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Imperfect data and hydraulic modelling of urban drainage networks

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The logo for CROQUIS, with each letter in a different color and a hand-drawn, sketchy style.The logo for ANR (Agence Nationale de la Recherche), with 'anr' in blue and red lowercase letters and a registered trademark symbol.

ECSQARU 2023

The 17th European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty

Imperfect data and hydraulic modelling of urban drainage networks

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT DRAINAGE WATER NETWORKS BUT WERE AFRAID TO ASK

Carole Delenne, in collaboration with: Yassine Belghaddar, Nanée Chahinian ... and many others !



Le Cycle Naturel de l'eau

(Le grand cycle)

Natural Water Cycle



Flood Risk

▶ Risk = combination of hazards and issues

▶ Floods from 1995 to 2015*:

▶ 2,3 billion people affected

▶ 157000 victims

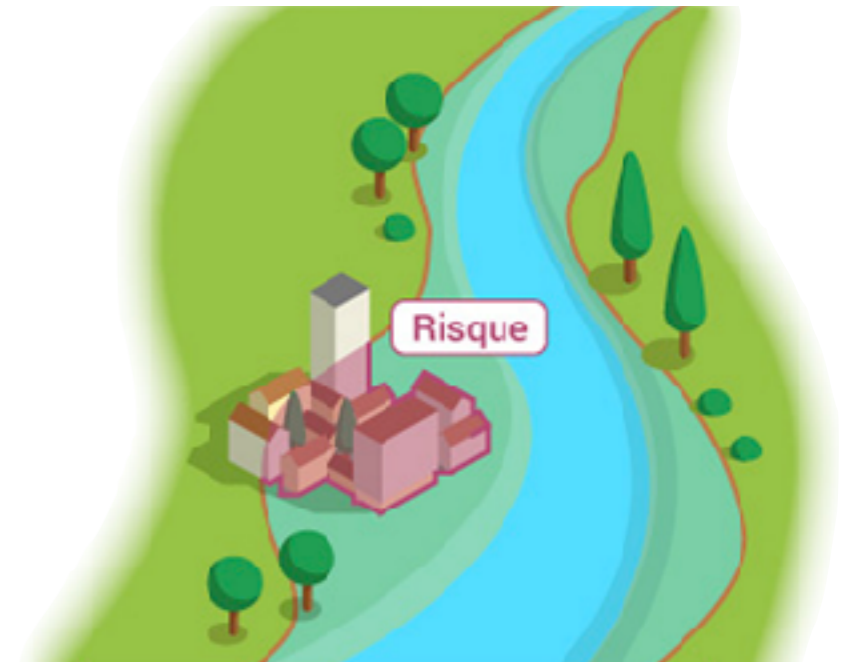
*United Nations report “The Human Cost of Weather Related disasters”, 2015



Hazard: river overflow in the major bed



Issues: people, economical activities...

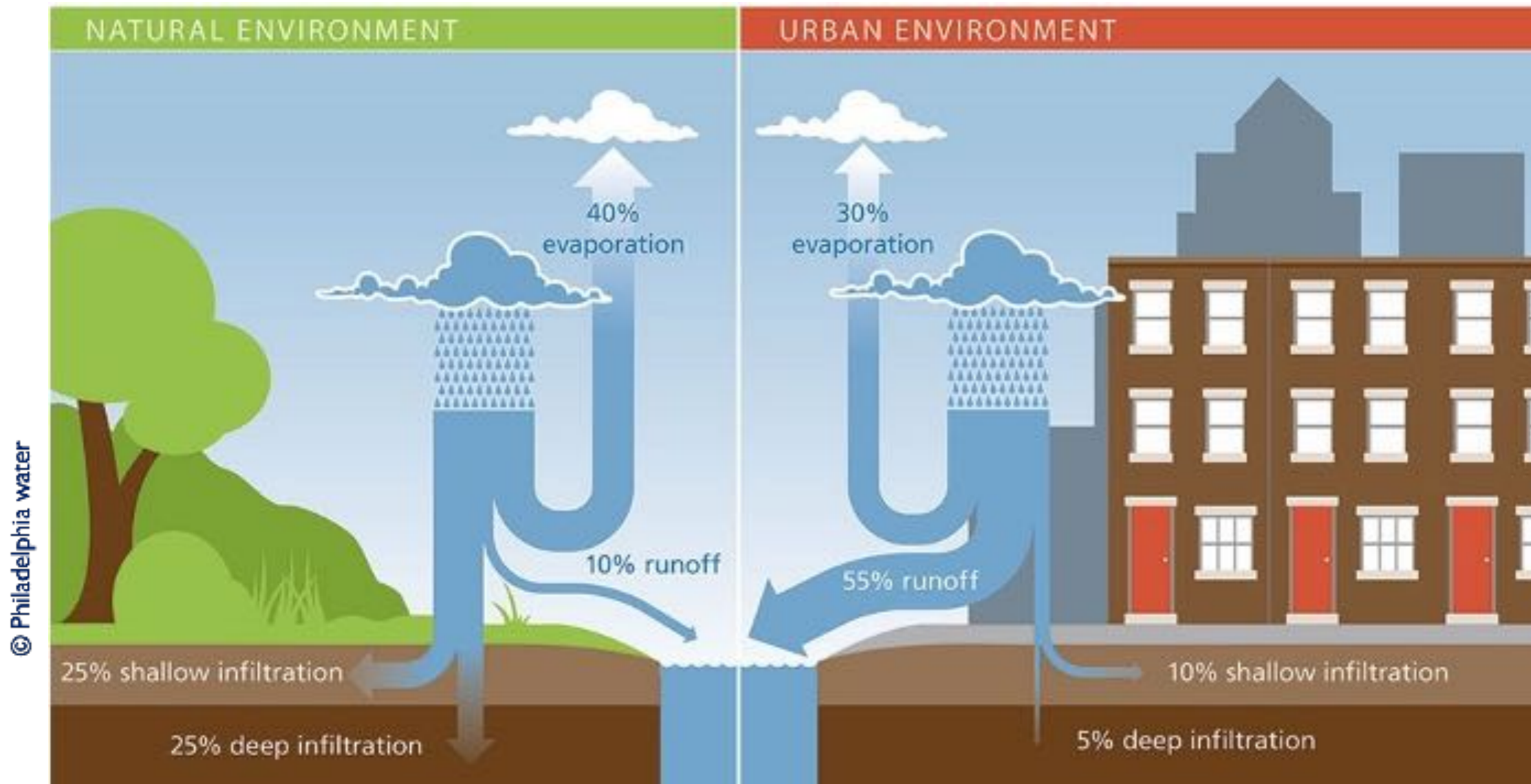


risk: flood of severity depending on the hazard (extent of the flood) and the issue (vulnerability)

Adapted from

“Les inondations : aléa, enjeu, risque” © Agence française pour la biodiversité / Réalisation Matthieu Nivesse (d'après OIEau), 2018

