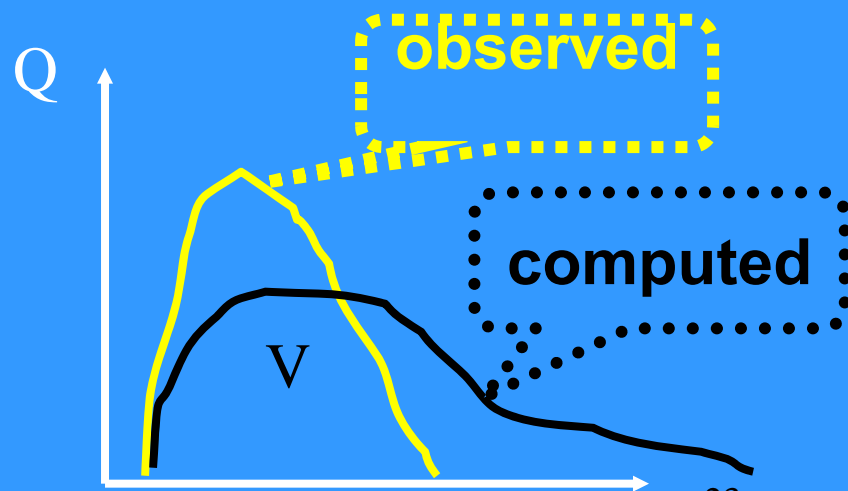
$$Q = Q_0 \exp(-(t-t_0)/k)$$

Parameter k calibrated, the basin is a park.



Urbanisation transformed the park into a parking lot

Is our k of any worth??



RESERVOIR MODEL IS A PHYSICAL **MECHANISTIC**
MODEL BASED ON ONE SINGLE PHYSICAL LAW:

CONSERVATION OF WATER

WHATEVER THE VALUE OF THE PARAMETER *k* ***THE***
CONTINUITY LAW WILL BE SATISFIED.

IS THIS MODEL **PREDICTIVE ?**

IT IS **PREDICTIVE** AS MUCH AS THE RAINFALL **VOLUME** TRANSFORMED IN THE DISCHARGE IS CONCERNED.

IT IS NOT WHEN THE **HYDROGRAPH FORM** IS CONCERNED; e.g. IF THE BASIN CHARACTERISTICS SUCH AS THE SOIL OCCUPATION HAVE BEEN MODIFIED

OR

WHEN THE RAINFALL IS OUT OF RANGE OF THE SAMPLE USED TO CALIBRATE THE PARAMETER ***k***.

WHAT ABOUT « CONCEPTUAL MODELS » THAT ARE SO OFTEN OPPOSED TO MECHANISTIC MODELS?

TO OPPOSE THE TWO CLASSES OF MODELS IS SENSELESS.

ALL MECHANISTIC MODELS ARE CONCEPTUAL. ALL MODELS ARE BASED ON CONCEPTS SIMPLIFYING REALITY.

MOST OFTEN PEOPLE CALL « CONCEPTUAL » MODELS BASED ON OVERSIMPLISTIC HYPOTHESES;

ONE MUST ALWAYS KNOW WHAT ARE THE LAWS THAT ARE CONCEPTUALISED IN A MODEL !!!!

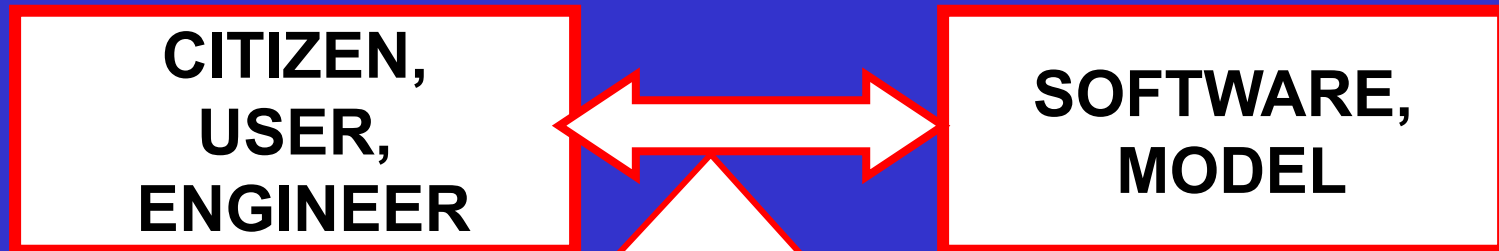
ESSENTIAL QUESTION IS:

**GIVEN THE NEEDS,
WHAT IS THE VALUE OF THE MODEL???**

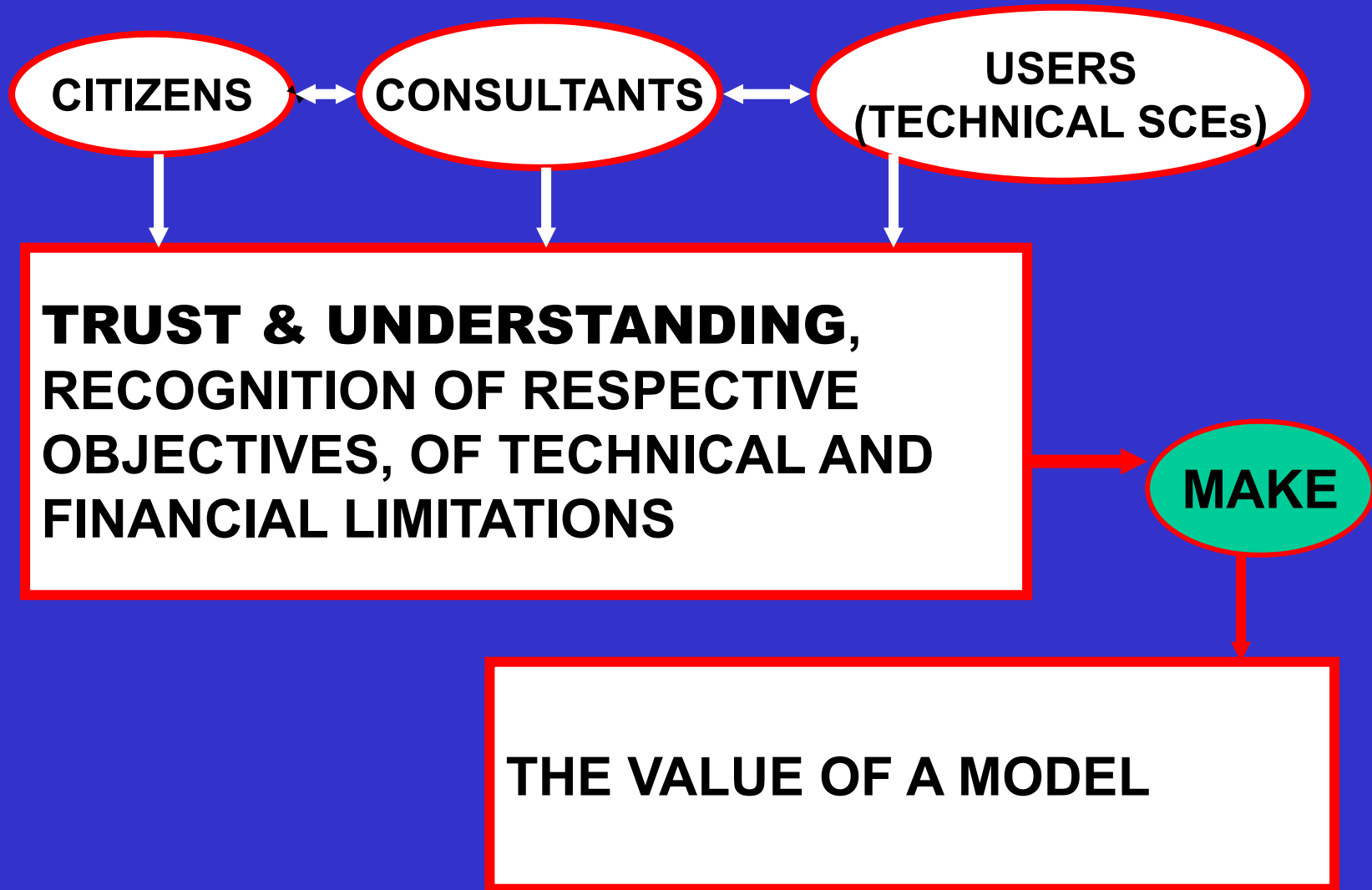
BASIC CRITERIA ARE :

