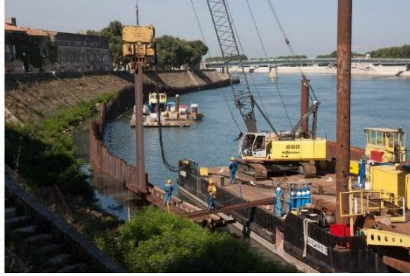



International Workshop on overflowing erosion of dams and dikes
11-14th december 2017 – Aussois, FRANCE

Session 1 : The Dam Owner' Perspectives : Issues and Engineering Needs
SYMADREM perspective

Thibaut MALLET, Technical Director

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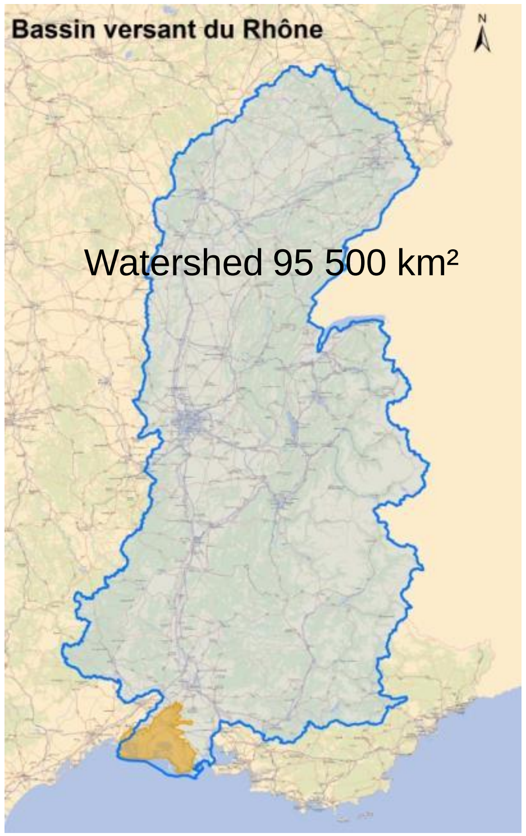
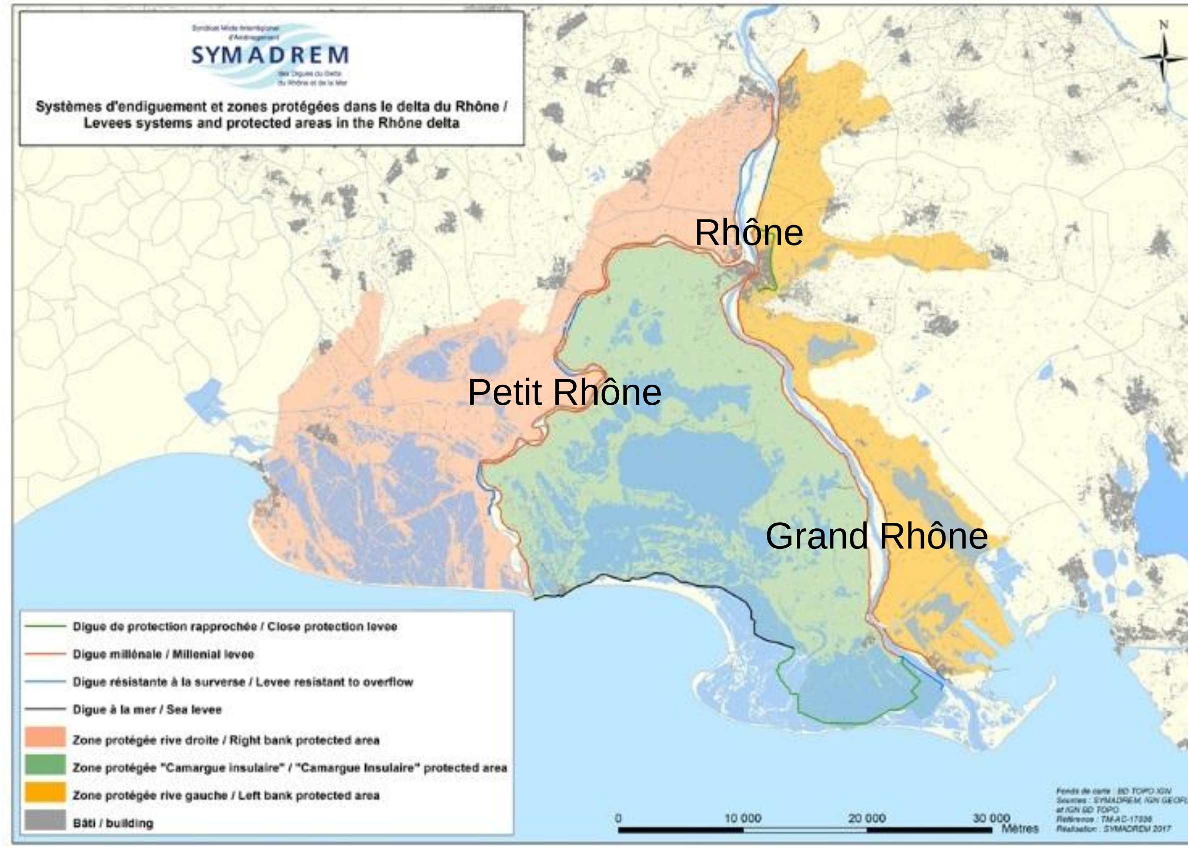
Cfbr