Natural vs Urban Environments

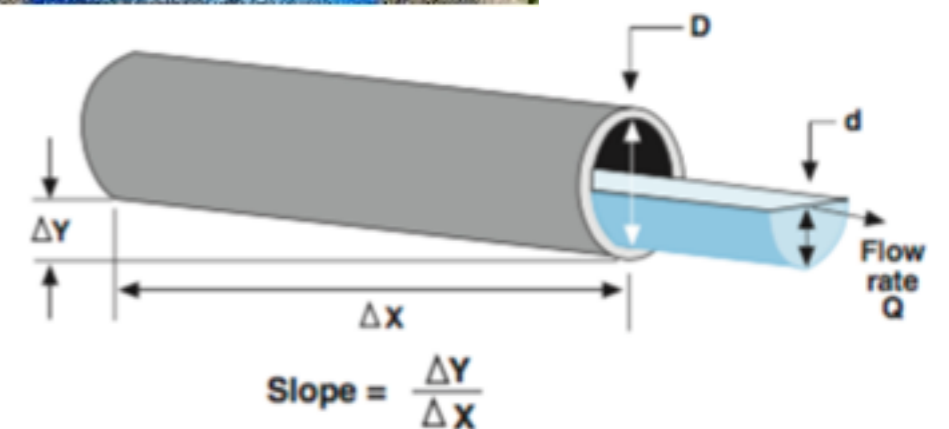
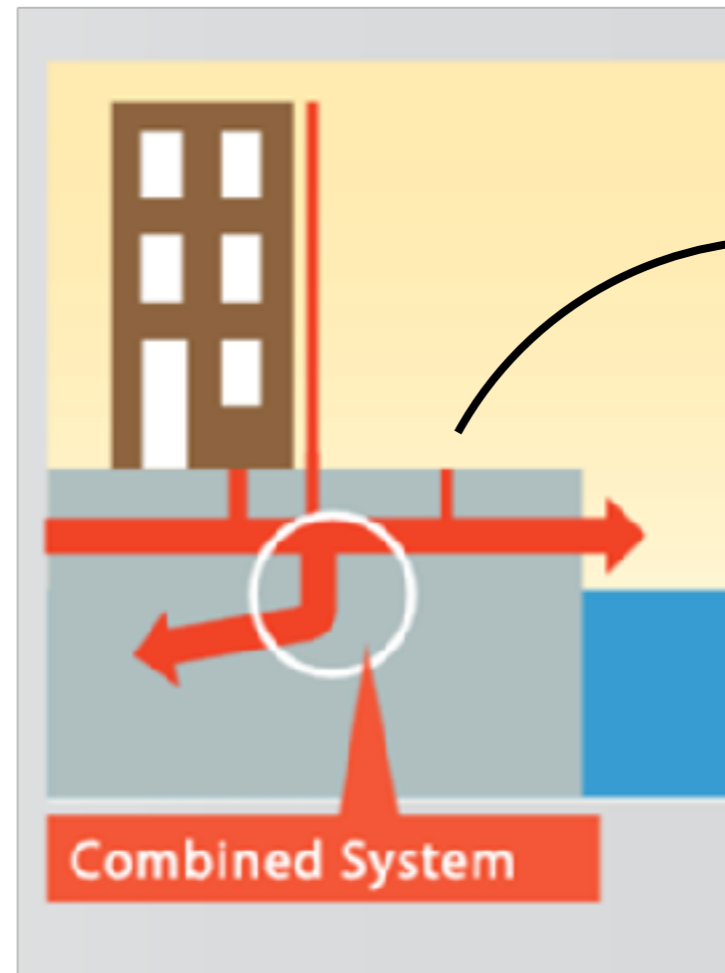
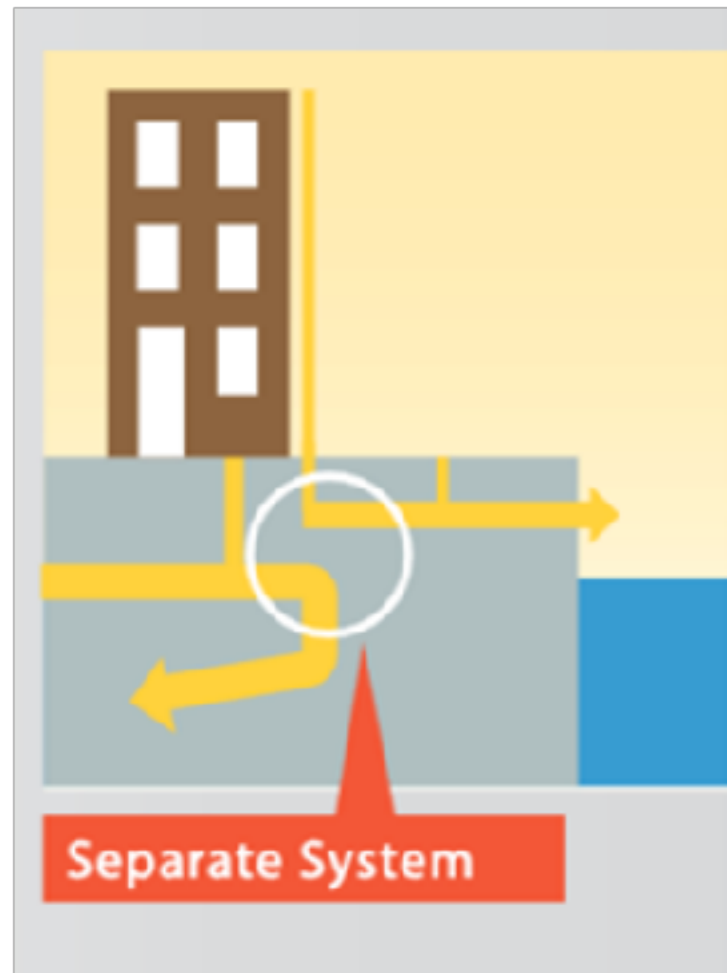


Urban water Networks:

- ▶ Channels and canalised rivers
- ▶ Drainage: wastewater / stormwater
- ▶ (Water supply)



Stormwater and wastewater networks



- ▶ Generated and planned by man
- ▶ Follows roads and ditches without loops (branched networks)
- ▶ Transport water from built areas to treatment plants or river/sea
- ▶ Closed conducts or open channels but mostly free surface flows
-> gravity flow (few pumps)

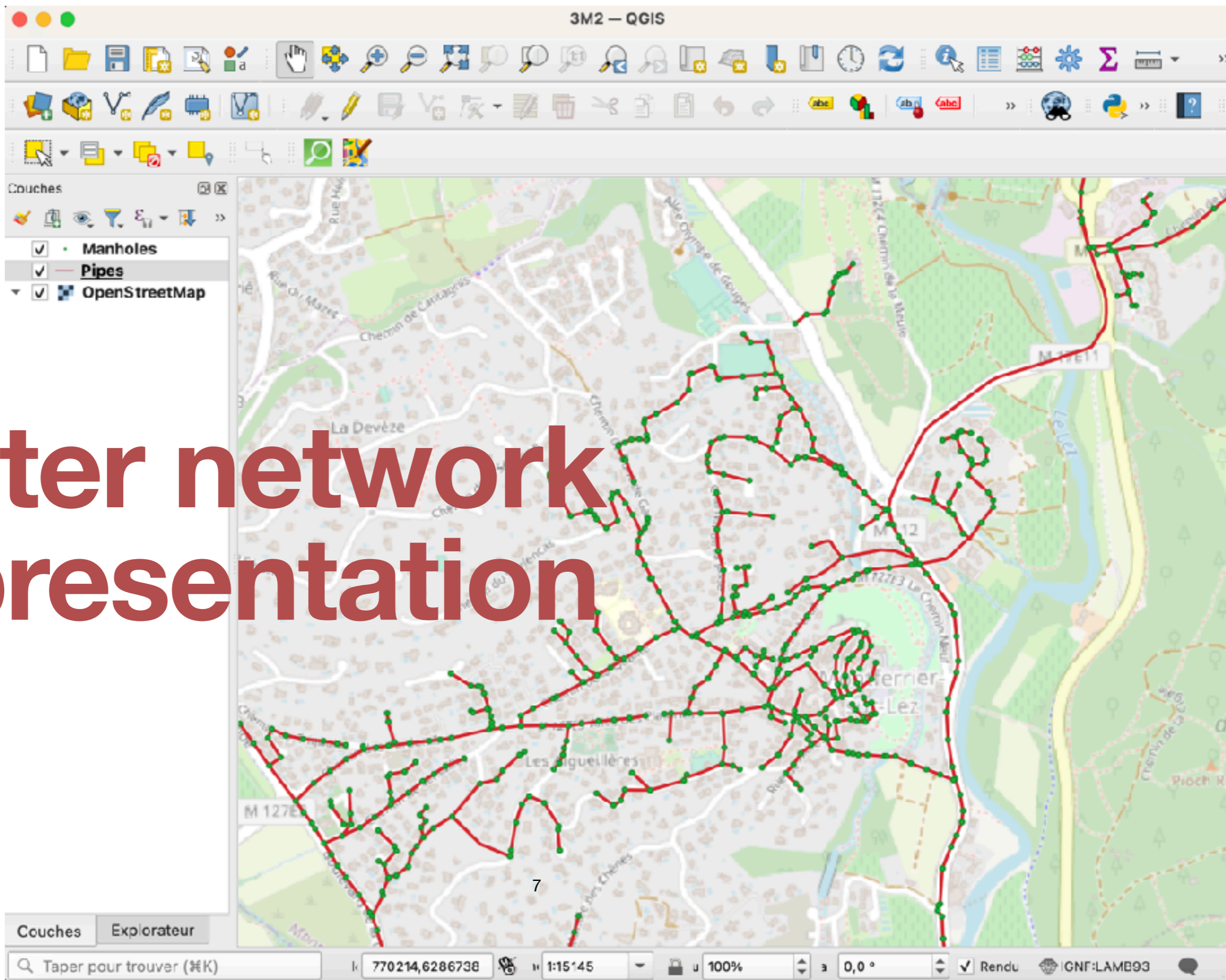
Urban flood modelling

- ▶ **Drainage networks play a crucial role during urban floods:**
 - ▶ normally acting as collectors
 - ▶ they can overflow downstream when saturated.
- ▶ **Not taken into account in most urban flood models**

whereas:

- ▶ **well established models for free surface flows and**
- ▶ **coupling between free surface and underground network models exists**
- ▶ **But crucial lack of information about drainage network (even in France)**
 - ▶ pieces of information: incomplete, imprecise, and even sometimes contradictory

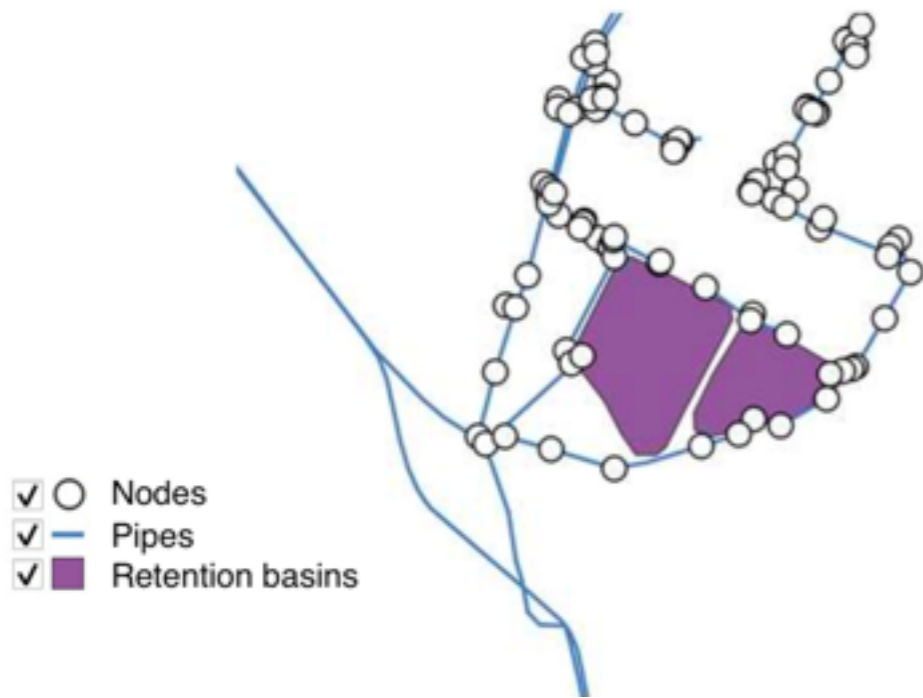
Water network representation



Geographic Information Systems

▶ Drainage networks represented by:

- ▶ Points: network's nodes, *i.e.* manholes, devices...
- ▶ Polylines: network's pipes
- ▶ Polygons: surfaces such as retention basins



▶ Classical format=shapefile .shp

- ▶ Composed of 6 files, including: Geometry as set of vertices (shp), Attribute data file (dbf), Geographical projection (prj)...

▶ Associated attributes

A screenshot of a GIS software interface displaying a table of attributes for a drainage network. The table has columns for DIMENSIONS, ECOUL, FCHAUSSEE, PFIL, PFIADIER, LONGUEUR, MATERIAU, and PENTE. The data is organized into rows, with some rows highlighted in blue. The interface also shows a toolbar and a status bar at the bottom.

	DIMENSIONS	ECOUL	FCHAUSSEE	PFIL	PFIADIER	LONGUEUR	MATERIAU	PENTE
1	200	GRAVITAL...	999.0000...	999.00...	999.00...	28.00000...	INCONNU	0.00000...
2	999	GRAVITAL...	999.0000...	999.00...	999.00...	53.20999...	INCONNU	-17.5888...
3	150	GRAVITAL...	999.0000...	999.00...	999.00...	27.50000...	INCONNU	0.00000...
4	999	GRAVITAL...	55.02000...	55.108...	999.00...	0.189999...	PVC	115.108...
5	150	GRAVITAL...	58.78000...	57.430...	999.00...	12.80000...		64.7578...
6	300	GRAVITAL...	999.0000...	999.00...	999.00...	80.39999...	INCONNU	0.00000...
7	50	REFOULE...	999.0000...	999.00...	999.00...	199.9000...	INCONNU	0.00000...
8	300	GRAVITAL...	999.0000...	999.00...	999.00...	5.400000...	INCONNU	0.00000...
9	300	GRAVITAL...	999.0000...	999.00...	999.00...	18.59999...	INCONNU	0.00000...
10								
11								
12	1200	GRAVITAL...	999.0000...	999.00...	999.00...	17.79999...	INCONNU	0.00000...
13								
14								
15	200	GRAVITAL...	59.48000...	58.140...	999.00...	91.80000...		0.00000...
16	200	GRAVITAL...	64.01000...	62.289...	62.289...	42.50000...	INCONNU	0.00000...
17	500	GRAVITAL...	999.0000...	999.00...	999.00...	40.79999...	INCONNU	0.00000...

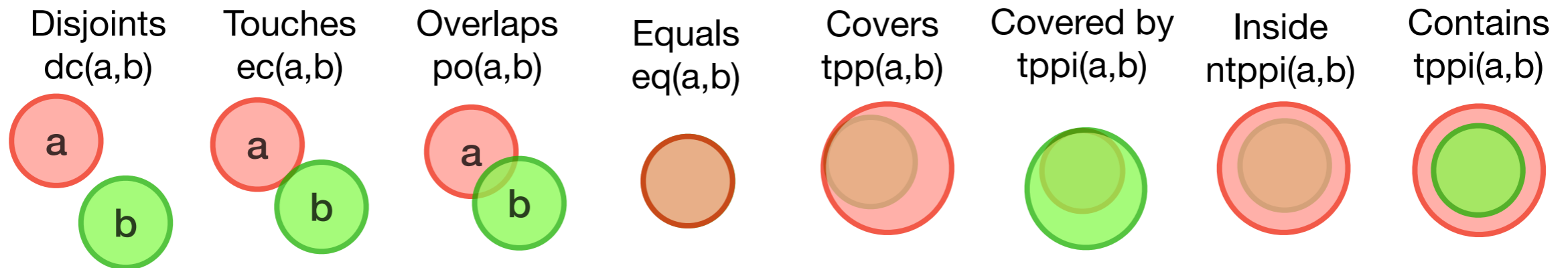
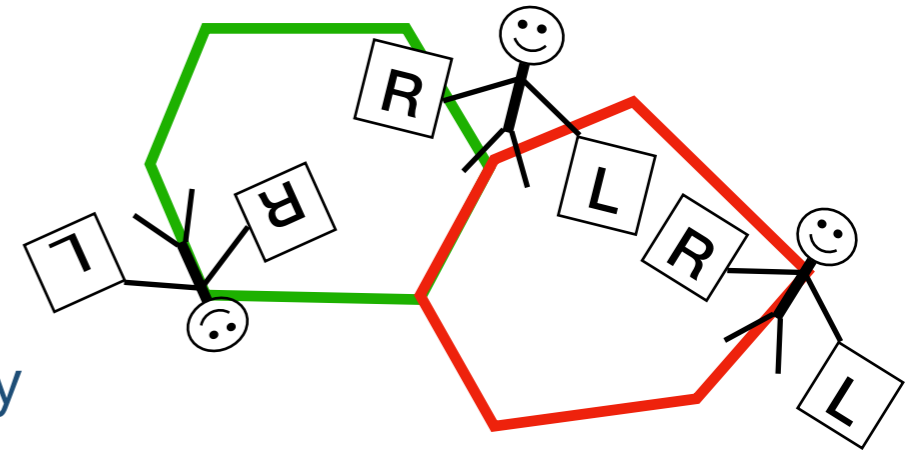
2 main issues:

- 1 shapefile = 1 type of geometry only => e.g. no real connection between nodes and pipes
- Attributes: missing, false, contradictory...

Geographic Information Systems

Topology not displayed directly but may be built:

- ▶ Lines: “From” and “To” nodes for connectivity
- ▶ Polygons: “Right” and “left” polygons for adjacency



dc: disconnected, ec: externally connected, po: partially overlapping, eq: equals, ntpi: (non) tangential proper part (inverse)

Network topology

- ▶ often not reported in stormwater/sewer open access data sources
- ▶ missing data on elevation/slope renders it difficult to infer

Some attempts to address data limitations

Node and polyline overlays

Duplicate data

Missing attributes and metadata

Approximative geolocalisation

Contradictory data

Multi-format data

...