- **HOW A MODEL IS BUILT, SET UP?**
- **WHAT PHENOMENA CAN IT SIMULATE ?**
- **HOW HIGH IS ITS COST ?**
- **HOW EASY CAN ONE INTERPRET ITS RESULTS?**

MAN AND THE TOOL :



**ARE ALL RELATIONS, NECESSARY
TO SUCCEED, CLEAR TO ALL?**



WHAT ABOUT *THE* SOFTWARE ?

SOFTWARE IS NECESSARY BUT

- FAR FROM BEING SUFFICIENT ALONE,

- IN GENERAL THERE IS NO SINGLE SOFTWARE SOLUTION:

***SEVERAL SOLUTIONS* ARE POSSIBLE**



**THE VALUE OF A MODEL IS ALSO MADE BY
THE MODELLER, BY HIS *KNOWLEDGE* AND
EXPERIENCE OF :**

- hydraulics and physics in general ,
- flow patterns, hydraulics and topography of the river,
- objectives, purpose of the model to be built,
- available simulation software systems.

IN THIS ORDER OF IMPORTANCE !!!!

DOES THE MODELLER KNOW WELL :

- hydraulics
- river to be modelled
- purpose of the model
- the software to be used ???



NO

YES

FLOP !!!!



SUCCESS!!!!





**IN WHAT FOLLOWS MAIN ARGUMENT IS
ABOUT SYNERGY OF MODELLER'S
KNOWLEDGE WITH SOFTWARE TOOLS**

**THIS IS CARRIED OUT ON EXAMPLE OF
FLUVIAL HYDRODYNAMIC MODELS**

**THE PURPOSE IS TO SHOW THAT THE
ESSENTIAL ROLE IS THAT OF HYDRAULIC
ENGINEER, NOT OF THE SOFTWARE**



DISCRETISATION DILEMMA:

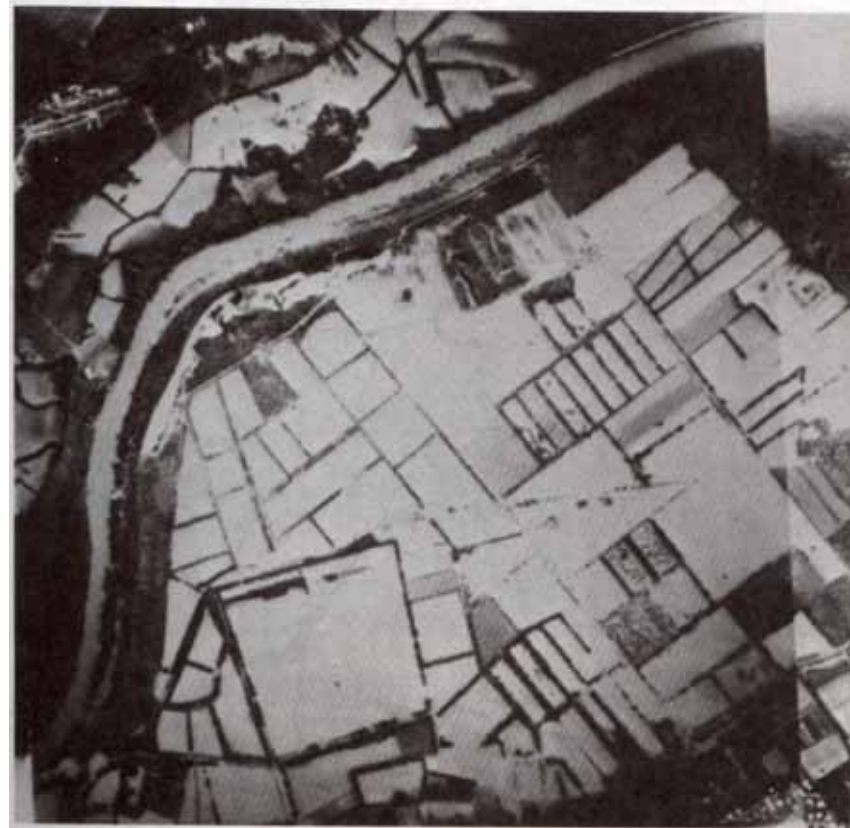
CONSIDER MODELLING OF A RIVER AND ITS INUNDATED PLAINS

IS THE PROBLEM:

- ONE-DIMENSIONAL (1-D) ?
- TWO-DIMENSIONAL (2-D) ?

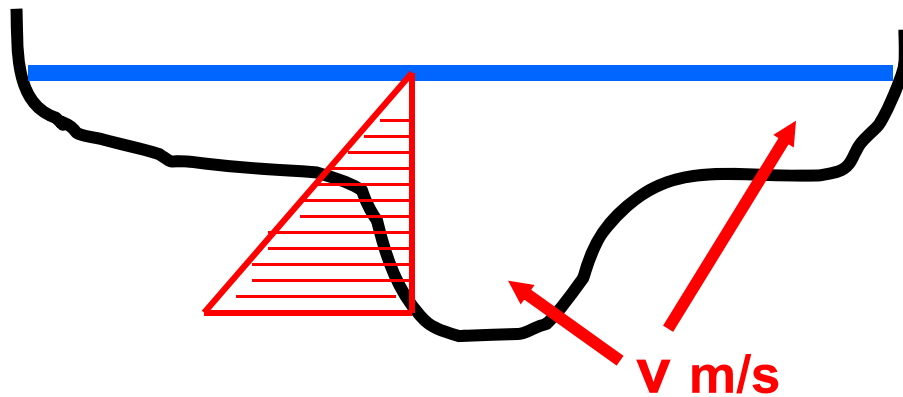
OR

- QUASI – TWO-DIMENSIONAL (1-D and cells) ????



Adour River (France) inundation

De Saint-Venant hypotheses of 1-D flow:



Uniform velocity v at every point of the cross-section

Free surface horizontal across the section

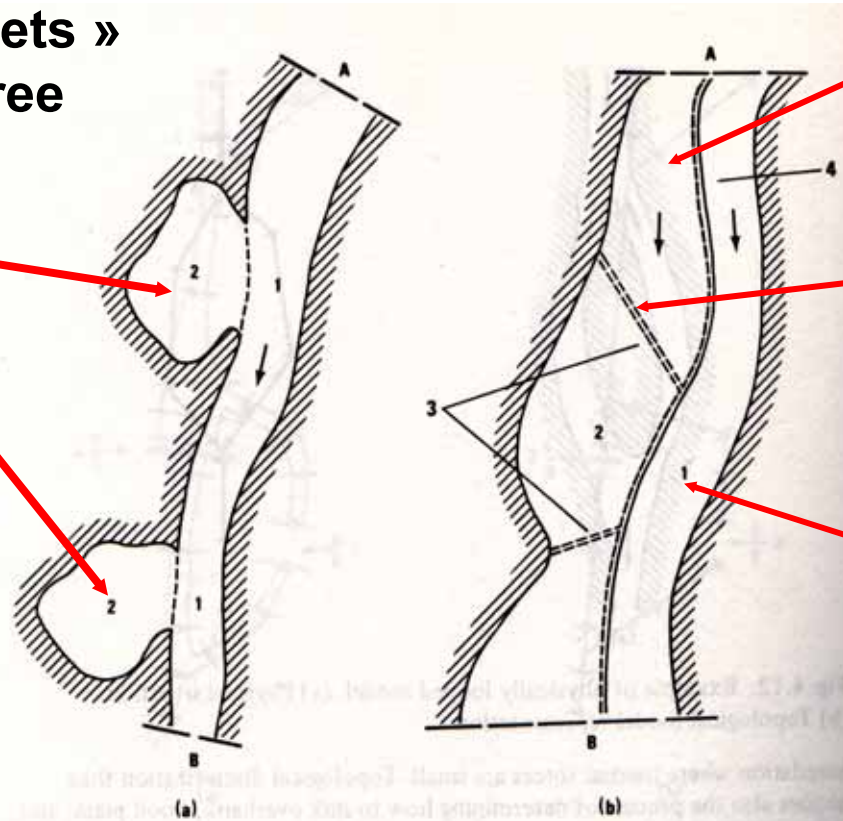
Vertical distribution of the pressure is hydrostatic

