A method to predict pipe renewal impact on drinking water supply systems water losses

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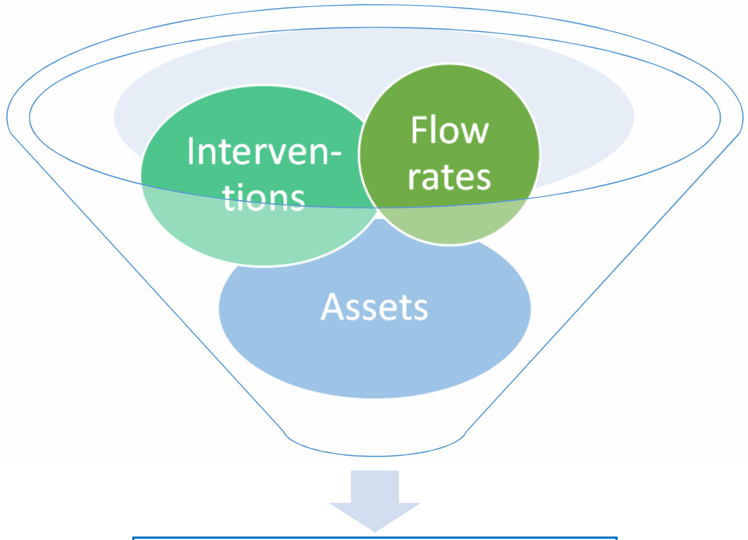
Context and method

Context

- INRAE / Veolia / Vedif research collaboration: "Effectiveness of actions to reduce losses from drinking water networks“
- First axis: Impact of pipes renewal on water losses
- Case study: Syndicat Mixte d’Adduction d’Eau Potable des Eaux de Loire - *Drinking Water Supply Service of "Eaux de Loire"* (EDL DWSS)