Wastewater network knowledge

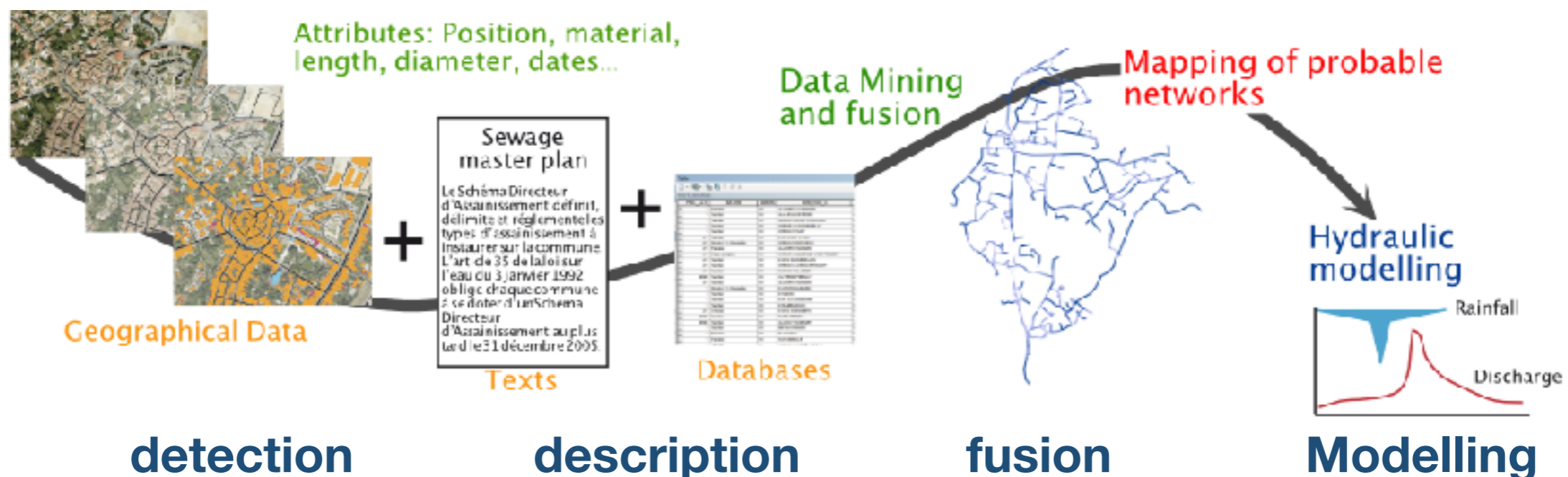
▶ Lack of information prevents from hydraulic modelling

- ▶ Algorithms exist to determine the optimal configuration of the network

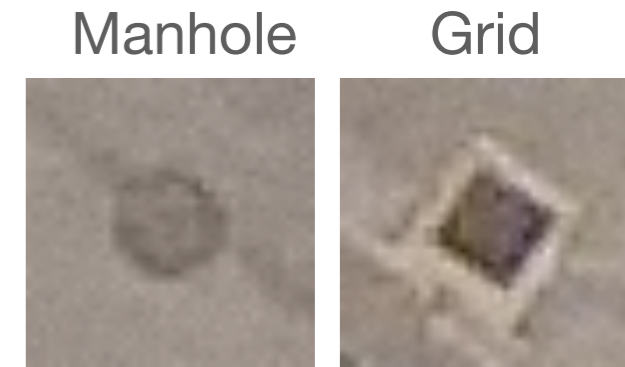
[Walter, 1995; Afshar, 2007 ; Moeini et Afshar, 2012 ; Swamee & Sharma, 2013].

- ▶ But optimal configuration \neq real network

▶ Emergence of a new research theme at HSM through several projects since 2014



Mapping using manhole cover detection

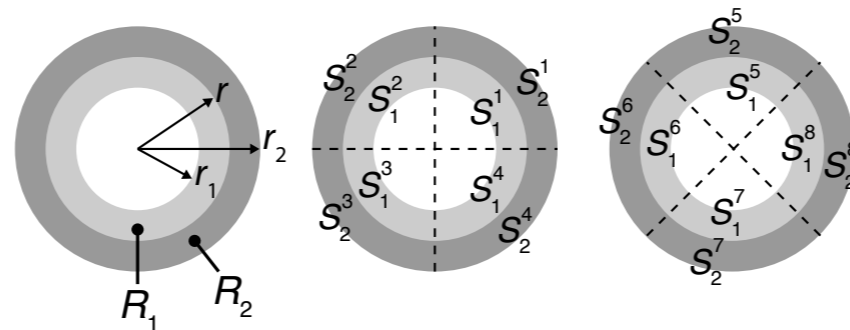


► Local project « THUB » (2014 N. Chahinian)

- Acquisition of 5cm resolution images of Gigean and Prades-Le-Lez

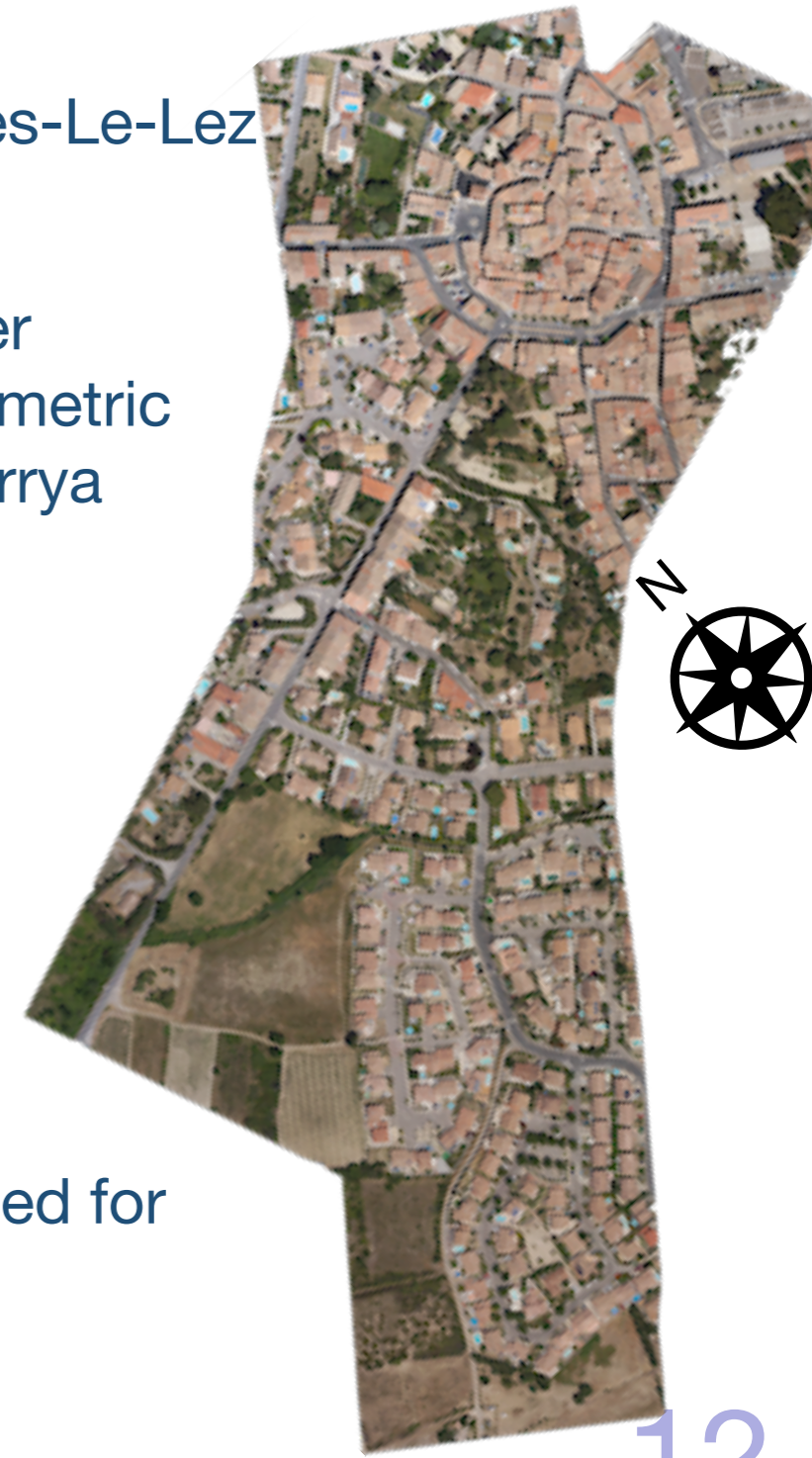
► Method

- pre-treatment: road detection, vegetation and shadow filter
- Manhole cover detection: circular filter based on the radiometric difference between object and its environment (Bhattacharyya coefficient [Niigaki2012])



► Meeting with ICAR team (LIRMM):

- Comparison with a learning-based method (SVM) developed for grave detection (Pasquet et al., 2015 JURSE)