Head-losses can be represented by a Chèzy, Strickler or Manning coefficient

**Do you believe this ???
And yet...**

How to schematise the flow in the river and its inundated plains?

Storage « pockets »
of horizontal free
surface



Fields,...

Dykes, roads,
canals, ditches,...

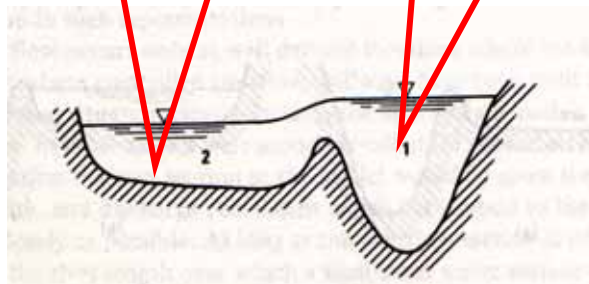
Main bed



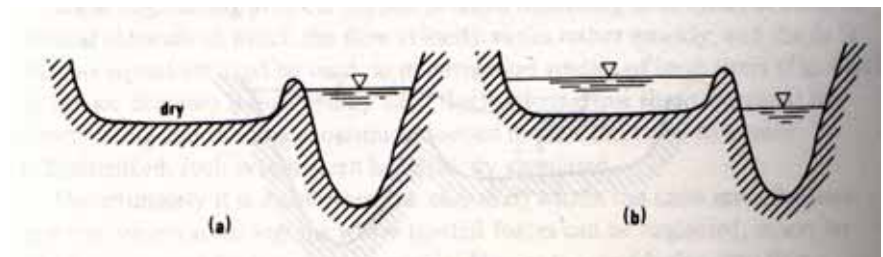
Is the situation 1-D?

Flooded area

Main bed



Is not the reality rather like:



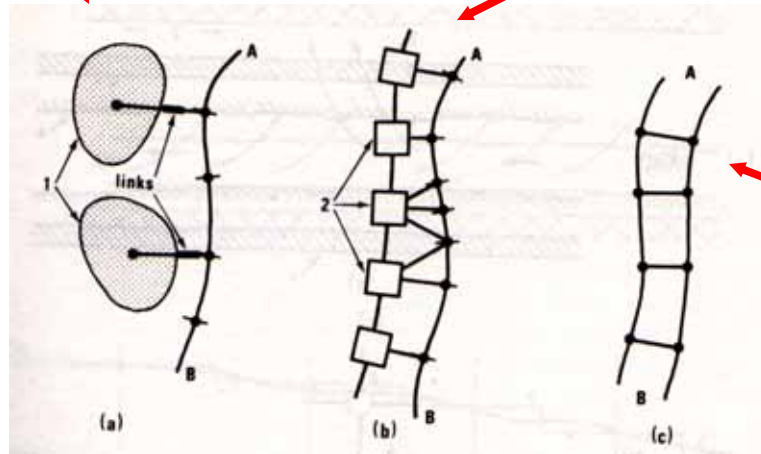
Rising flood

Receding flood

Possible modelling options:

De Saint-Venant 1-D type
+ storage «pockets »

De Saint-Venant 1-D type
+ interconnected « cells »



De St-Venant 1-D type
interconnected network

Implication: to know enough about theory, algorithms & software !!!