Method



Data processing

Method for estimating volumes of leaks associated with interventions

Break prediction model

Assessment of the volume of leakage avoided by a renewal program

Data processing

Meter flows every quarter of an hour

↓

Control of homogeneity and time regularity

↓

Filtering of null, negative or aberrant data

↓

Calculation of DMAs' flows

↓

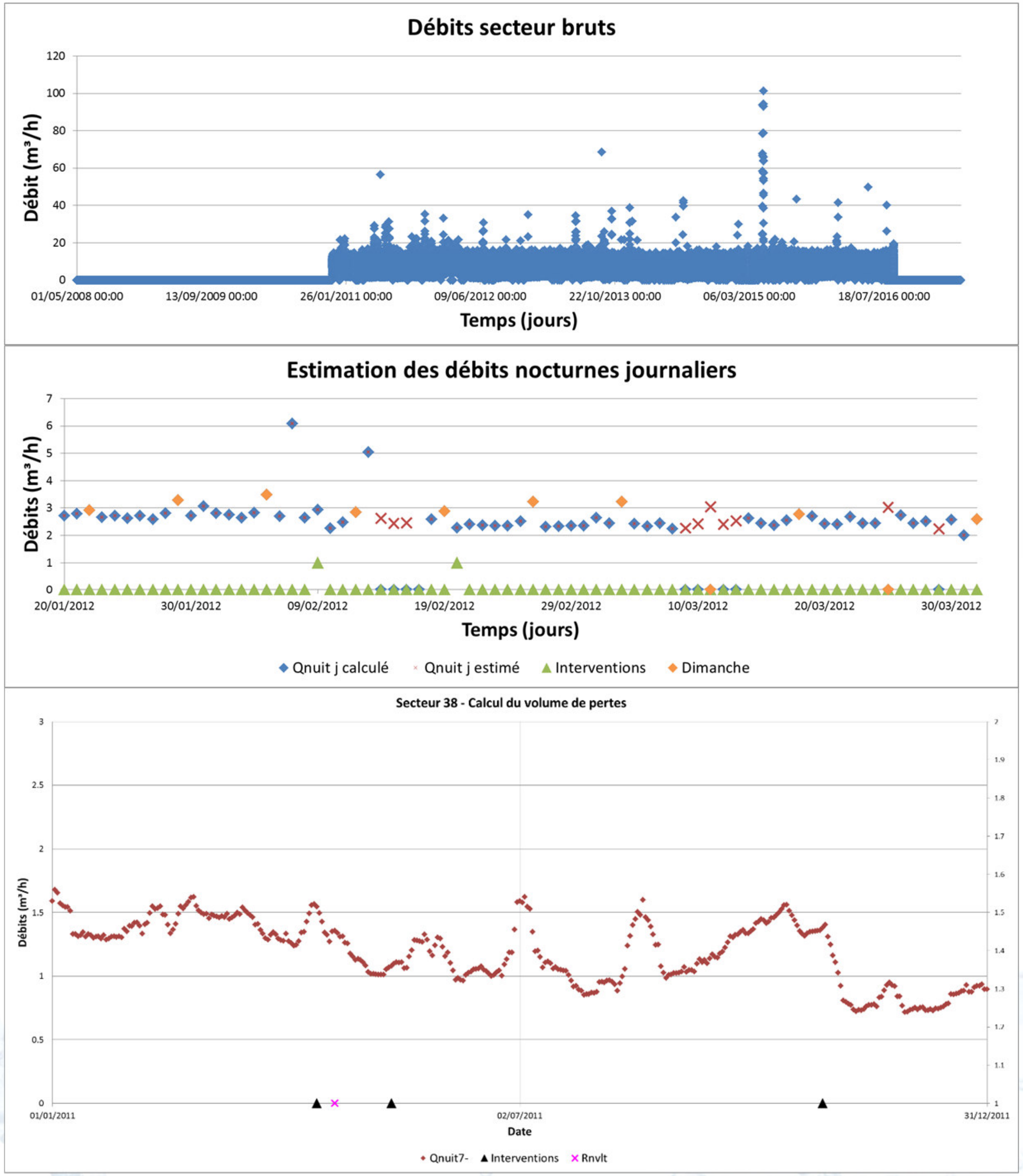
Calculation of daily night flows

↓

Data completion

↓

Calculation of average daily night flows over 7 rolling days



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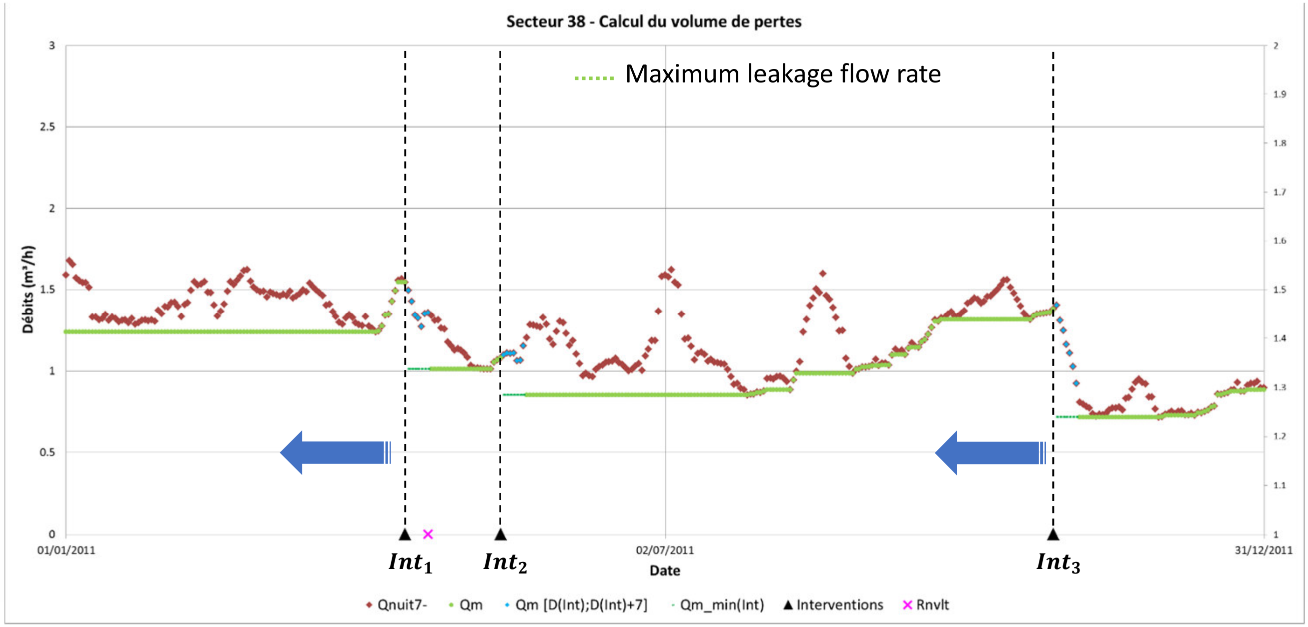
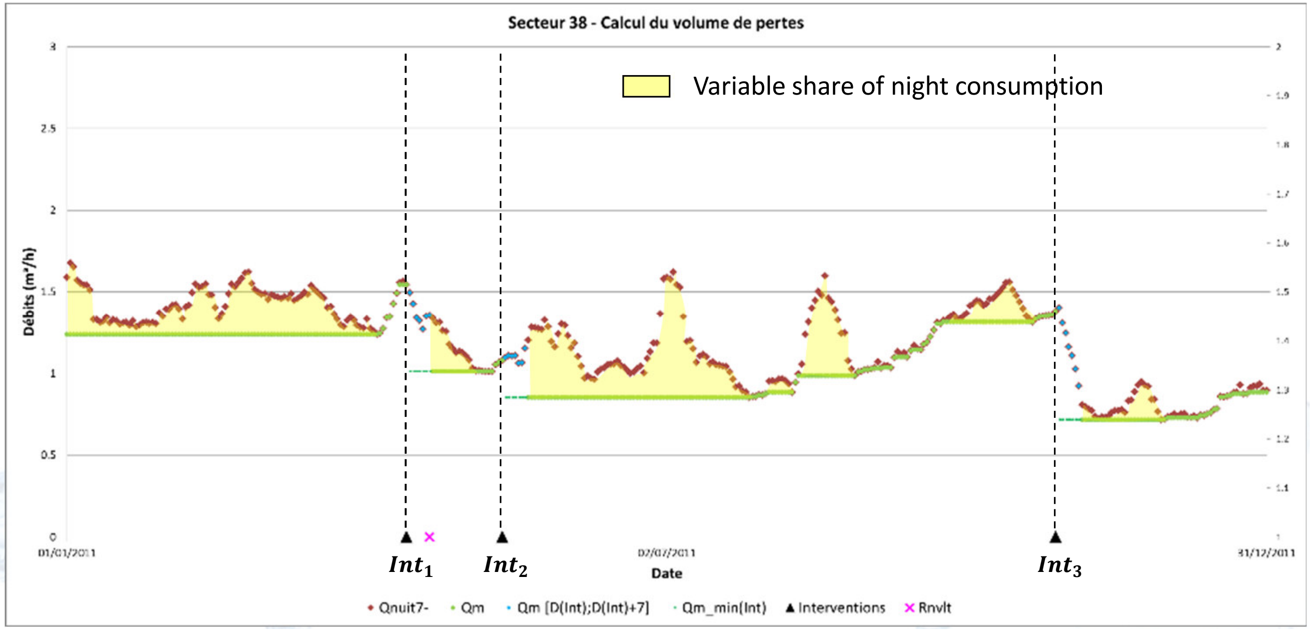
Method for estimating volumes of leaks