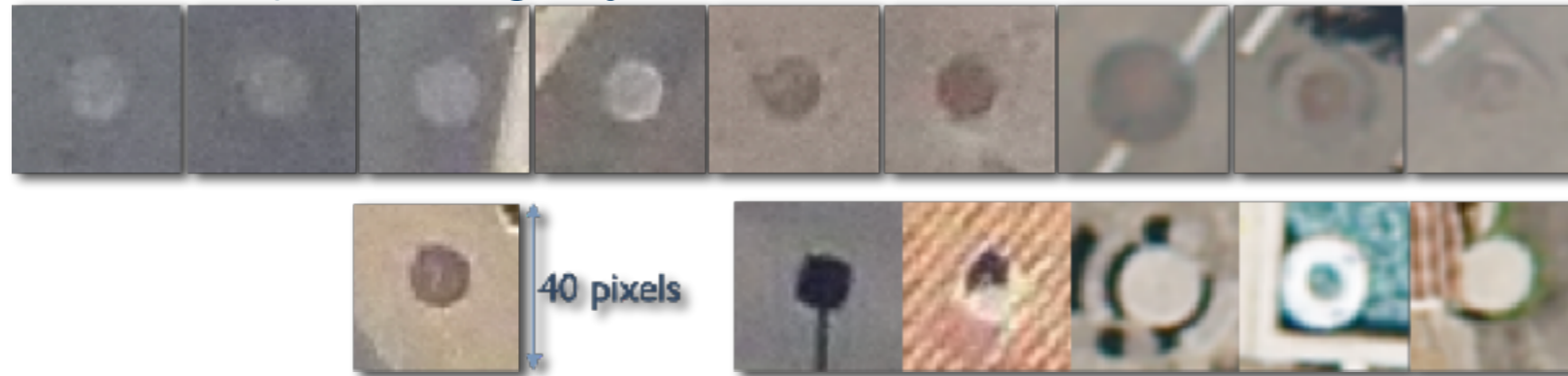


Cart'Eaux project

Chercheur d'avenir 2015 (HSM, LIRMM + LISAH and TETIS)

Difficulties of manhole cover detection

- ▶ small objects, slightly contrasted, confusions



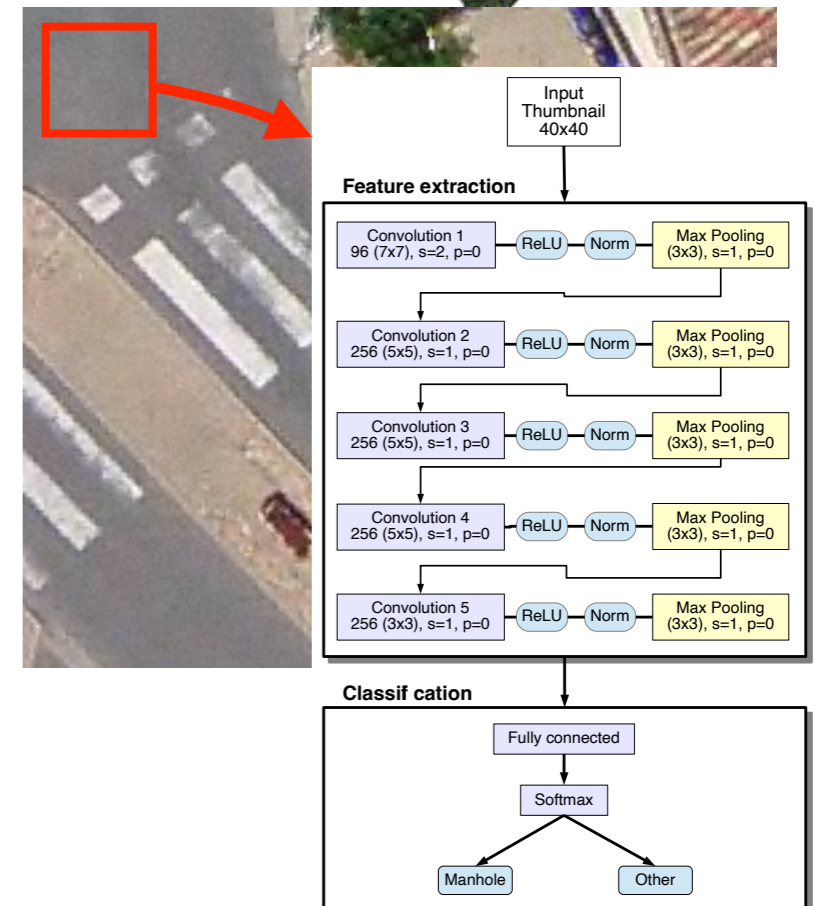
Deep Learning

- ▶ Learning database:

- Prades le Lez: 5cm resolution images in natural colours (RGB)
- Only 605 covers => database augmentation (env 20 000 covers and 50 0000 others)

- ▶ AlexNet:

- Convolutional Neural Network CNN
- Parameters adaptation to small objects
- 5 layers
- 40x40 sliding window over the whole image (4 pixels step)



Manhole cover detection: Validation

▶ Gigean's image: 100 covers

▶ Comparison **detection** / **truth**:
a=%common surface

- ▶ True Positive (TP): $a > 50\%$
- ▶ False Positive (FP): $a \leq 50\%$
- ▶ False Negative (FN): non detected cover



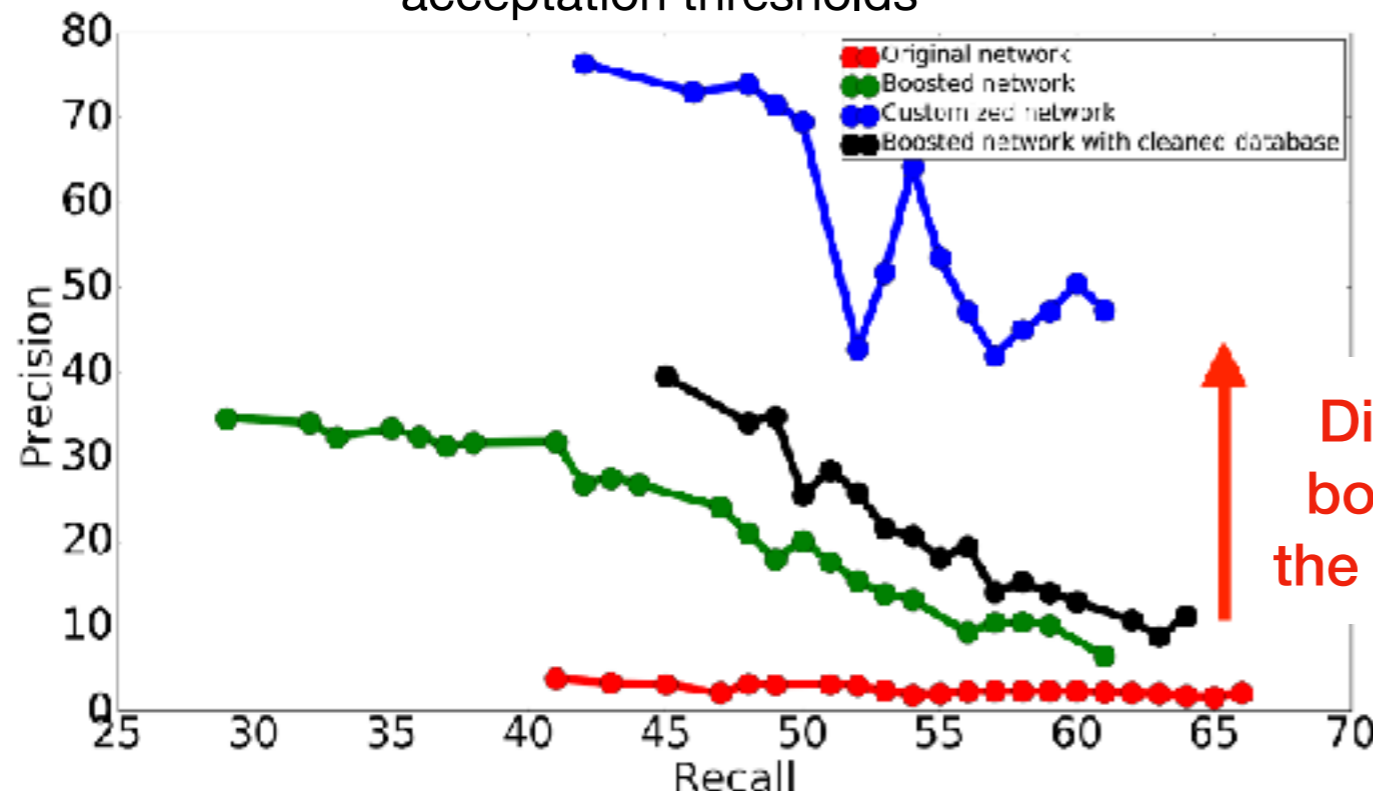
$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