SYMADREM : a public institution (25 people) responsible for :

- ✓ **Monitoring and maintenance of levees in all circumstances**
- ✓ **Studies and levees improvements works**





Q1	=	4 200 m³/s
Q10	=	8 500 m³/s
Q100	=	11 500 m³/s
Q1000	=	14 500 m³/s

- 3 fluvial systems and 1 maritime system
- river levees : 225 km & sea levees : 50 km
- levees height : between 1 and 6 m
- 115 000 people protected

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Levees of SYMADREM

River levees during dec. 2003 flood (T=100 years)

Levees were erected on other old levees in the second half of the 19^{th} century after the great floods of 1840 and 1856 (return periods >> 100 years).

Annual probability of failure is between 10^{-1} and 10^{-2}, which is considered as a unacceptable risk for 110 000 people living in the delta.

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A system very exposed to the hazards of breaches during floods

The last great flood : dec. 2003 - T≈ 100 years

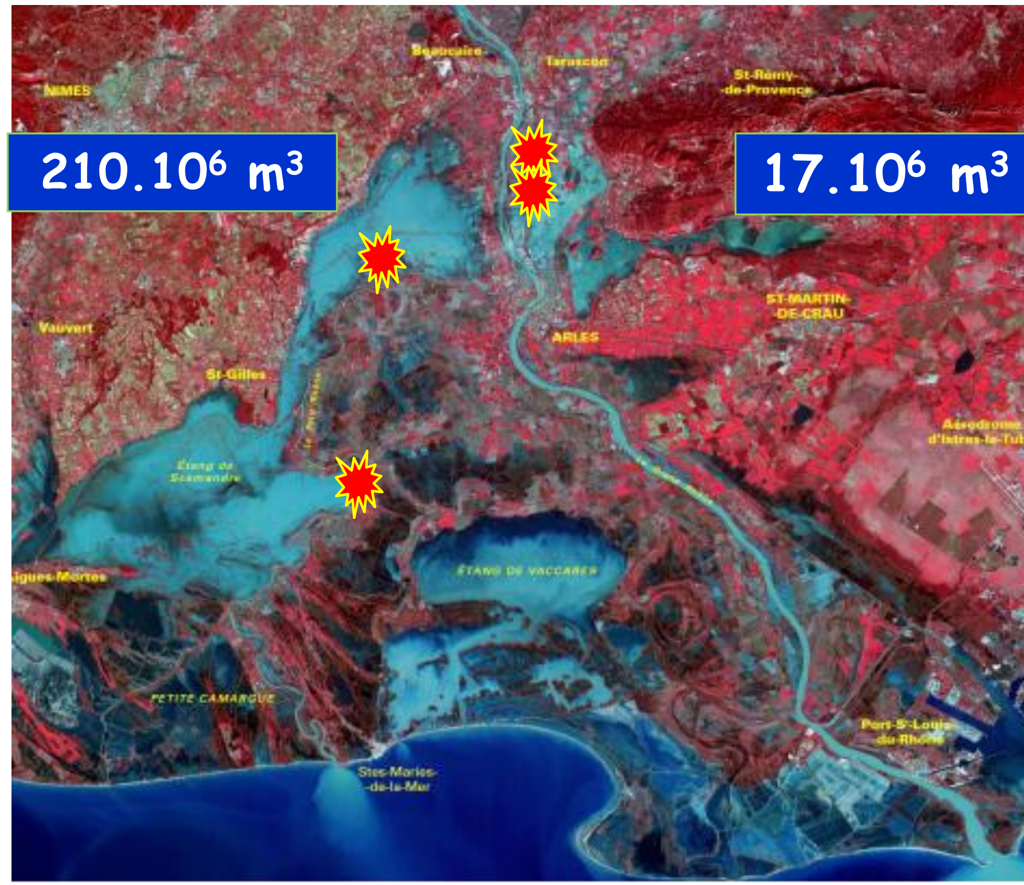
4 breaches

Damages : 700 Millions €

Spilling Volume

$210.10^6\ m^3$

$17.10^6\ m^3$



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Statistics of failures







Statistics of embankment dam failures over the world (ICOLD 2015 after Foster § Al.)