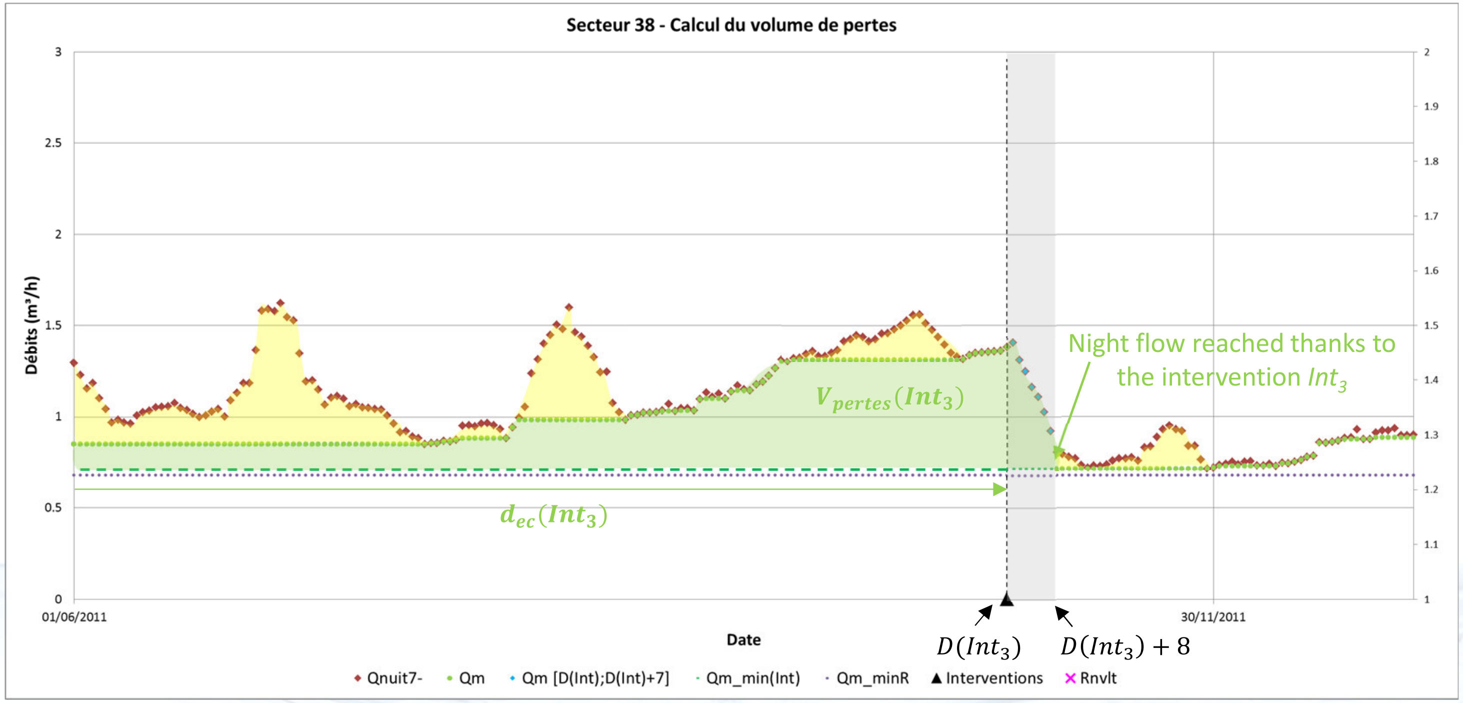
- Strong assumption: The leakage flow rate cannot in any case decrease without intervention i.e. repair or renewal of pipe or connection
- The green line is built going back in time and is, in this way, always decreasing between two interventions
- The volumes between the green and red lines (in yellow) are considered as the variable share of night consumption (this includes leaks on the private parts of connections)





