Urban Hydrology class: Introduction to modelling activities

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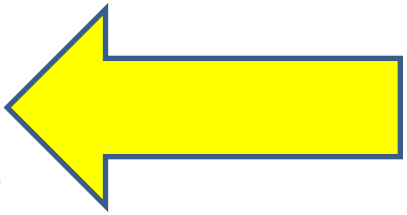
Goals of the course

- To know how to model urban hydrological processes using different type of models
- Examples of application:
  1. Rational Method
  2. Routing System (RS) MINERVE
  3. Probabilistic Modelling (REBEKA II)



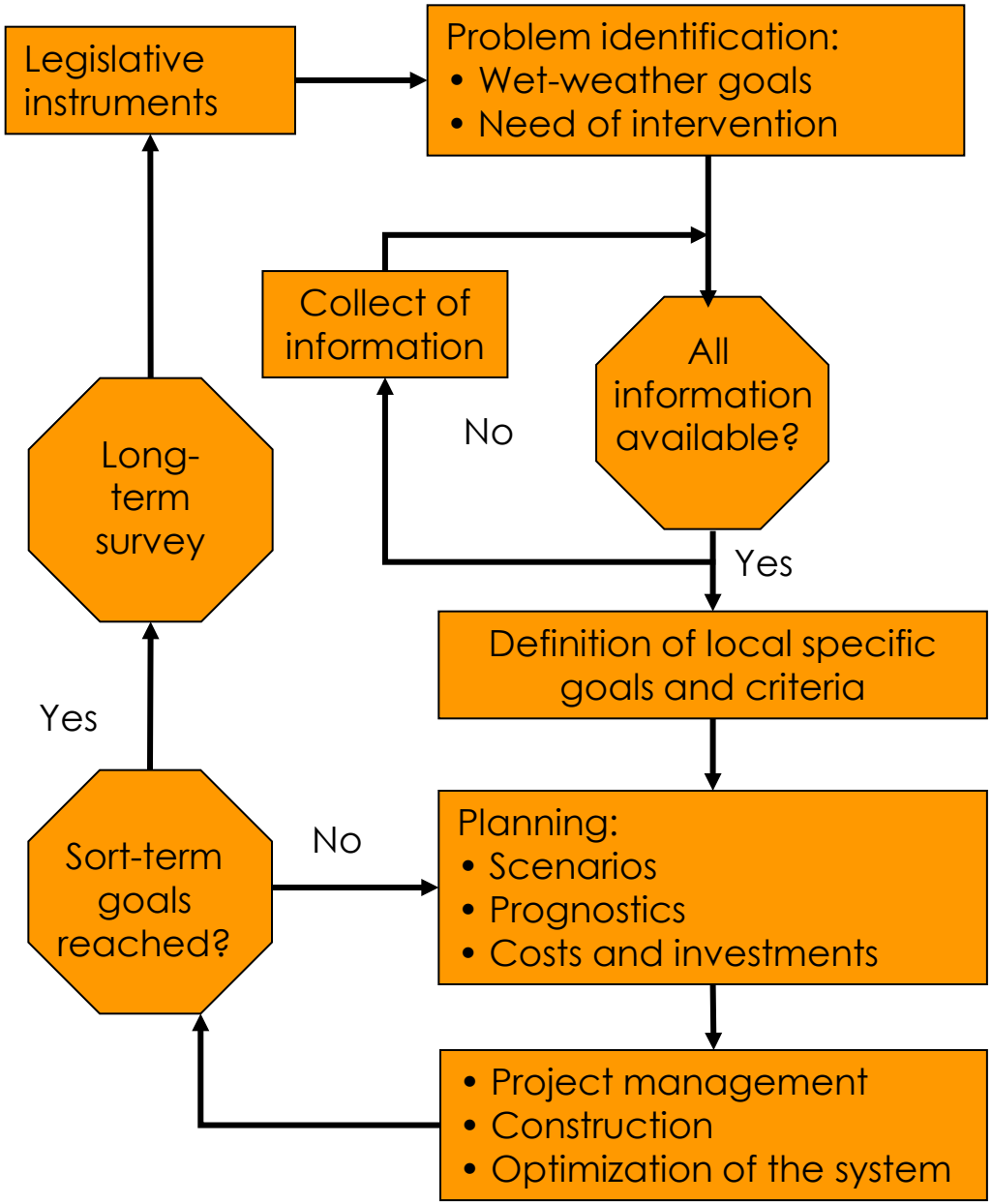

Legislative instruments
Problem identification:
• Wet-weather goals
• Need of intervention
Collect of information
All information available?
No
Yes
Long-term survey
Definition of local specific goals and criteria
Yes
Sort-term goals reached?
No
Planning:
• Scenarios
• Prognostics
• Costs and investments
• Project management
• Construction
• Optimization of the system

Table of content

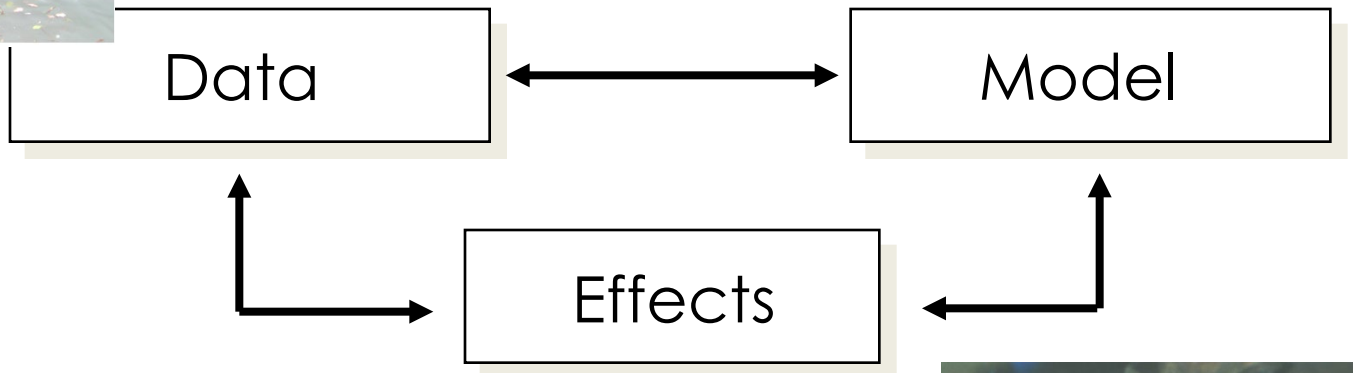
- Introduction to modelling
- Model conceptualization
- Choice of a software
- Data collection
- Model validation
- Scenarios
- Some critical points with modelling…
- Rational method: sizing of a sewer network

Introduction

Why a model ?

$$Q = C \cdot i \cdot A$$

$$F_d = C \cdot W_C \cdot \left(1 - \frac{\tau}{\tau_{crit}}\right) \quad si\ \tau < \tau_{crit}$$



Introduction

$$\ln\left(\lim_{z\to\infty}\left(\left(\left(\overline{X}^{T}\right)^{-1}-\left(\overline{X}^{-1}\right)^{T}\right)!+\frac{1}{z}\right)^{2}\right)+\sin^{2}(p)+\cos^{2}(p)=\sum_{n=0}^{\infty}\frac{\cosh(q)*\sqrt{1-\tanh^{2}(q)}}{2^{n}}$$

$$\left.\begin{aligned}1&=\ln(e)\\ 1&=\sin^{2}(p)+\cos^{2}(p)\\ 2&=\sum_{n=0}^{\infty}\left(\frac{1}{2}\right)^{n}\end{aligned}\right\}\ \ln(e)+\sin^{2}(p)+\cos^{2}(p)=\sum_{n=0}^{\infty}\left(\frac{1}{2}\right)^{n}\ \left\{\begin{aligned}1&=\cosh(q)*\sqrt{1-\tanh^{2}(q)}\\ e&=\lim_{z\to\infty}\left(1+\frac{1}{z}\right)^{2}\end{aligned}\right.$$

$$\ln\left(\lim_{z\to\infty}\left(1+\frac{1}{z}\right)^{2}\right)+\sin^{2}(p)+\cos^{2}(p)=\sum_{n=0}^{\infty}\frac{\cosh(q)*\sqrt{1-\tanh^{2}(q)}}{2^{n}}$$

$$\left.\begin{aligned}0!&=1\\ \left(\overline{X}^{T}\right)^{-1}-\left(\overline{X}^{-1}\right)^{T}&=0\end{aligned}\right\}\ \left(\left(\overline{X}^{T}\right)^{-1}-\left(\overline{X}^{-1}\right)^{T}\right)!=1$$

$$1+1=2$$ **...but not always!!!**

Simplicity is the ultimate sophistication

(Leonardo da Vinci)

Introduction

1. Initial evaluation
- Review of existing data
- Conceptualization of the model
- Definition of the problem
- Choice of the software

2. Collect of data
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- Measurements and data for the validation (rain, flow, concentrations...)