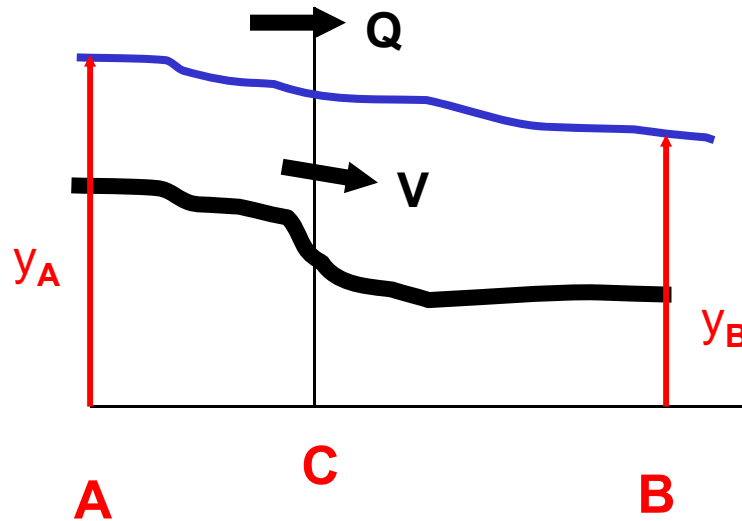
BETTER SOLUTION IS TO USE 2-D MODEL. BUT, *from engineering point of view*, IT WOULD BE ABSURD IN MOST CASES, BECAUSE THE FLOW ON THE PLAIN IS NOT OF THE SAME KIND AS IN MAIN STREAM.

HENCE INTRODUCTION OF MIXED « QUASI 2-D » APPROACH:

Inundated plain is represented by interconnected network of “cells”



EXAMPLES OF LINKS BETWEEN CELLS:

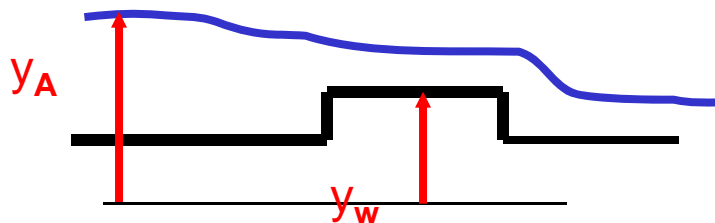


Link taking inertia into account :