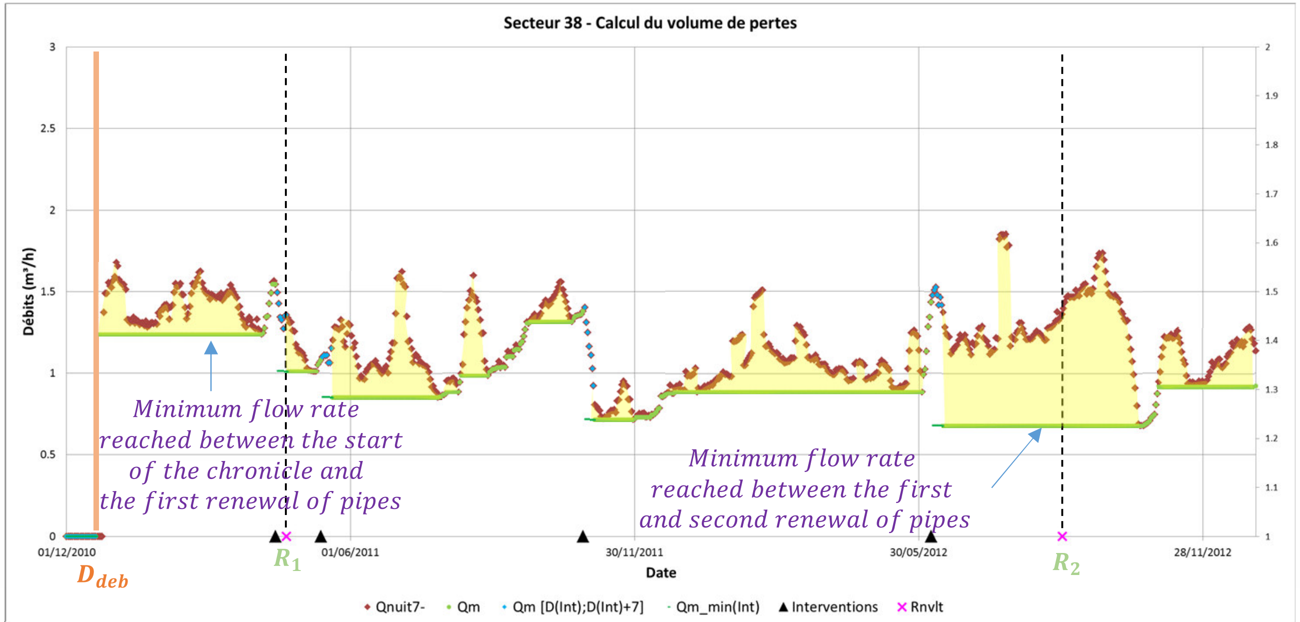
Method for estimating volumes of leaks

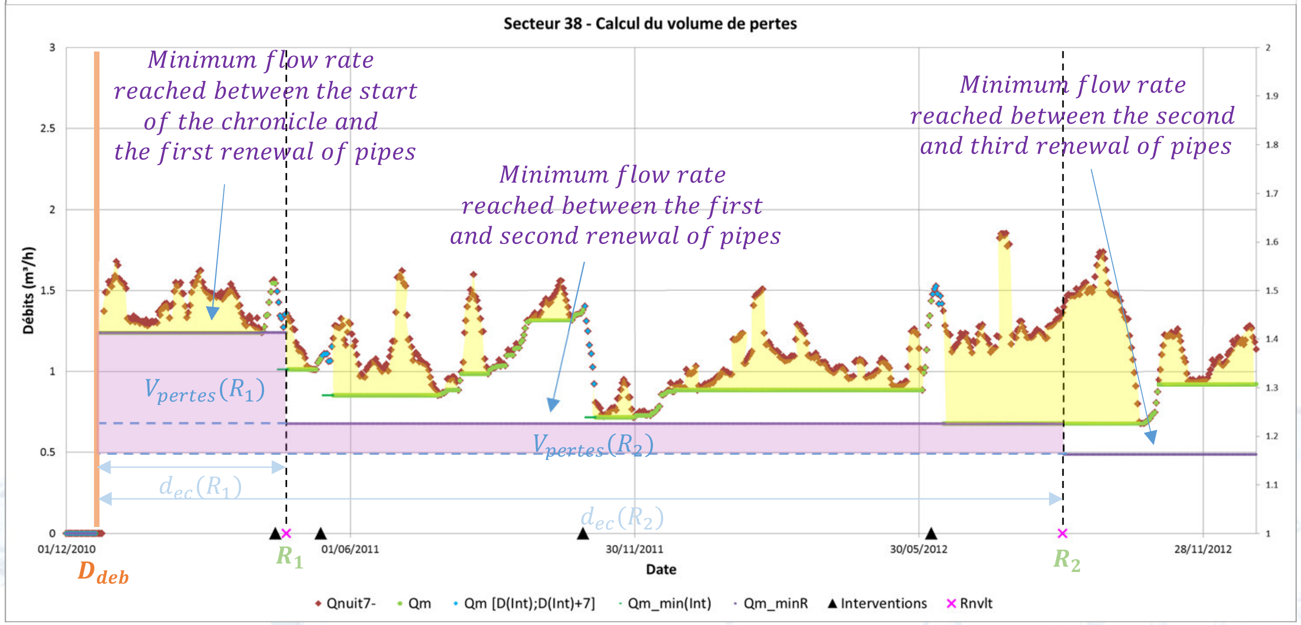
- The volume associated with a repaired leak (in green) is bounded by the green line up to the previous intervention and the straight line corresponding to the minimum of the green line after the repair
- The duration of the leak is determined by looking in the past for the first night flow below the minimum of the green line after the repair



Method for estimating volumes of leaks

- The volume associated with a renewal of pipes (In purple) is bounded by lines associated to the minimum flow rates reached between two successive renewals or between the start of the chronicle and the first renewal