3. Selection of model parameters
- Analysis of measured data
- Values obtained from the literature

4. Validation of the model
- Comparison between measurements and results
- Sensitivity analysis

5. Evaluation of future scenarios
- Selection of design conditions
- Comparison of different scenarios

Model conceptualization

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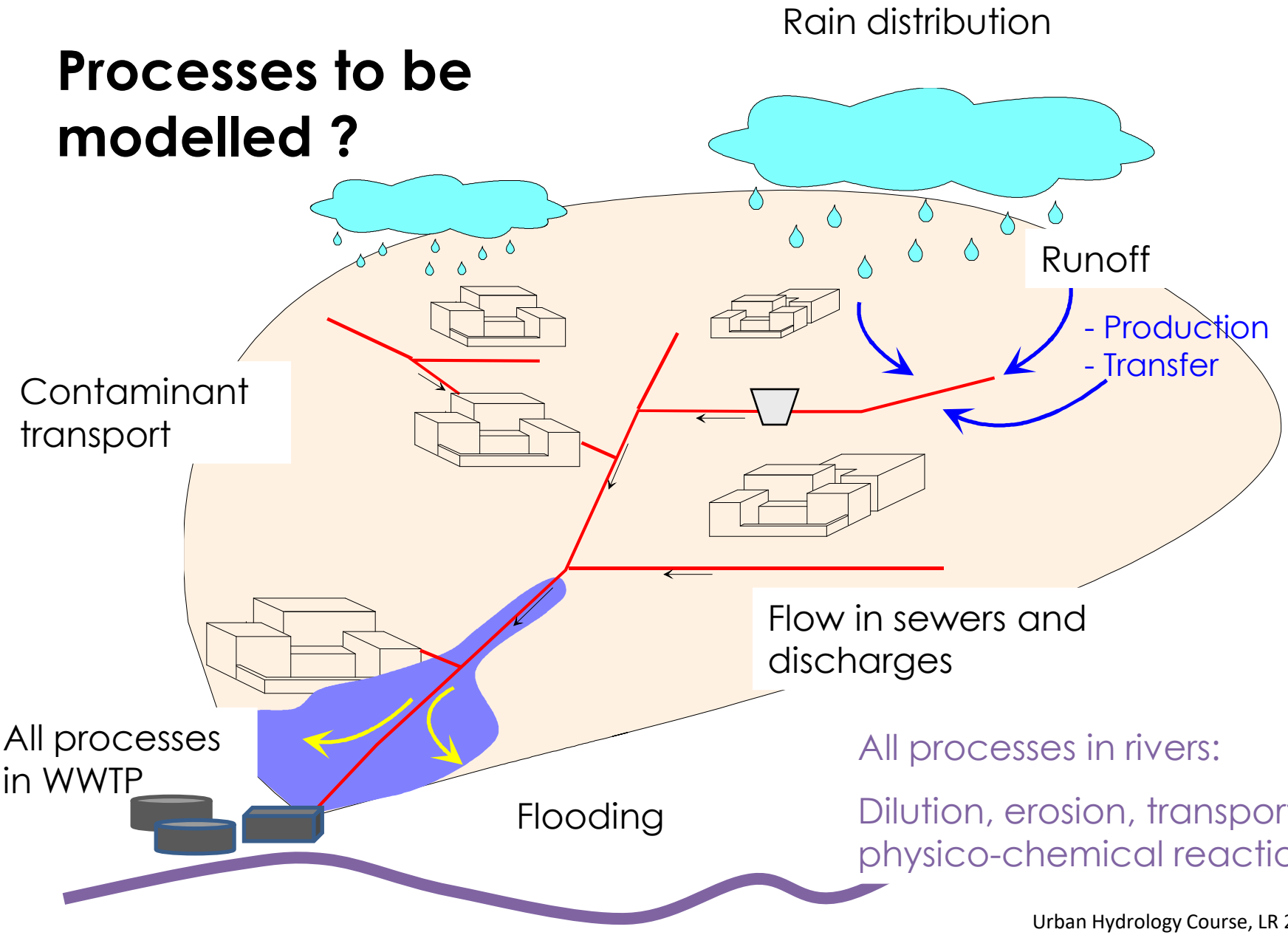
1. Conceptualization of the model

Processes to be modelled ?



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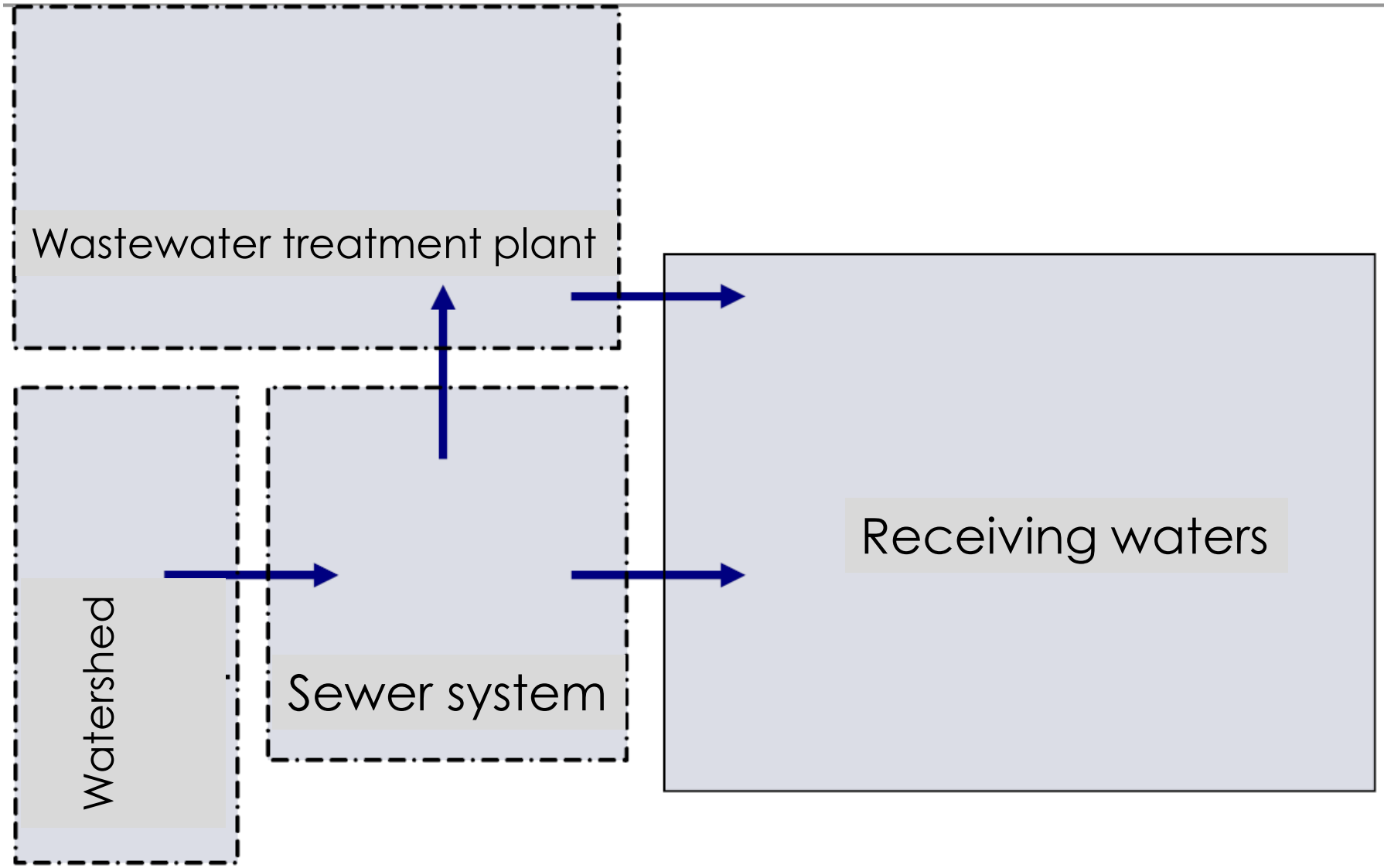