$$f(Q, V, y_A, y_B) = 0$$

e.g.: de Saint-Venant equations

Inertialess link : $Q = f(y_A, y_B)$



e.g. Strickler formula

$$Q = S(h_C) k h_C^{2/3} [(y_A - y_B)/2]^{1/2}$$

where $S(h_C) = \text{cross-section}$

e.g.: weir equation

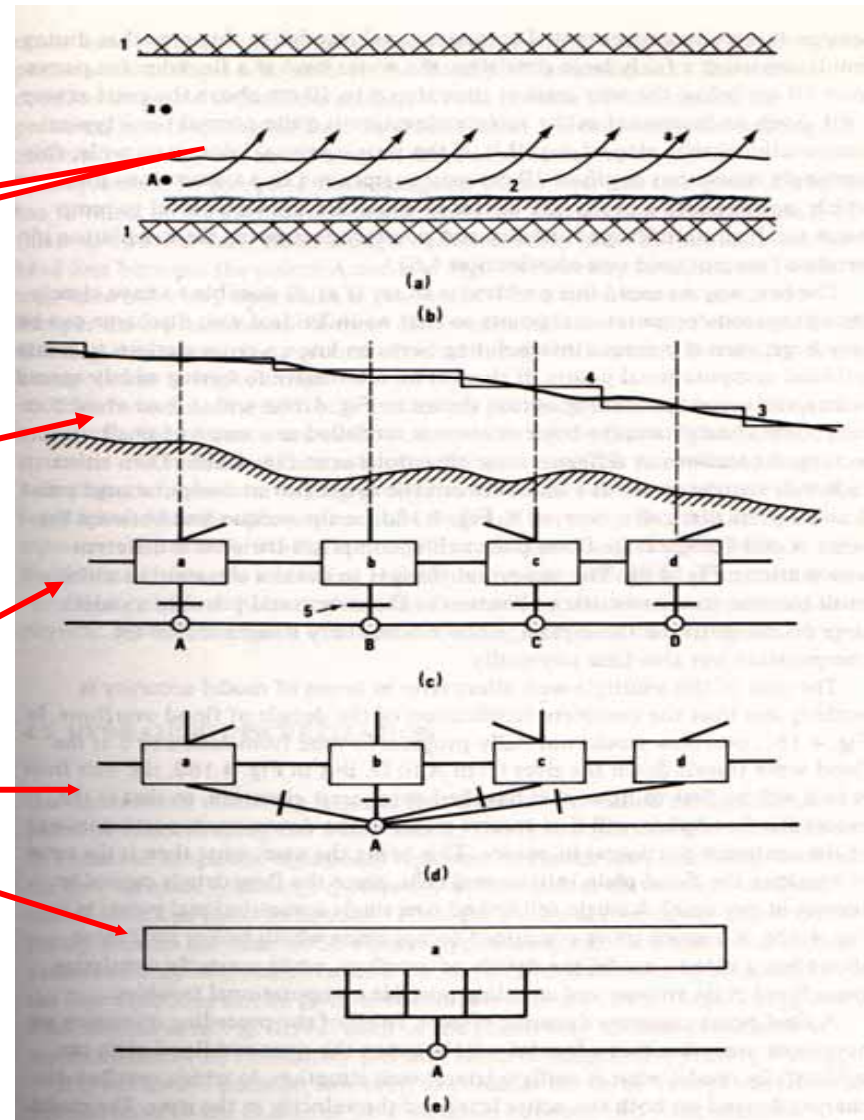
$$Q = C b [y_A - y_w]^{3/2}$$

Dykes overflow, some modelling options with quasi-2D:

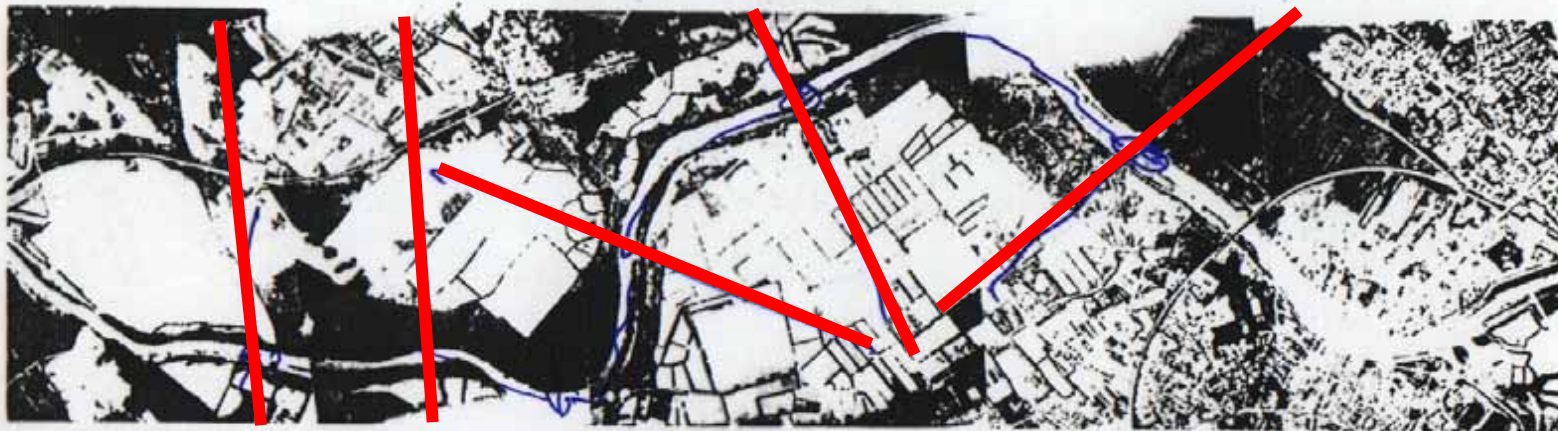
Physical situation

Longitudinal profiles of the free surface, of the dyke crest and of the bed

Three various possibilities to schematise (if the available software tool allows!)



UNSA – Hydro-Europe - Software, models and simulation



Above: 1-D discretisation; Below: quasi- 2-D (river + cells)