Method for estimating volumes of leaks associated with interventions

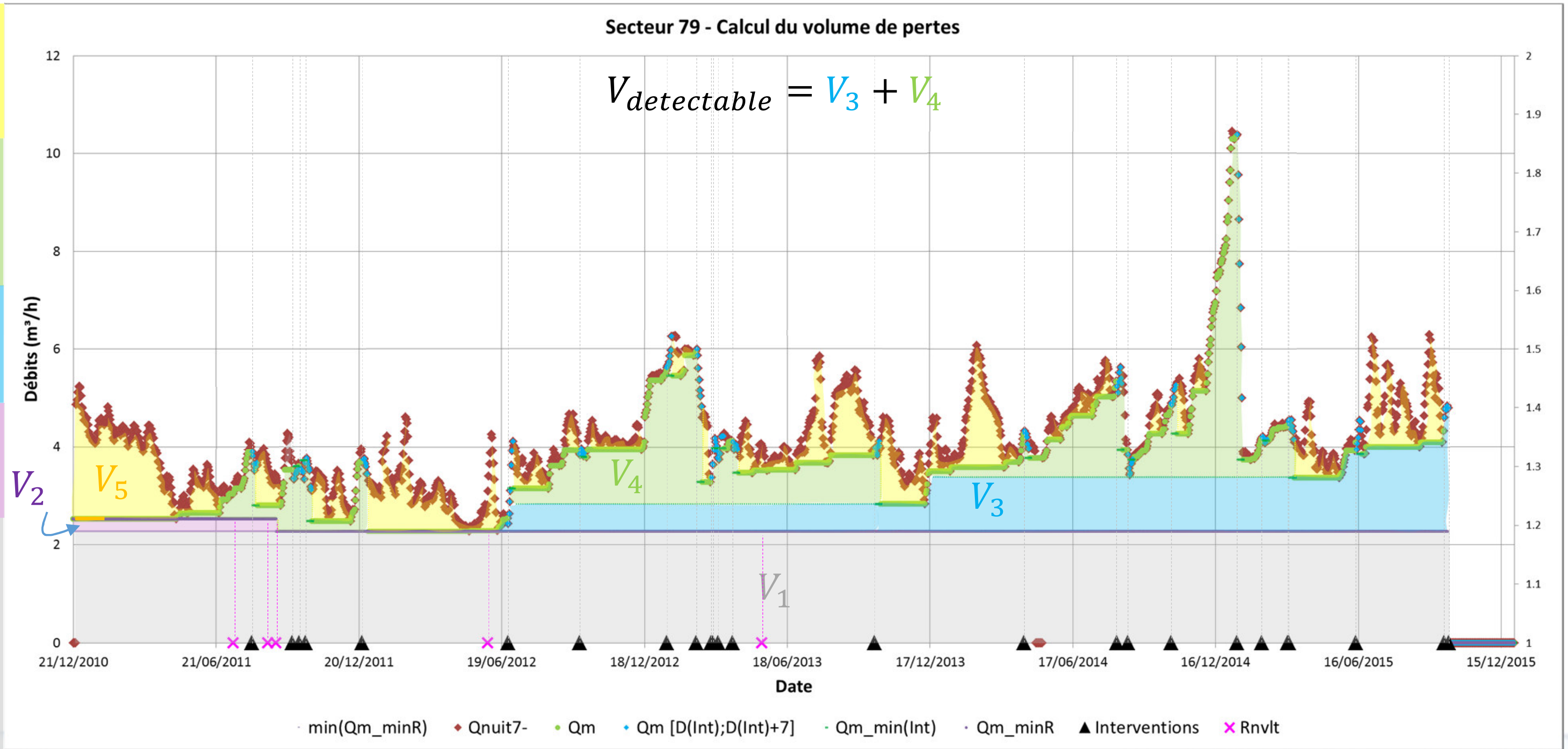
V_5: Marginal consumption

V_4: Detectable lost before repair

V_3: Detectable not detected

V_2: Background lost before renewal

V_1: background night consumption and leakage



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Application to "Eaux de Loire" DWSS

- 30 DMAs totaling 713 kilometers of pipes and 11,700 connections.
- Flow measurements data on interventions available between 2009 and 2015

Summary of average volumes of observed leaks

Support	Matériau	Diameter (mm)	Number	Volume (m³)
Pipes	PVC	< 80	82	**1 141**
		≥ 80	40	**1 366**
	Cast Iron	< 80	56	**1 506**
		≥ 80	58	**1 871**
	Other	All	14	**1 067**
Connections	All	All	274	**1 173**