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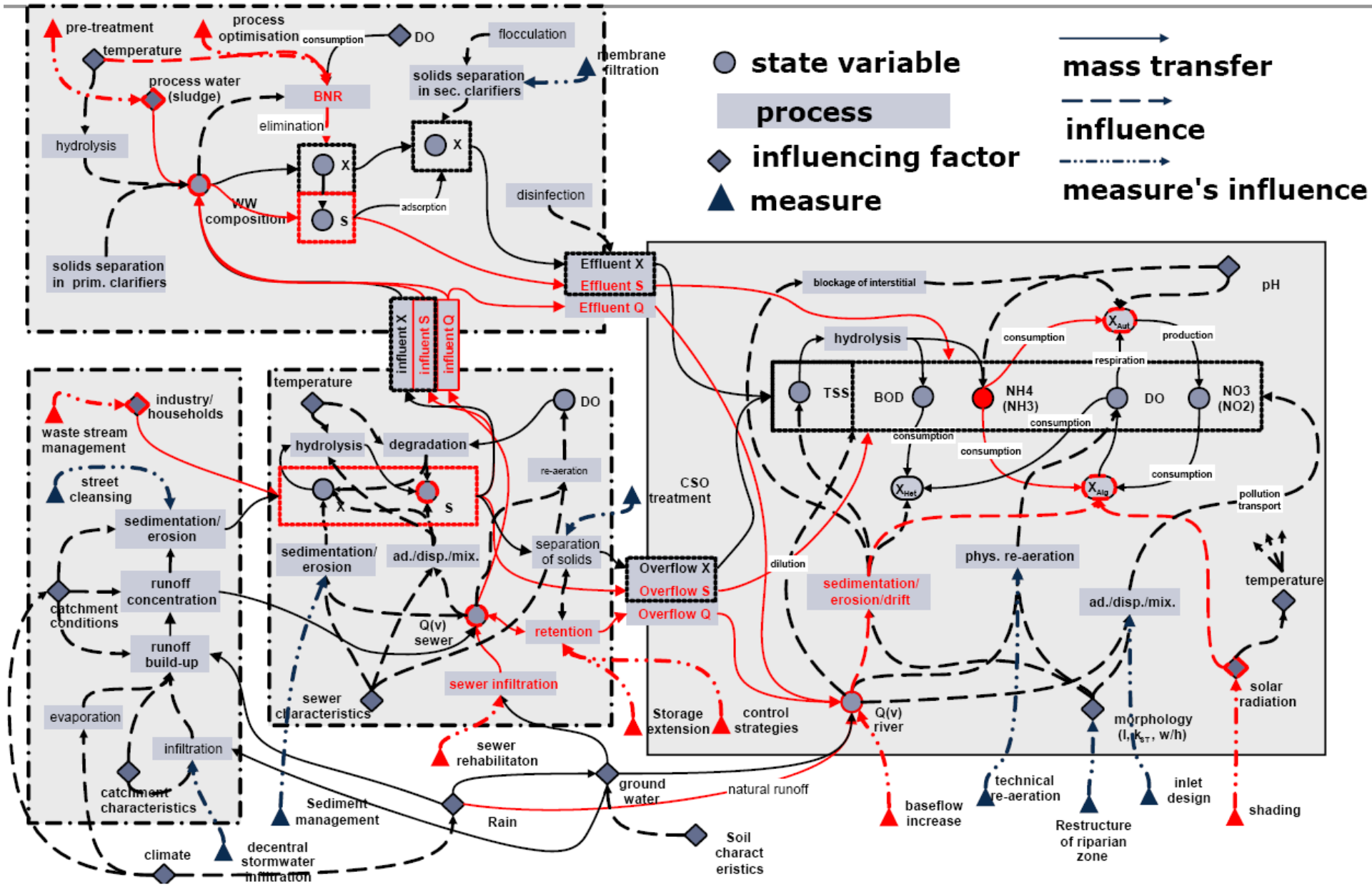

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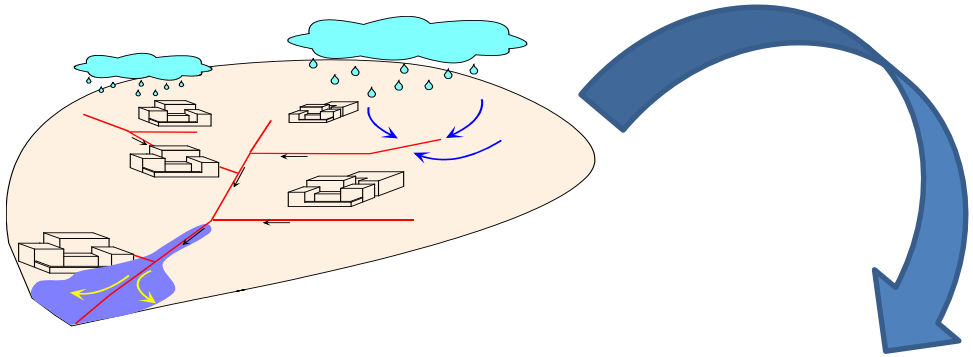
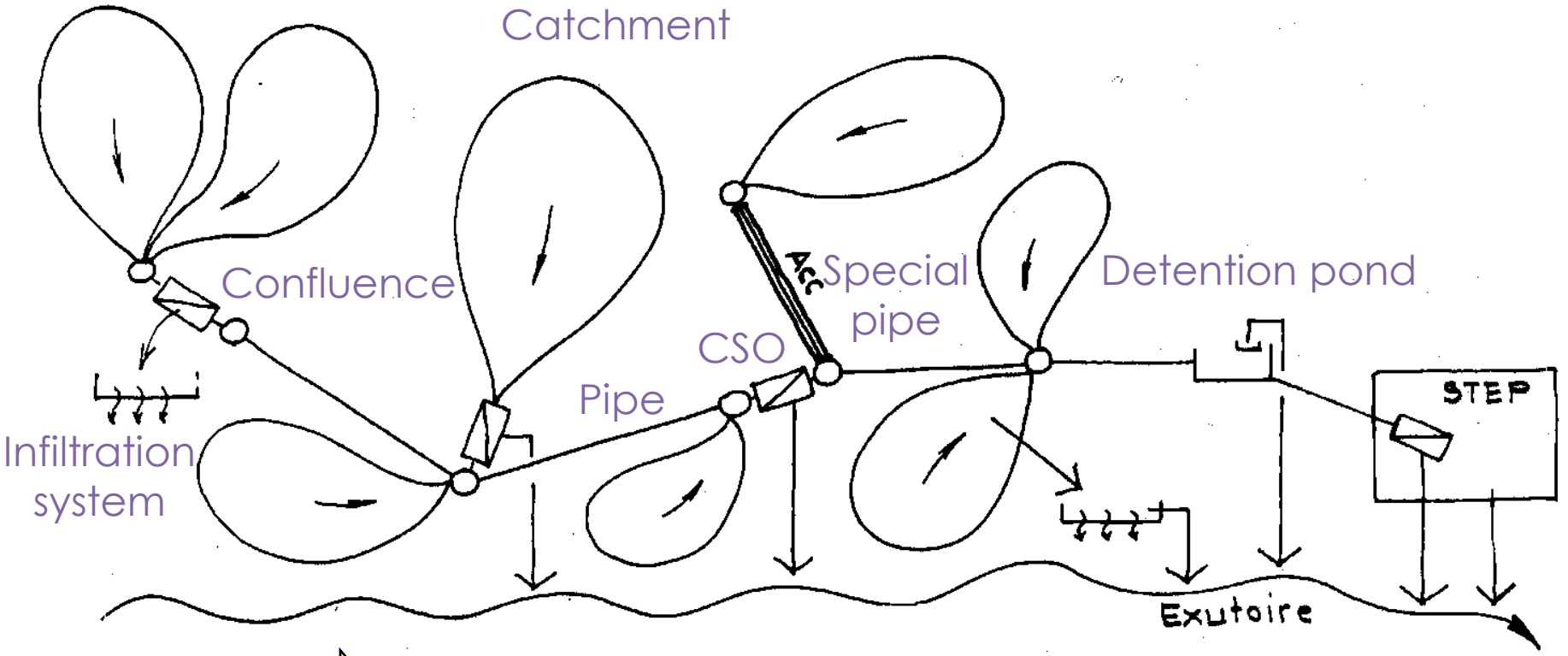