Total detected

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

Total true

ROC curve: precision vs recall for different acceptance thresholds



Different boosts of the network

Still lots of False Positives

- ▶ Best rate of detection with threshold of 0.26
- ▶ Recall = 60% — Precision = 47%
- ▶ Perspective: check the presence of manhole cover on streetview

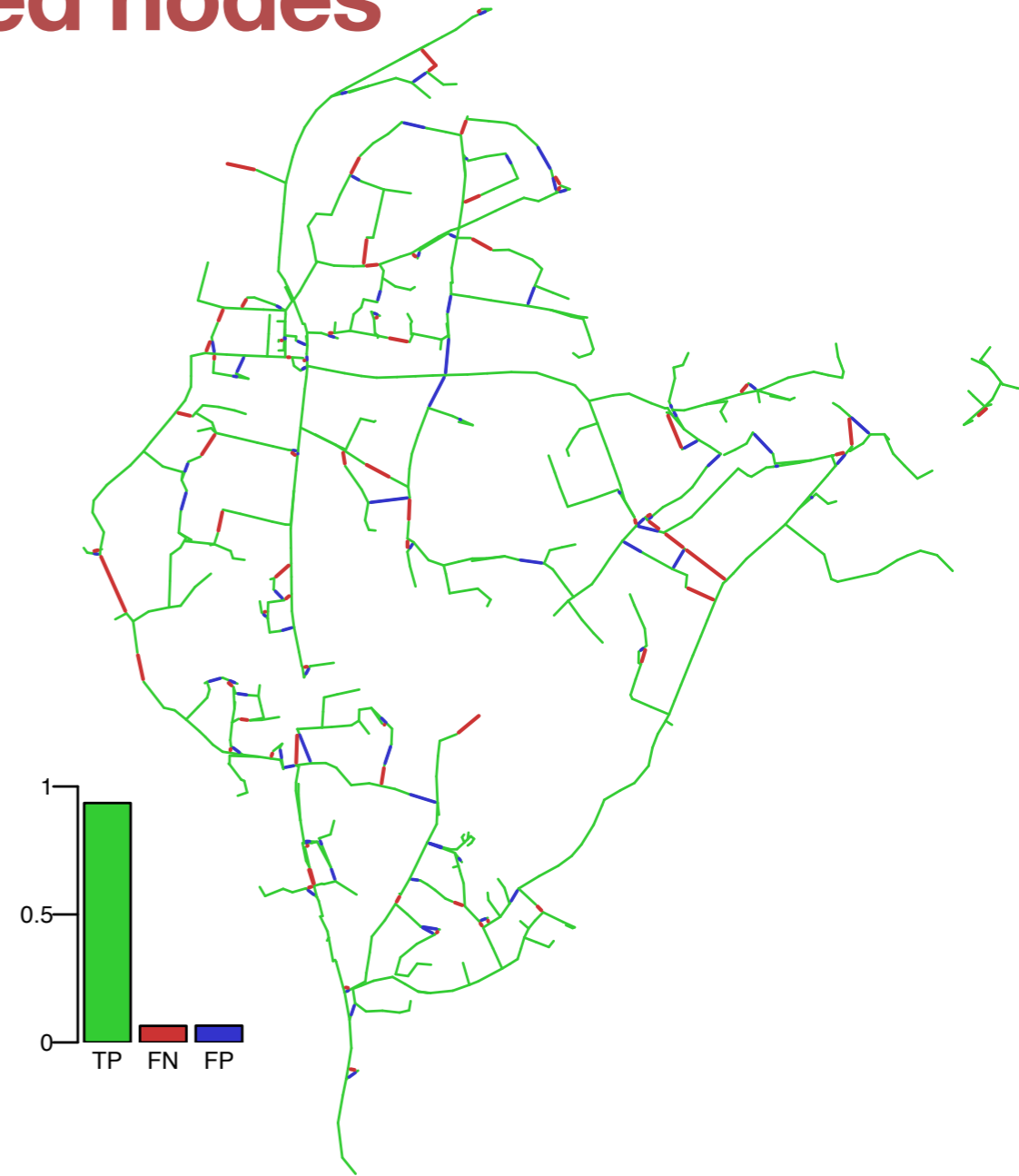
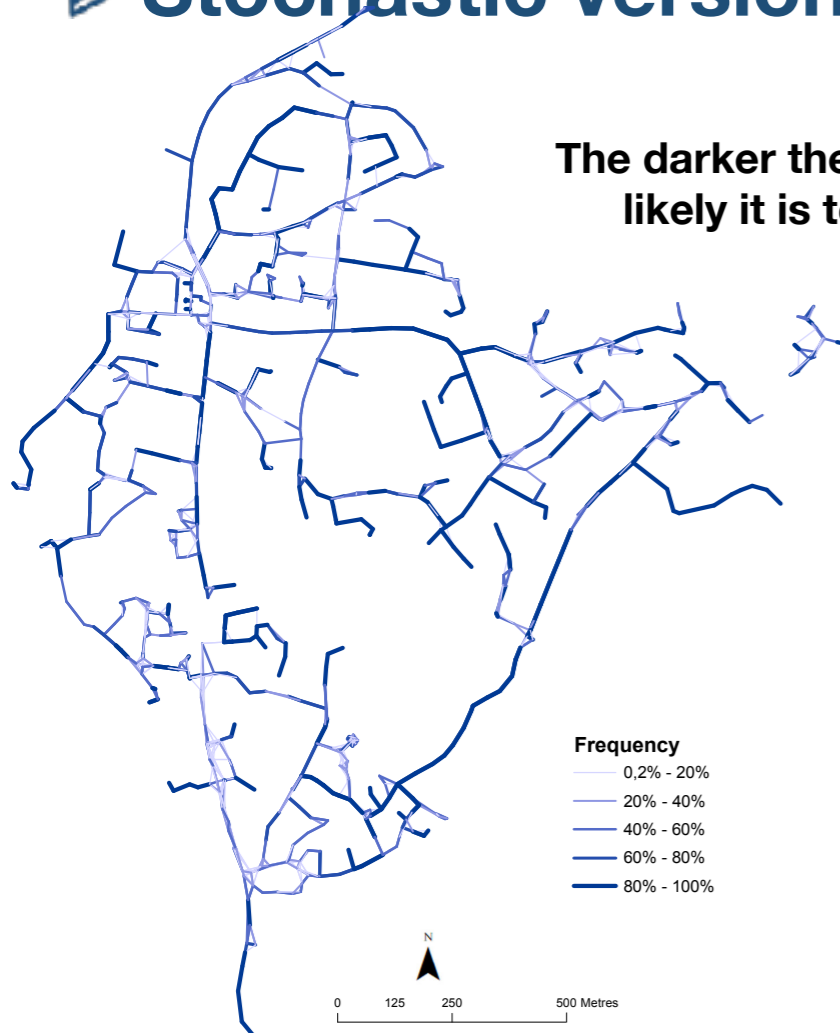


Network mapping from detected nodes

▶ Based on “business” cost functions

- ▶ slope
- ▶ length
- ▶ angle between pipes
- ▶ + penaltys if a pipe goes out the street or through buildings

▶ Stochastic version



N. Chahinian et al. CEUS, 2019 <hal-02275903>.
B. Commandre et al., ICUD Conference on Urban Drainage, 2017.

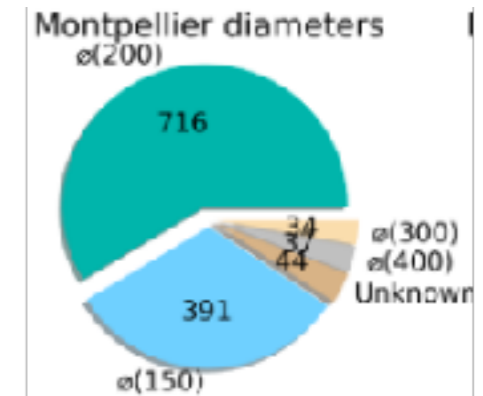
But the pipes' characteristics are still unknown!