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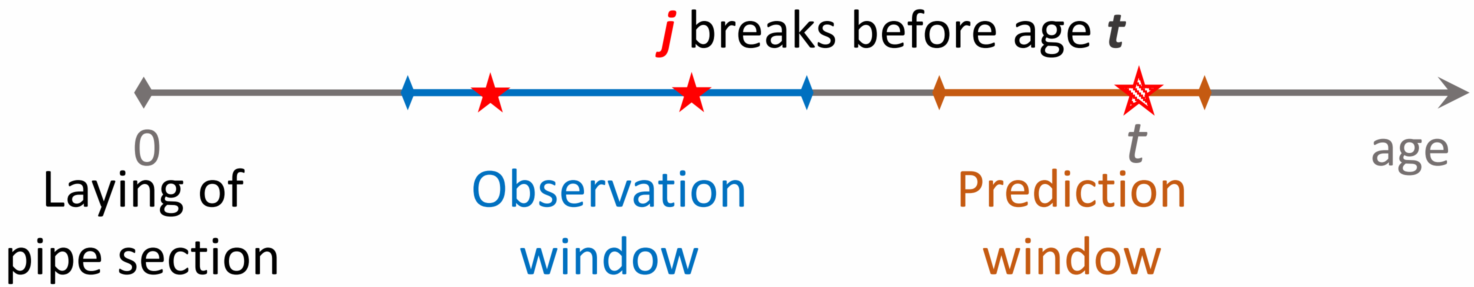
Break prediction model

https://casses.inrae.fr/en/



$$\mathrm{E}(dN(t)|N(t-)=j) = (1+\alpha j) \times \left(\delta t^{\delta-1}\right) \times \left(e^{Z^T\beta}\right)$$

Risk of breakage at age t

α Previous breaks

δ age

β other factors

Intensity function of the LEYP model

Linear Extended Yule Process, [Le Gat, 2007]

Calibration of break prediction models

	Pipe model	Connections model		
Alpha	2.9231	3.4141	++	++
Delta	1.0000	1.0000	=	=
DIA	-0.0024	-0.0018	-	-
Log(LNG)	0.3326	0.2329	+	+
MAT [Cast Iron]	0.0000	0.0000		
MAT[PVC]	-0.6116	0.3983	-	+
MAT[Other]	-0.4785	0.2046	-	+
IP[[01/01/1900;01/01/1951[]	0.0000	0.0000		
IP[[01/01/1951;01/01/1971[]	0.6813	0.8098		
IP[[01/01/1971;01/01/1981[]	0.4256	0.4108		
IP[[01/01/1981;01/01/2001[]	0.2633	0.3706		
IP[[01/01/2001;26/10/2015]]	0.2956	0.3223		

- A significant effect of previous breaks (α)
- No direct effect of ageing (δ=1)
- The risk decreases when the diameter (DIA) increases and increases with the length of the pipe section (LNG)
- Cast iron pipes break more than those made of other materials and connections on cast iron pipes break less than those on pipes of other materials (MAT)
- When the installation date is known, the older the installation period (IP), the greater the risk (which clearly reflects an aging effect)

Forecast of breakages and associated leak volumes over the period 2018-2022

Observation period: 2009 - 2015

	Nb Pipes	L Pipes	Nb pipe breaks	Pipes fail rate	Nb Cnct breaks	Cncts fail rate
Cast Iron	4 451	558	603	0.157	344	0.090
PVC	17 915	2 601	734	0.041	748	0.042
Other	2 068	252	71	0.051	84	0.060
TOTAL	**24 434**	**3 411**	**1 408**	**0.061**	**1 176**	**0.051**