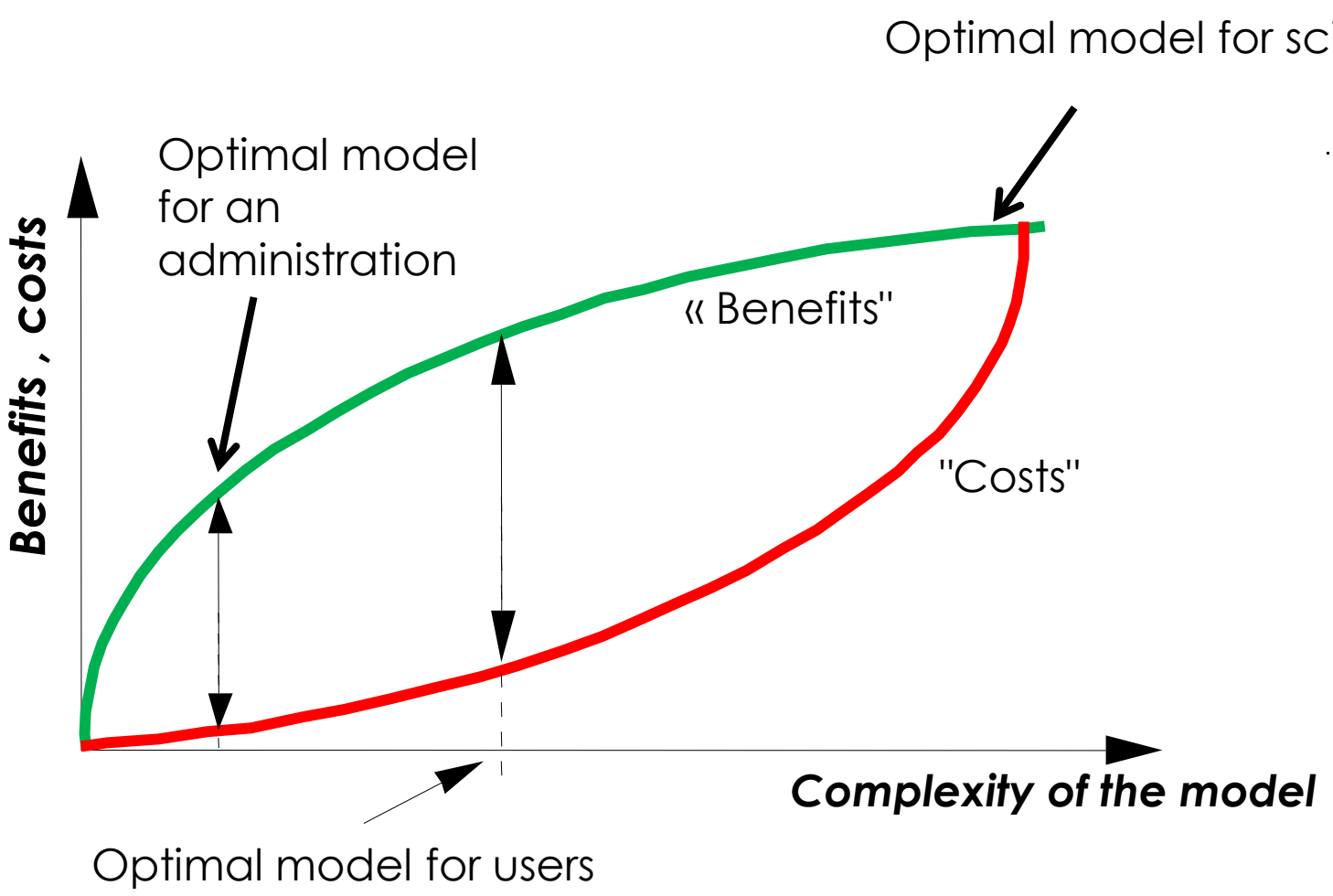


Key for deterministic modelling = discretization of the system in single units

1. Conceptualization of the model

Urban Hydrology Course, LR 27.03.2025

1.2. Choice of the model



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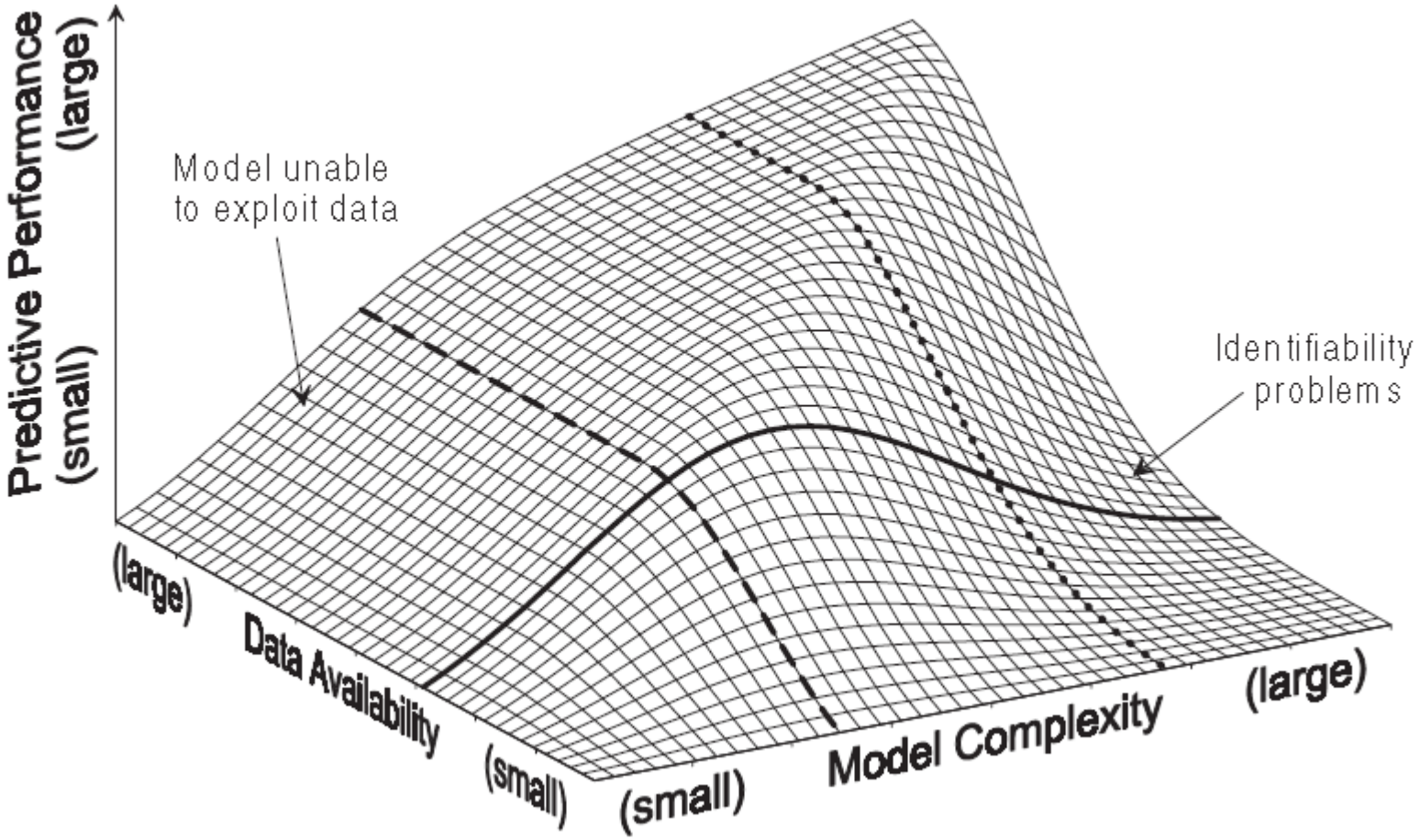

From Grayson R and Blöschl G, «Spatial Patterns in Catchment Hydrology, Observations and Modelling », Cambridge University Press, 2000

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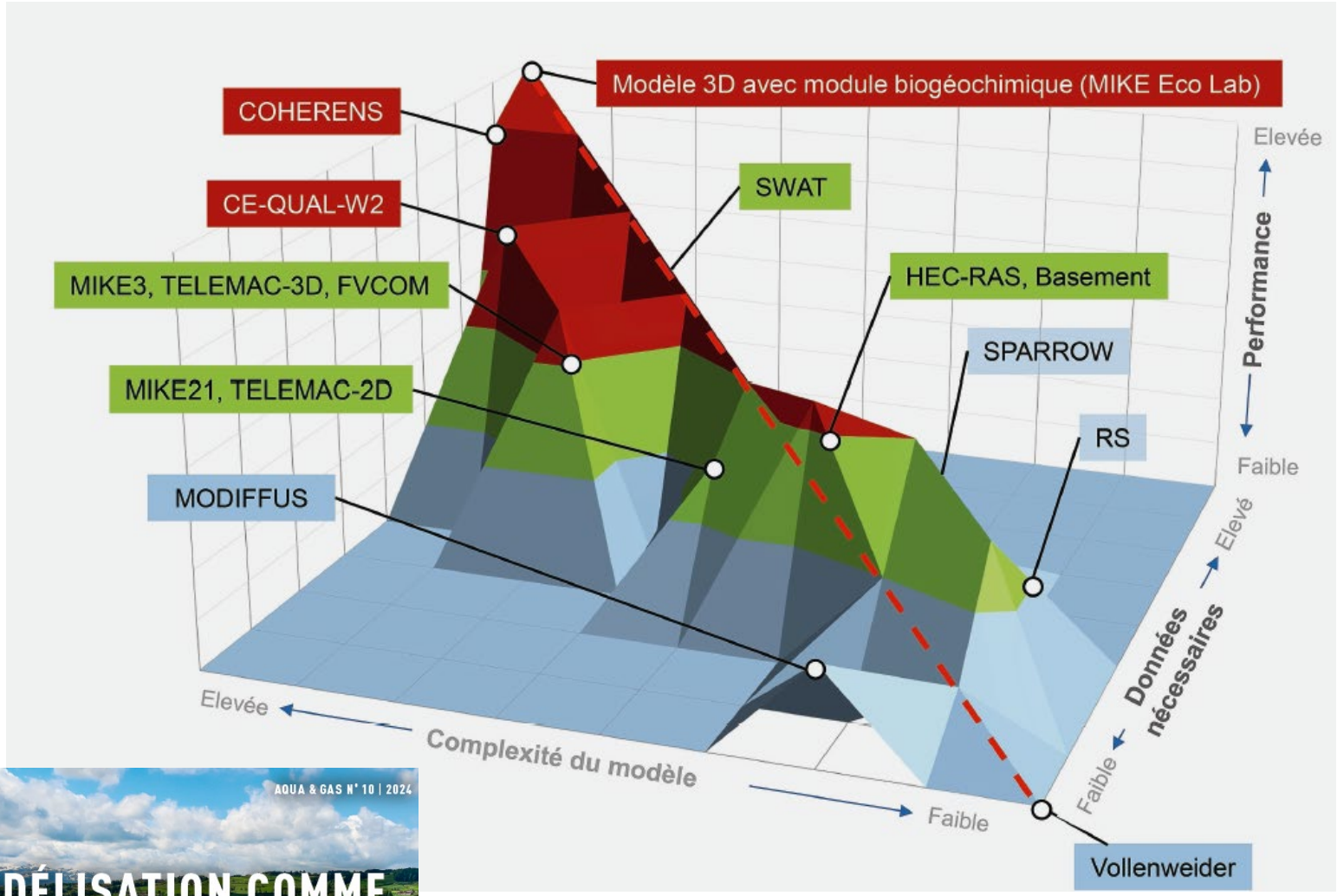