Pipes characteristics

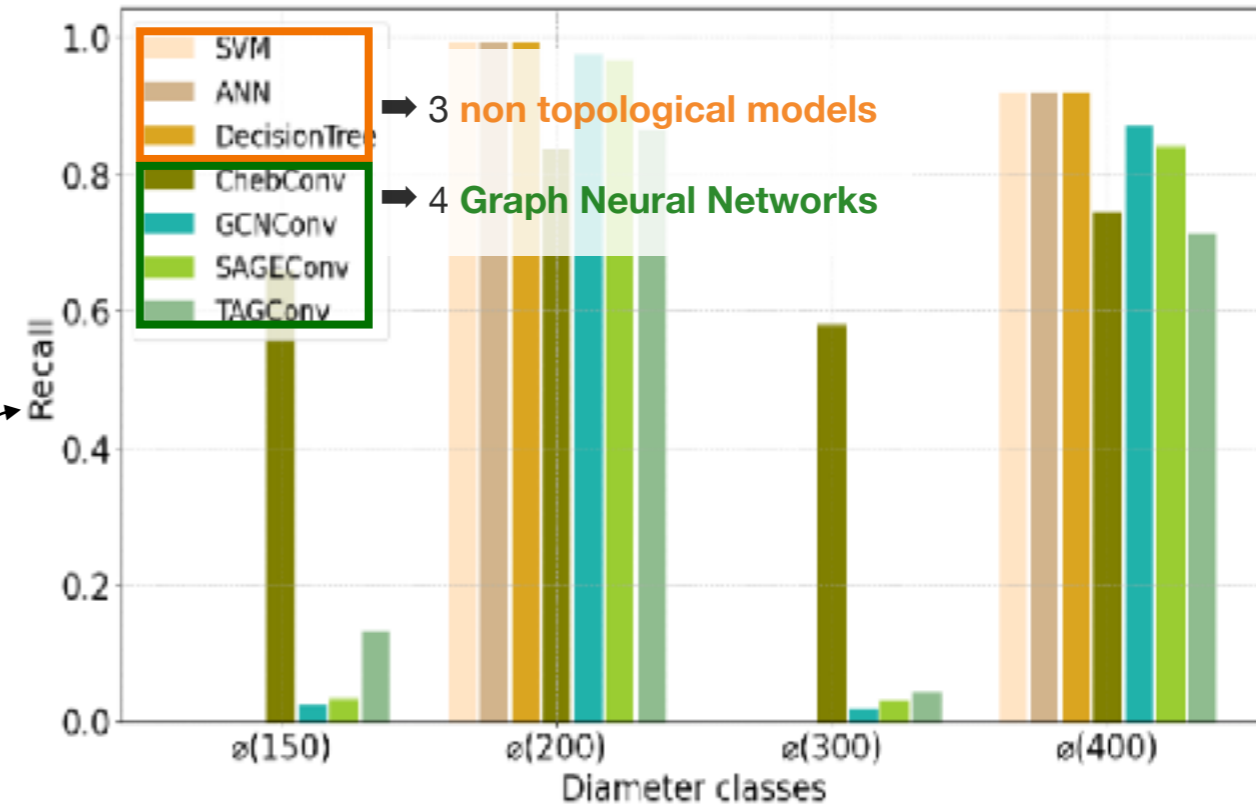
► CIFRE PhD Y. Belghaddar
(Berger-Levrault, UM, USMBA)
“*Data fusion for urban networks mapping*”

► 3 Axes

- Implementation of a generic model for merging multi-source data
 - images, texts, tabular databases...
- Geographical data fusion
 - Use of belief theory for element matching from different maps
- Missing data completion
 - Use of Graph Neural Networks: Account for network's structure => better prediction of minority classes



Example:
Prediction of missing diameters



Recall for each class (TP/NbClass)
30% of the database for learning, 70% for the test.

Pipes Characteristics: MeDo Project

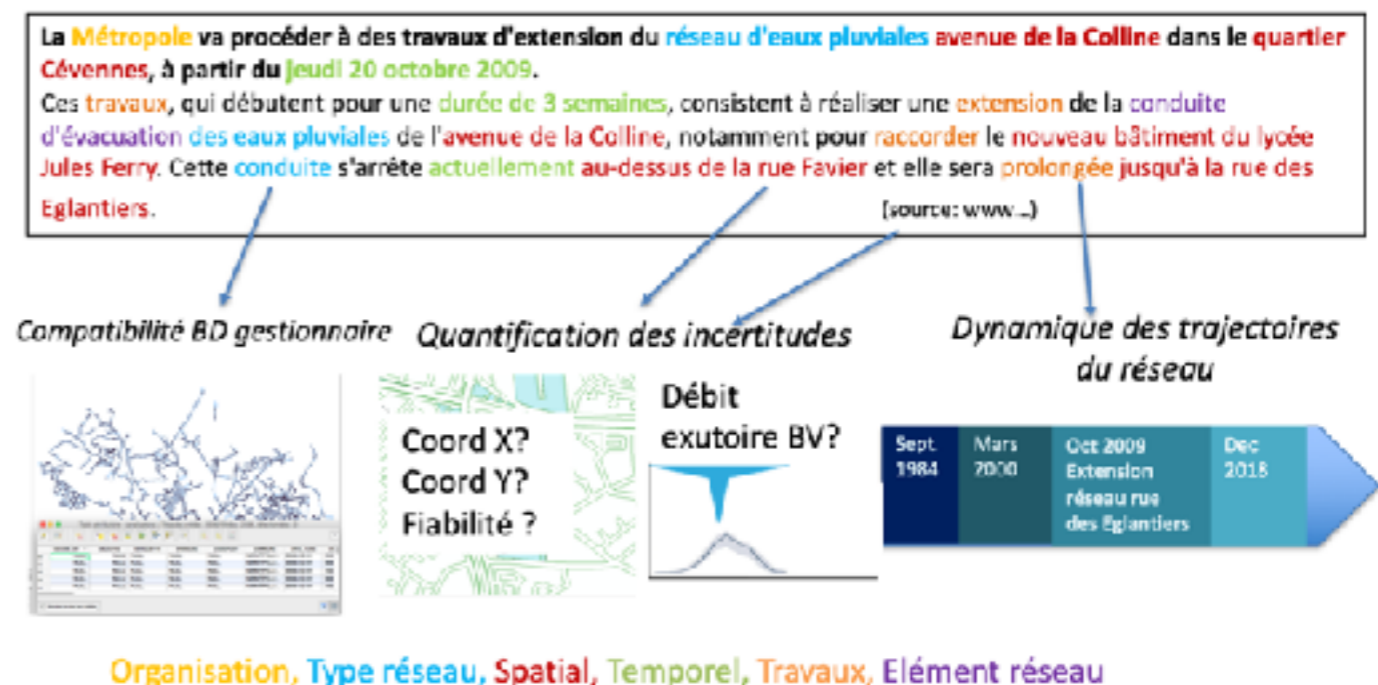
Megadata, Linked Data and Data Mining for Wastewater Networks

► Objectives:

- Take advantage of web megadata to provide network geometry and "ancillary" data that can be used by network managers.
- Creation of a corpus relating to the history of the network
- Keep a record of breakdowns and work carried out on the network

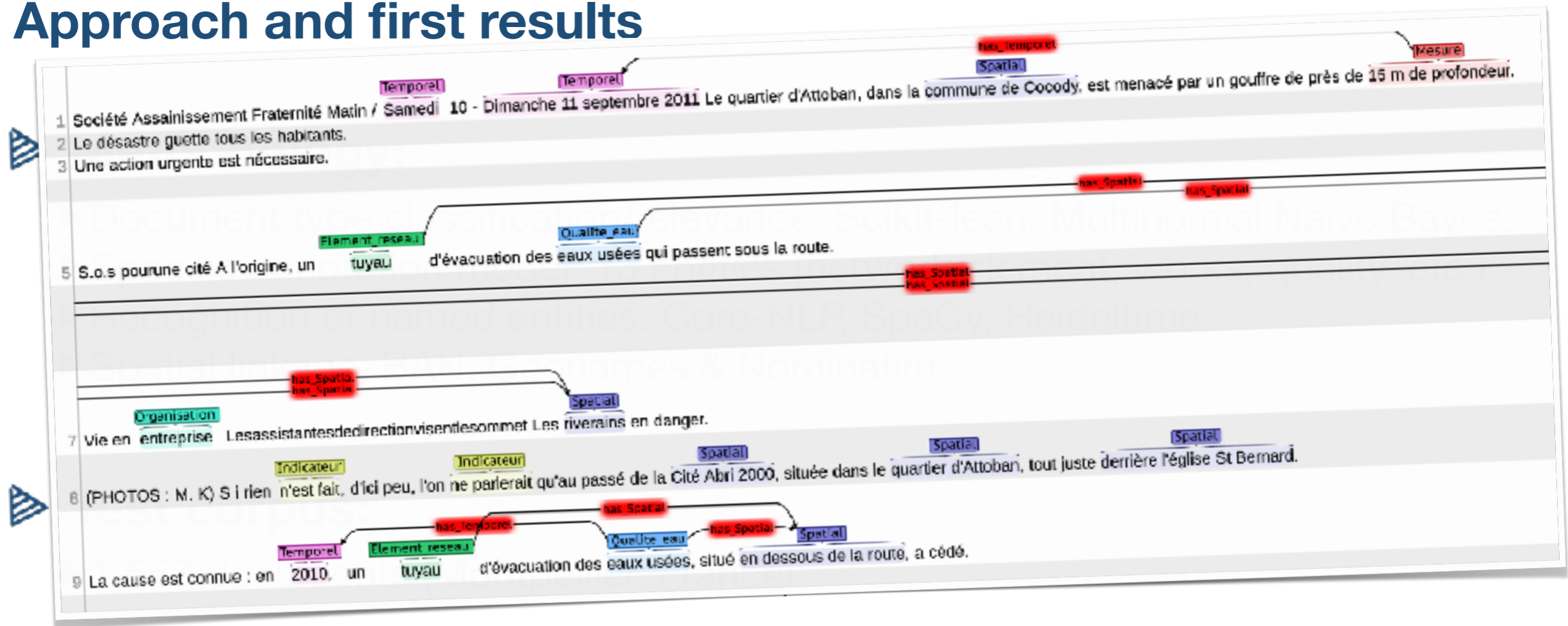
► Challenges

- Translate unstructured textual information into quantitative data and structured knowledge of the network.
- Transform approximate information into uncertain knowledge.