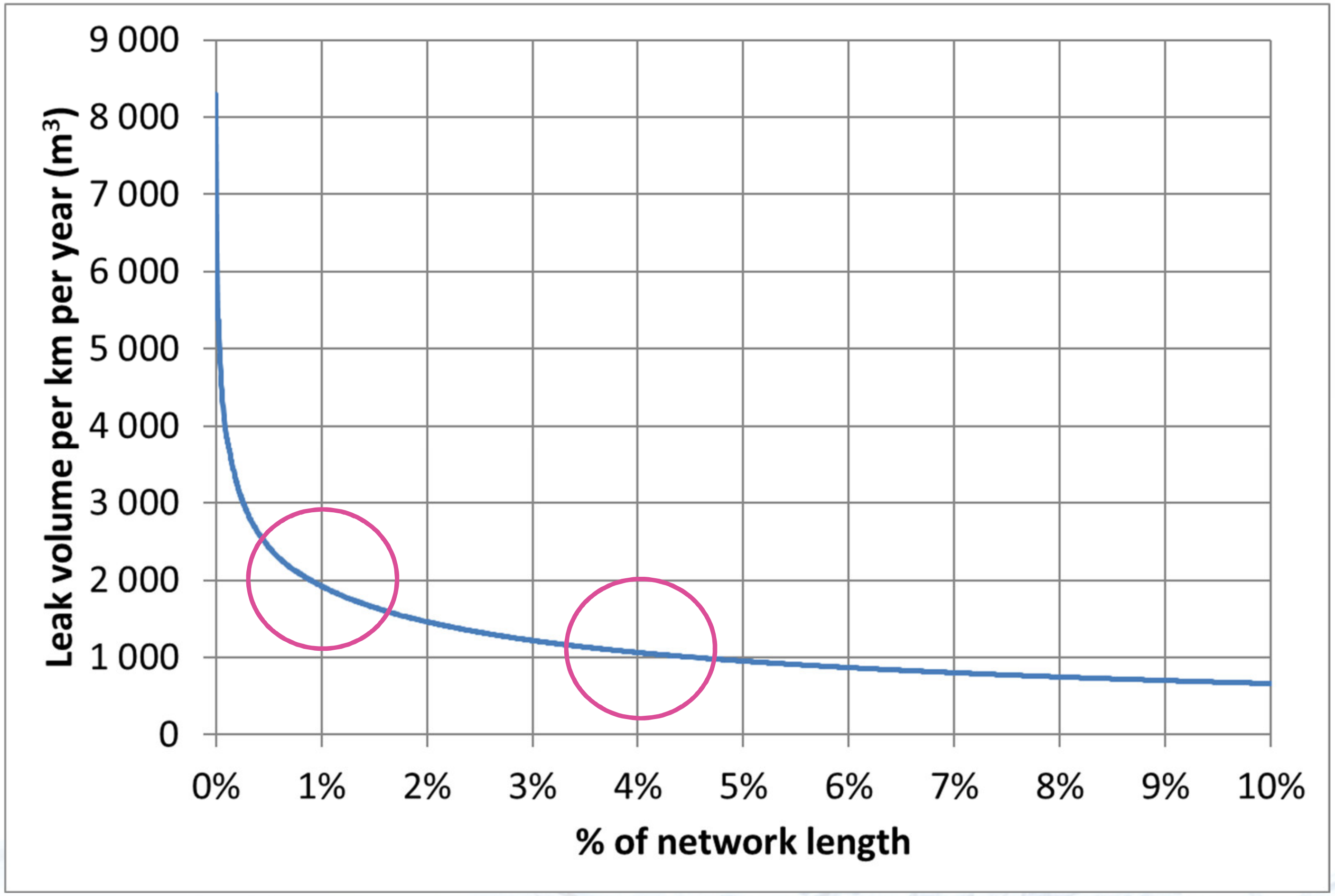
Prediction period:2018 - 2022

	Predicted pipe breaks	Pipes leak volume (m^3)	Predicted Cnct breaks	Cncts leak volume (m^3)	Total leak volume (m^3)
5 years	1 155	1 660 947	961	893 019	2 553 966
1 year	231	332 189	192	178 604	510 793
Fail rate (breaks/km.year)	0.068		0.056		
LLI (m^3/km.day)		0.27		0.14	0.41

- Break rates on pipes and connections are rising

- Detected leaks are responsible for 0.4 m^3/km.day
- Knowing that the linear losses index of the DWSS is close to 1.0 m^3/km.day, it can be estimated that background or undetected leaks represent approximately 0.6 m^3/km.day

Leakage accumulation



Pipe sections being sorted by decreasing risk of leakage, the volume of detectable leakage avoided per km of network renewed decreases rapidly:

- 2,000 m^3 / km.year for the first %
- 1,000 m^3 / km.year for the first 5%

% Networh length	% predicted breaks	% Detected leaks volume
1%	11%	13%
2%	17%	20%
3%	21%	24%
4%	25%	28%
5%	28%	32%

Disparity of leaks according to the types of pipe

	CI[0;80[	CI[80;400]	PVC[0;80[	PVC[80;400]	Other[0;80[	Other[80;400]
% Networh length	2%	14%	52%	25%	4%	3%
% Predected leaks volume	13%	32%	33%	15%	4%	2%

- Small diameter cast iron pipes represent 2% of the network length but are responsible for 13% of the volumes lost by detectable leaks.

Conclusion

Results

- A data processing method at DMA level that makes it possible to associate a duration, a flow rate and a volume of water loss with each intervention has been developed;
- Coupled with a break prediction, it makes it possible to prioritize the sections according to their risk of leakage and to assess the volume of detectable leaks that a renewal program can avoid.

Limits and prospects

- The volumes associated with diffuse leaks could not be reliably estimated;
- To go further, it is necessary to capitalize on the information associated with the renewal of pipes and connections (dates of decommissioning, technical characteristics of the renewed element, etc.)

Thank you for attention

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