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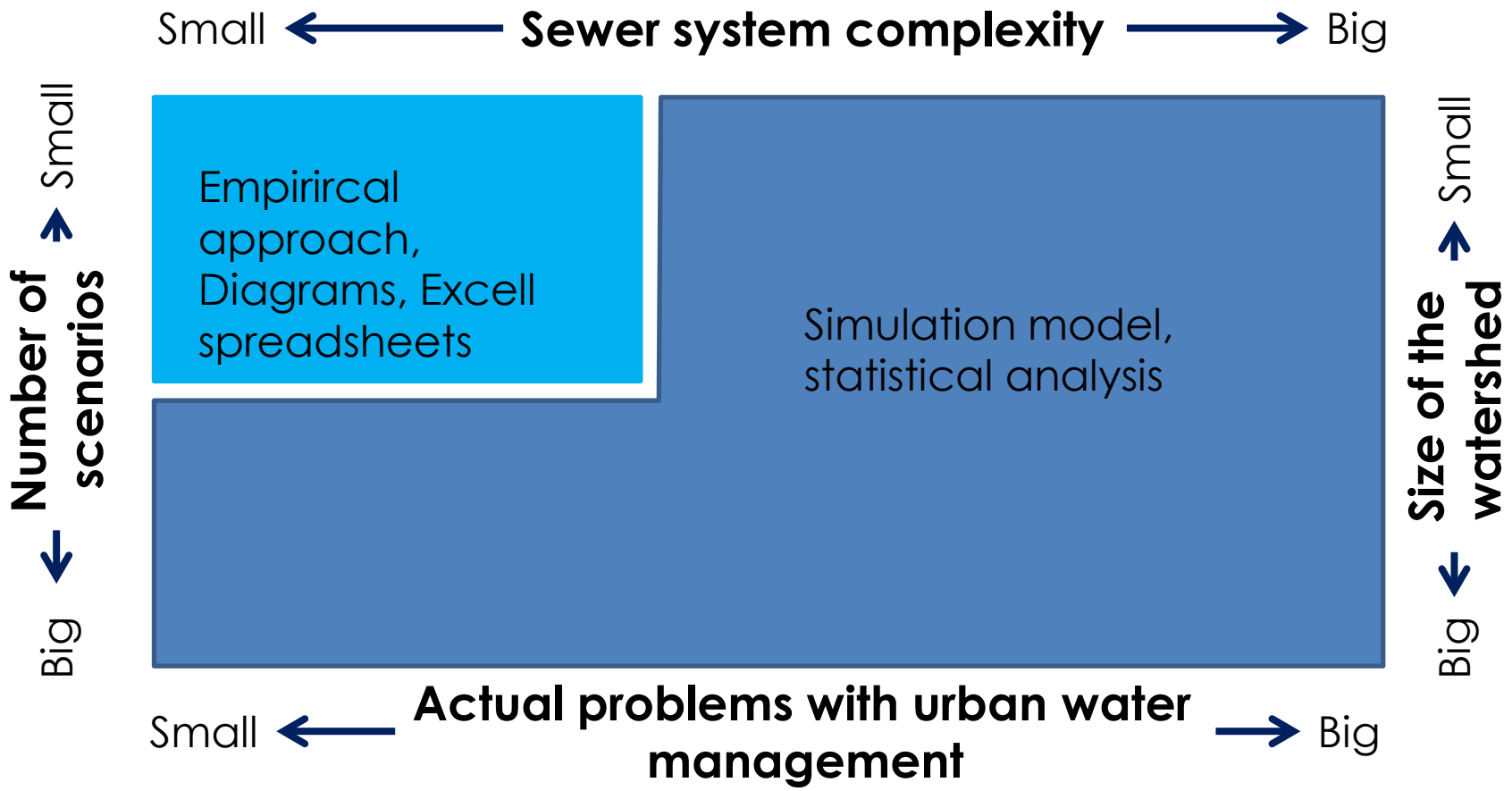

1.2. Choice of the model: some criteria

- Availability of trained personnel
  - nonconventional and usual software, numerous « tricks »
- Long-term commitment to the model
  - the model will be used for different future projects
- In-house model experience
  - no need of training and "warm-up" period
- Support of the model
  - update from developers (user assistance, correction of errors…)
- Acceptance of the model
  - fairly obscure models may meet your needs, but less credibility
- Commitment to modeling as a tool
  - Modeling as an integral part of problem-solving
- Suitable hardware
  - Not a real problem anymore, except for special cases

1.2. Choice of the model: some criteria

Type of models:
Statistical / empirical
Deterministic
Stochastic
Event-based
Multiple event-based
Continuous
…

Expected goals:
Planning
Detention
Pressurized pipes
Sizing
Water quality
…

Others:
Link with WWTP / River models
Dedicated processes studies
…

Numerous model on the market!

Storm Water Management Model (SWMM)
https://www.epa.gov/water-research/storm-water-management-model-swmm
Models based on SWMM: PC-SWMM, XP-SWMM, infoSWMM
http://www.chiwater.com/Software/PCSWMM/index.asp
http://xpsolutions.com/Software/XPSWMM/
http://www.mwhsoft.com/products/infoswmm/
OTTHYMO
http://www.clarifica.com/Products/EST/V02/home.htm
MOUSE / Mike Urban (DHI)
http://www.dhigroup.com/
CANOE (France)
http://www.canoe-hydro.com/
InfoWorks (Wallingford Software)
http://www.mwhsoft.com/products/infoworks_cs/
Suite Routing System (RS MINERVE, RS URBAN…)
http://infoscience.epfl.ch/record/116157/files/Comm_LCH_9.pdf
http://www.crealp.ch/fr/accueil/ressources/logiciels-general/rs-minerve.html
REBEKA
http://www.rebeka.ch/
HYSTEM EXTRAN
http://www.itwh.de/software/softwareprodukte.html