MeDo Project

Approach and first results



First results

- ▶ Good classification performance (F-score > 0.90)
- ▶ Detects certain entities e.g. works, network elements (F-score > 0.63).
- ▶ Very little quantitative data (geometry, flow rate)



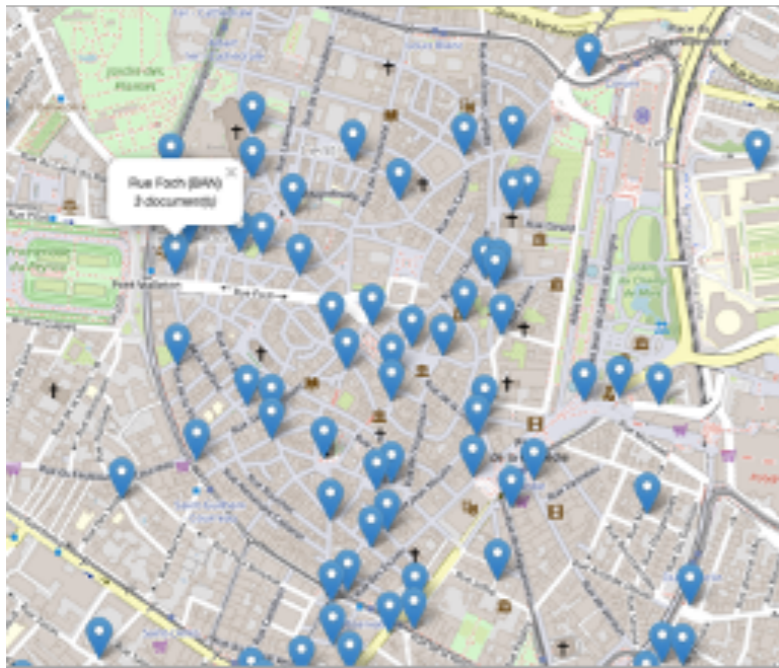
▶ **STARWARS: further work and applications in French, English and Italian**

MeDo Project

Transform information into data

► Objective: Integrate information into a geographic database

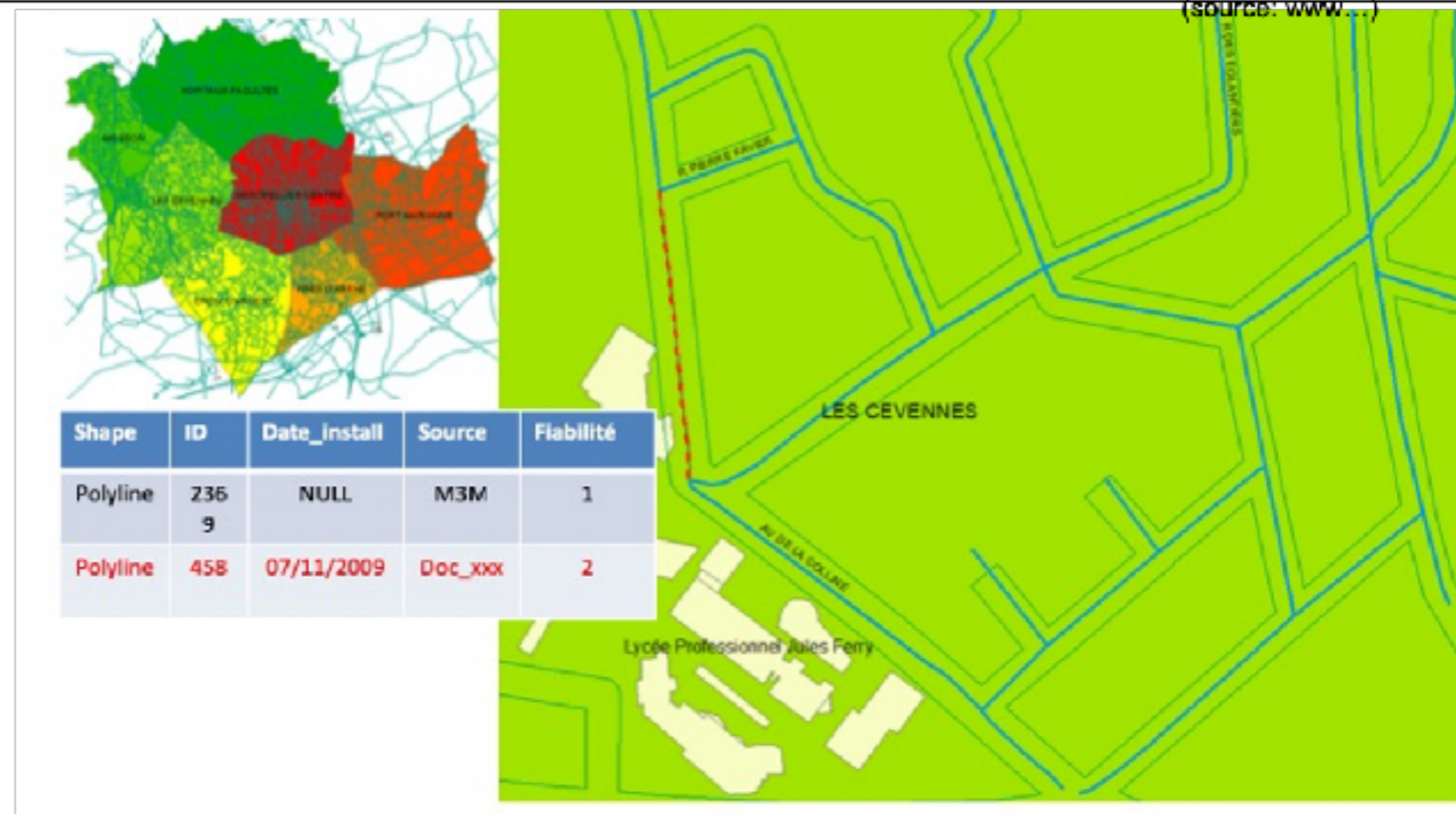
Demo on: http://webmedo.msem.univ-montp2.fr/?page_id=12



La **Métropole** va procéder à des **travaux d'extension** du **réseau d'eaux pluviales** **avenue de la Colline** dans le **quartier Cévennes**, à partir du **jeudi 20 octobre 2009**.

Ces **travaux**, qui débutent pour une **durée de 3 semaines**, consistent à réaliser une **extension** de la **conduite d'évacuation des eaux pluviales** de l'**avenue de la Colline**, notamment pour **raccorder le nouveau bâtiment du lycée Jules Ferry**. Cette **conduite** s'arrête **actuellement au-dessus de la rue Favier** et elle sera **prolongée jusqu'à la rue des Eglantiers**.

(source: www...)



To be continued...

2 Projects lead par Salem Benferhat (CRIL)



▶ ANR CROQUIS:

“Collecting, Representing, cOmpleting, merging and Querying heterogeneous and Uncertain waStewater and stormwater network data”

▶ Partners: Lens (CNRS), I3S/Inria Wimmics, HSM (IRD)

▶ Staff-Exchange STARWARS:

“STormwAteR and WastewAteR networkS heterogeneous data AI-driven management”

▶ Partners: Lens (CNRS, Univ. Artois), Afrique du Sud (Cape Town Univ.), Vietnam (Can Tho Univ.), Maroc (USMBA Fès), Italy (CNR Pise), Montpellier (UM, IRD)

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<https://sites.google.com/view/autumn-school-ia/>

One week left to register !