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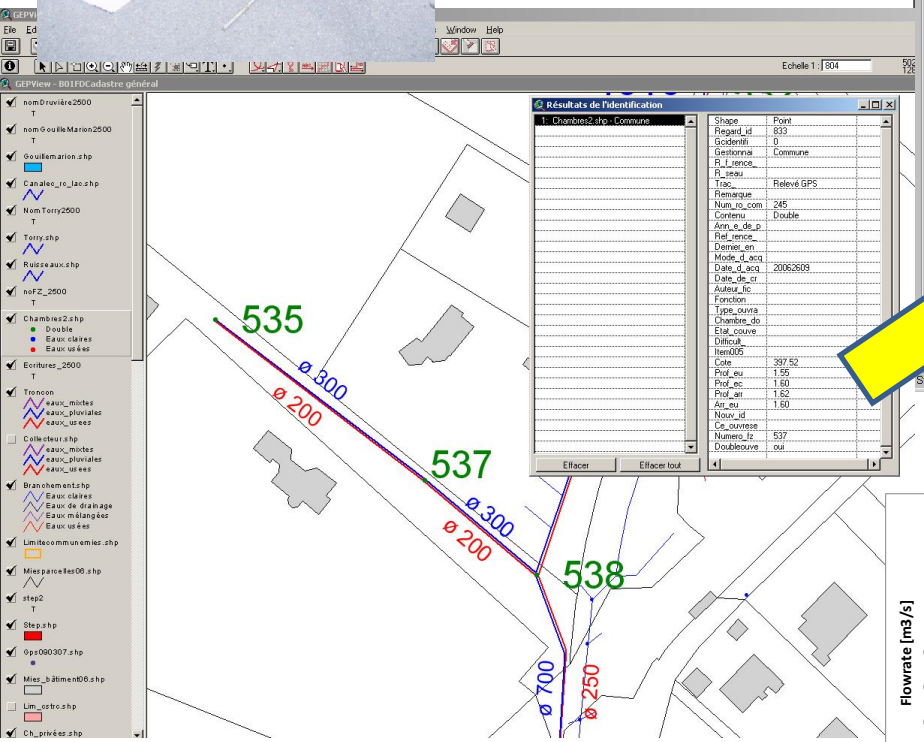
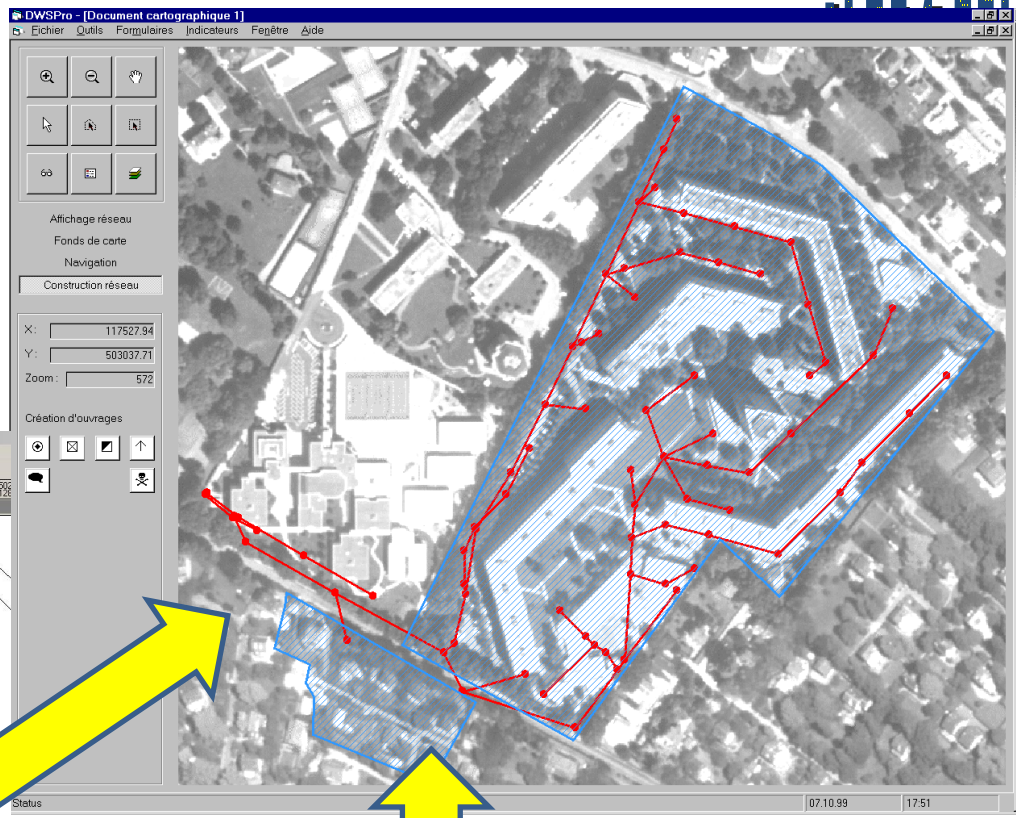
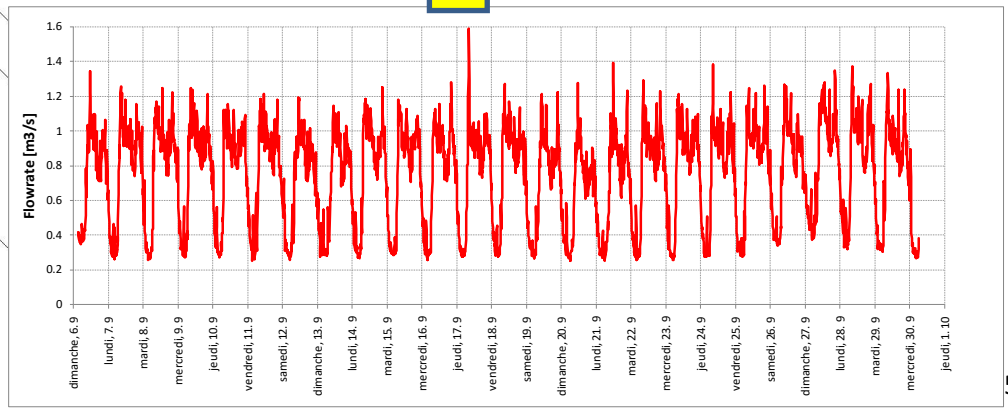
2. Collect of Data







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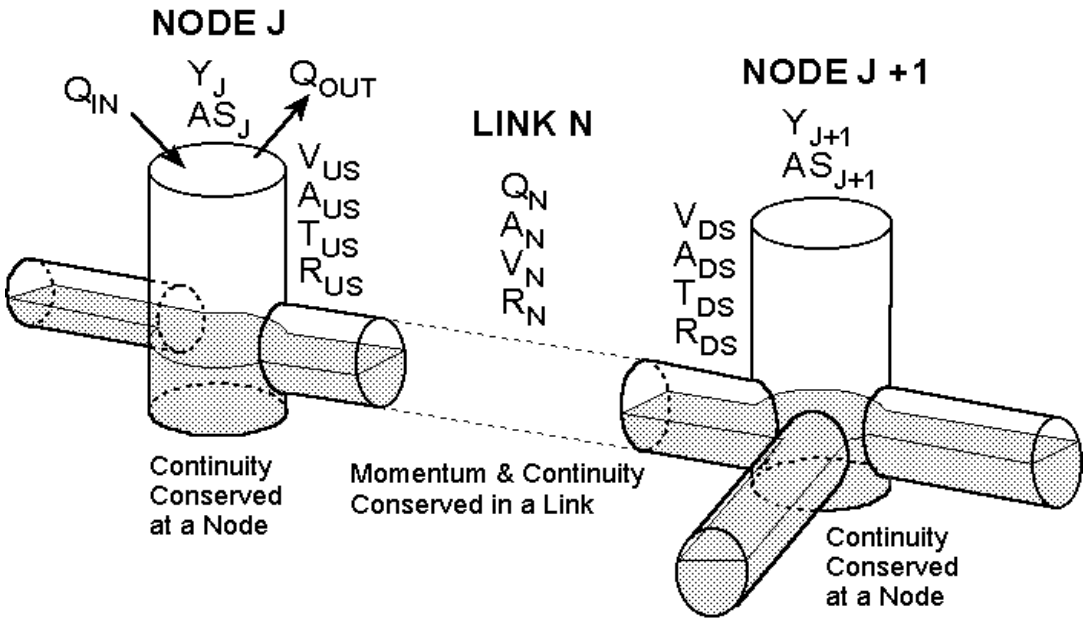
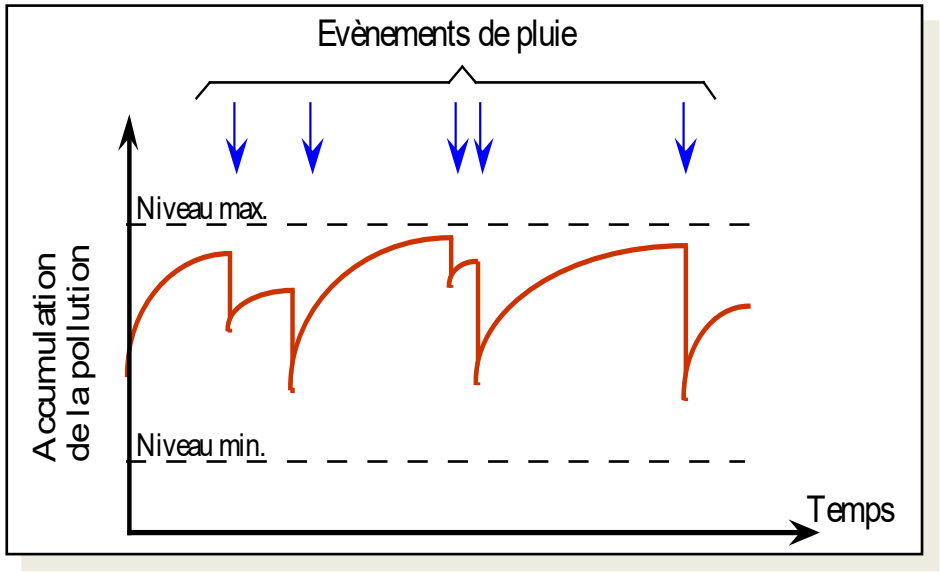
3. Analysis of data / parameters



- Control of the links between all elements
- Controls of slopes
- Units
- …

Selection of typical values for simulated processes (accumulation rate, Strickler coefficients, wastewater profiles…)



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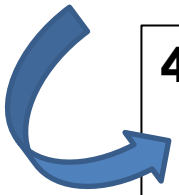

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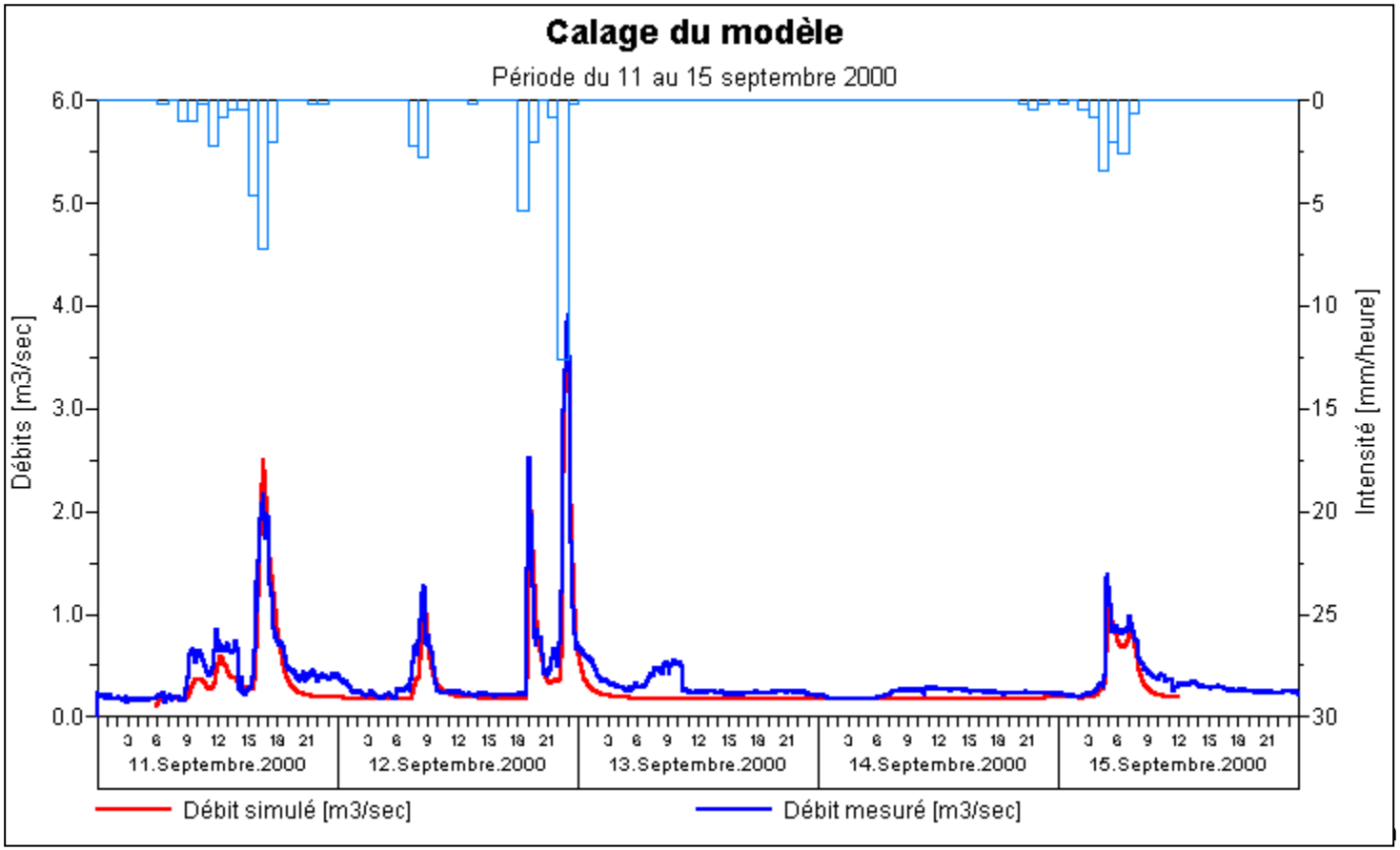
4. Validation of the model

$$Min\ F = \sum_{i=1}^{n} (q_i - r_i)^2$$

$$Min\ F = \sum_{i=1}^{n} (\ln(q_i) - \ln(r_i))^2$$

$$Nash\_coefficient = 1 - \frac{\sum_{i=1}^{n} (q_i - r_i)^2}{\sum_{i=1}^{n} (q_i - \bar{q})^2}$$

q: measured valued
r: simulated values
F: optimization function



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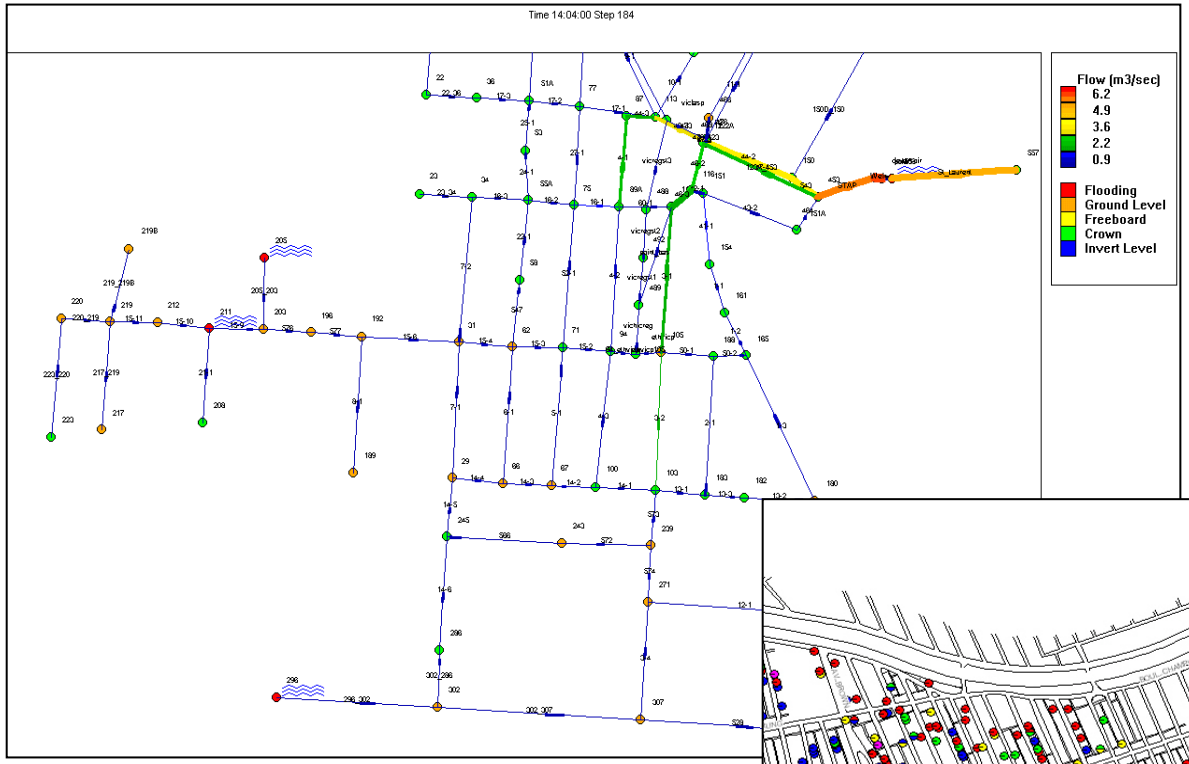


Exemple: Coupling model results for flooding during a rain event with complaints from citizens (flooding in cellars)

4. Validation of the model

Mapping floods with social media

https://blogs.egu.eu/geolog/2016/03/11/geosciences-coloumn-mapping-floods-with-social-media/

4. Validation of the model

Figure 4.6 – Modélisation - Comparaison des résultats de modélisation avec la carte de ruissellement de la confédération - Chauderon Nord [6] : (a) Résultats de modélisation (b) Carte de ruissellement de la confédération

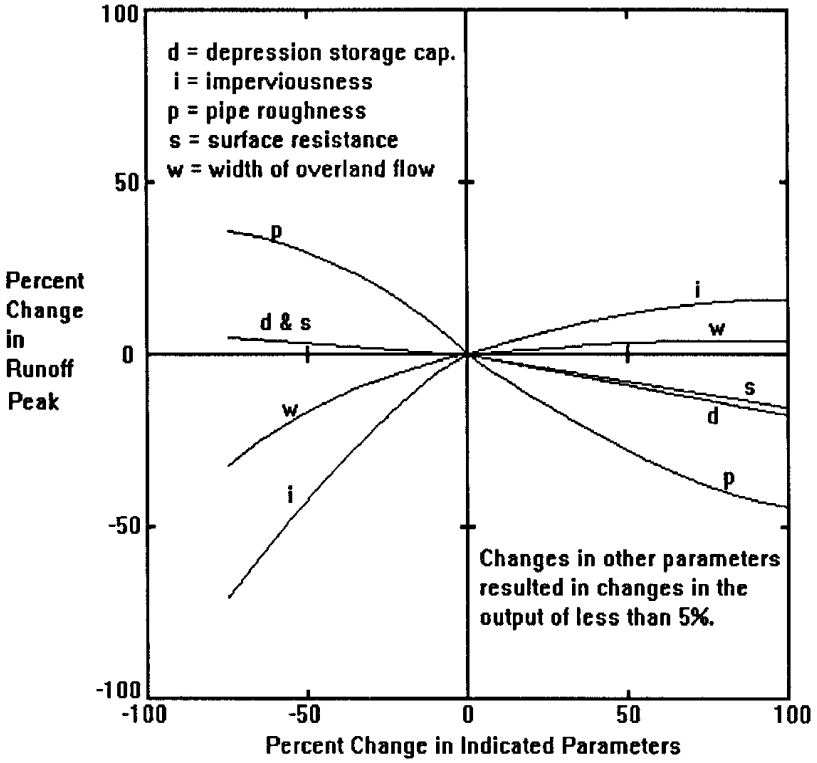
Antoine Passaquin (2025) Étude du ruissellement de surface Place Chauderon Lausanne – Master 2025

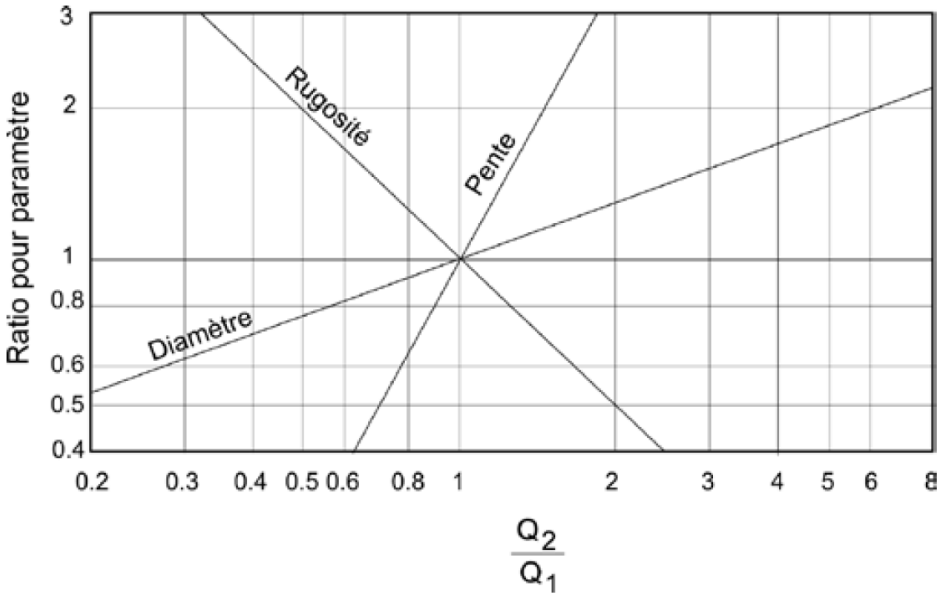
4. Validation of the model

4.1. Sensitivity analysis

Numerous parameters :

which one are the most sensitive / important?





Example for Manning equation:

$$Q = K \cdot S \cdot R^{2/3} \cdot J^{1/2}$$

If diameter double: capacity x 6

If slope double: capacity x 1.4

If roughness double: capacity x 0.5

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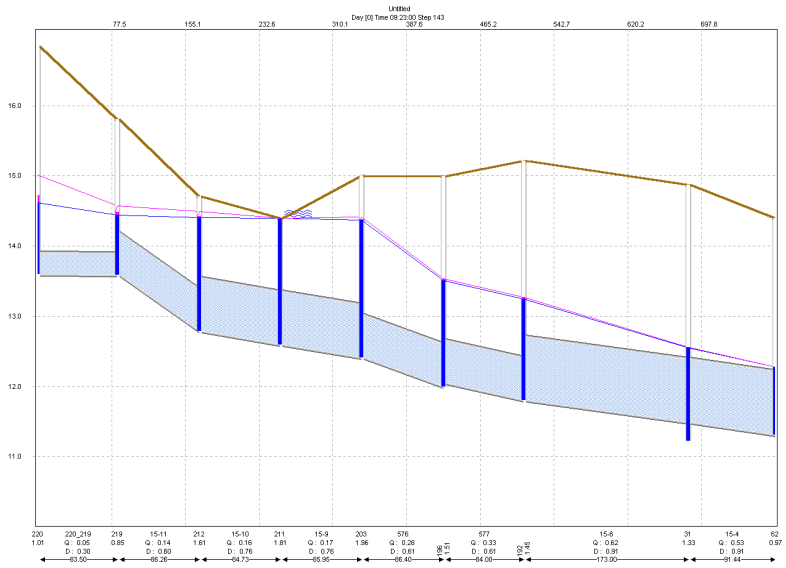
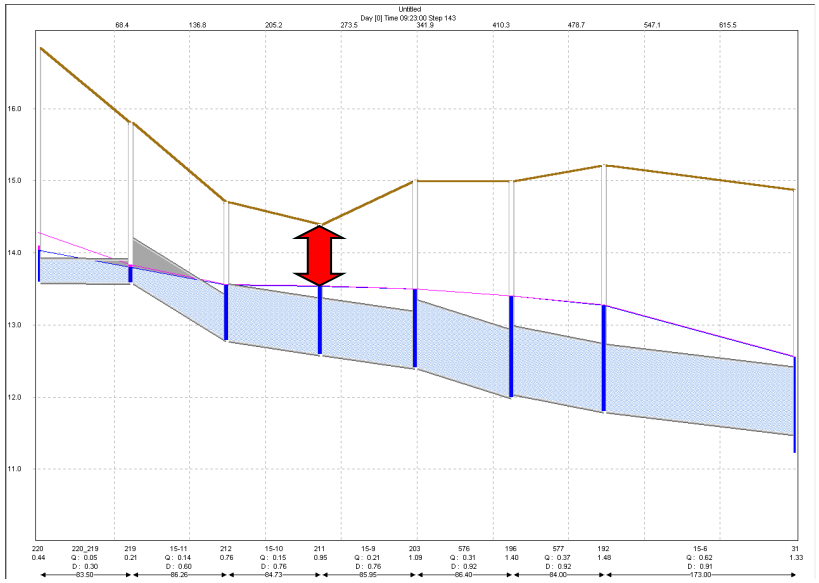


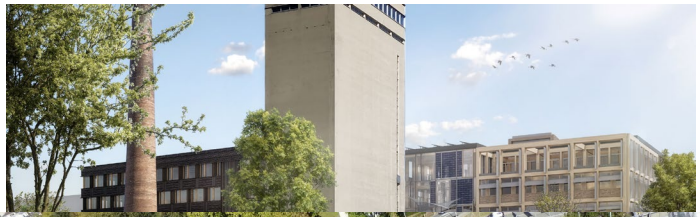
New urban development, rehabilitation of networks, urban densification, flooding controls, pollution controls, infiltration of stormwater, etc.

Example:
Change of sewer diameter to avoid flooding problems



5. Evaluation of future scenarios

- 2D modelling of bluefactory neighborhood
- Management of microtopography to avoid flood problems
- Modelling of local infrastructures



Some experiences with modelling…

The seven sins of urban hydrological models
(From Lee, 1973, « Requiem for large scale models »)

Hypercomprehensivness *(orgueilleux)*
Too high degree of sophistication

Grossness *(grossier)*
Very large model, simplified, not applicable for specific tasks

Hungriness *(gourmand)*
Need of large amount of data

Wrongheadness *(pervers)*
Many limitations and errors are undetected due to the size and complexity of the model

Complicatedness *(tortueux)*
Interactions between, variable, parameters, algorithms… too big even for developers

Mechanicalness *(borné)*
Errors are present in the resolution of algebraic, differential and integral equations

Expensiveness *(cupide)*
Not necessarily in buying it, but in terms of person-hours

Requiem for Large-Scale Models https://doi.org/10.1080/01944367308977851
Forty Years after Lee's Requiem: Are We beyond the Seven Sins? DOI:10.1068/b4103c

Some experiences with modelling…

- Try the simplest one
- Boundary conditions !
- Pollution model: impossible to validate a deterministic model ?
- No modelling activities without data for validation !
- Be very strict in the validation / scenarios modelling steps: a lot of files will be generated
- Always conduct a sensitivity analysis
- Long-term simulation, no single event
- Different scales, different models
- … it's just a tool !