Failure mechanism	Erosion		Embankment Sliding	
Failure mode	Overflow	Internal Erosion	Static Instability	Seismic instability
Statistics	48 %	46 %	4 %	2 %
	94 %		6 %	

Statistics of breaches and breaches in progress in the Rhône Delta (1840–2016) – Hazards Study SYMADREM

Failure mechanism	Erosion			Embankment Sliding	
Failure mode	Overflow	Internal Erosion	Affouillement externe	Static Instability	Seismic instability
Breaches 1840-2016 (Nb = 57)	33 %	67 %	0 %	0 %	0 %
Breaches 1993- 2016 (Nb = 12)	25 %	75 %	0 %	0 %	0%
Breaches & Breaches in progress 1993 – 2016 (Nb = 29)	17 %	83 %	0 %	0 %	0 %
	100 %			0 %	

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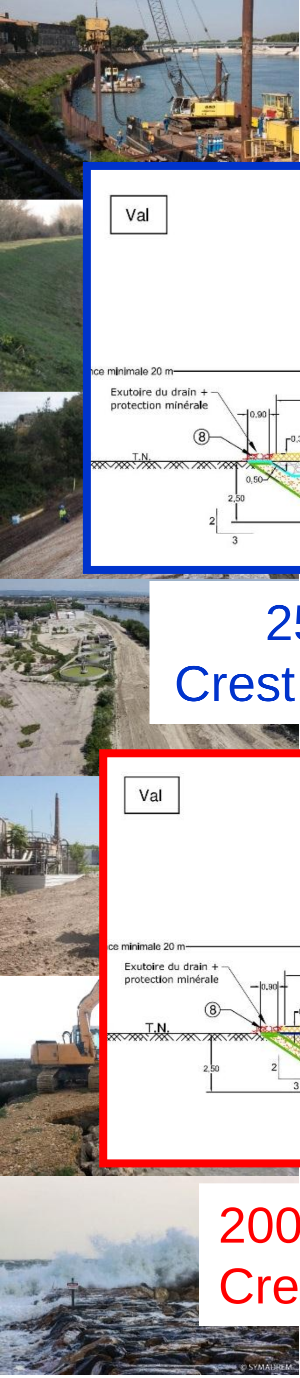
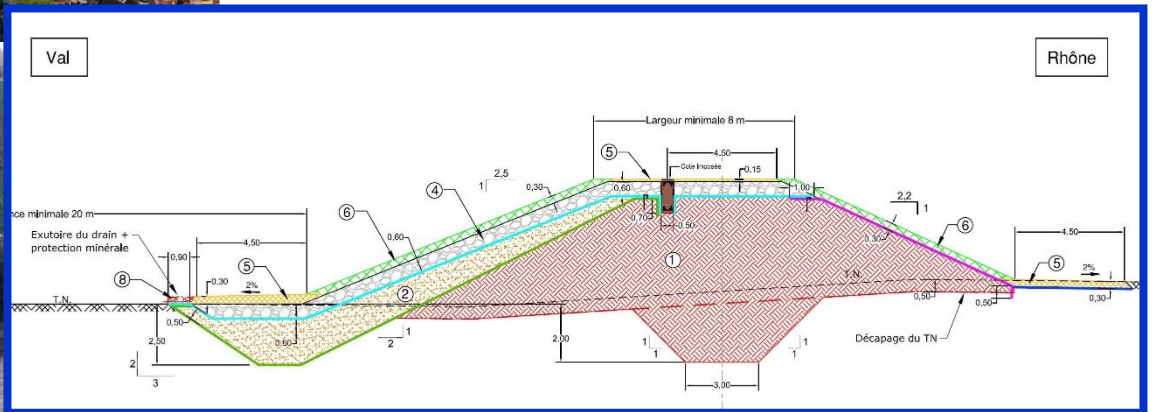
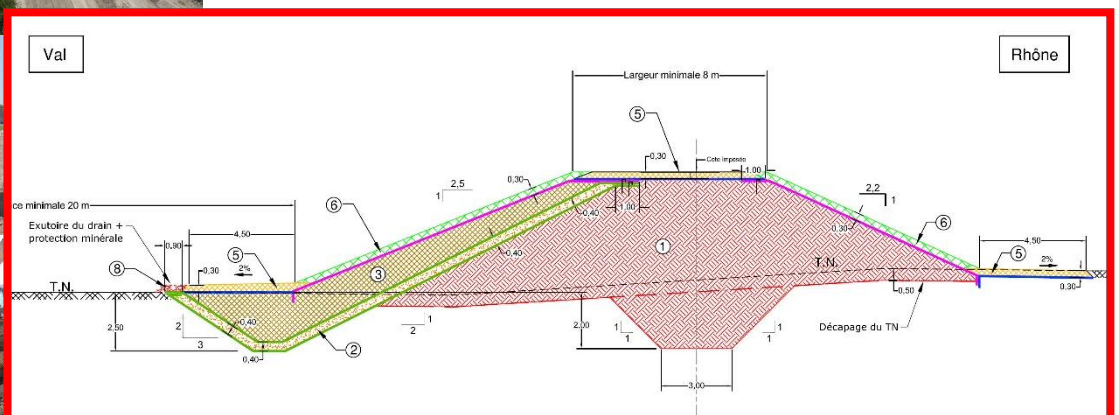
Large Program of levees securizing is implemented since 2007

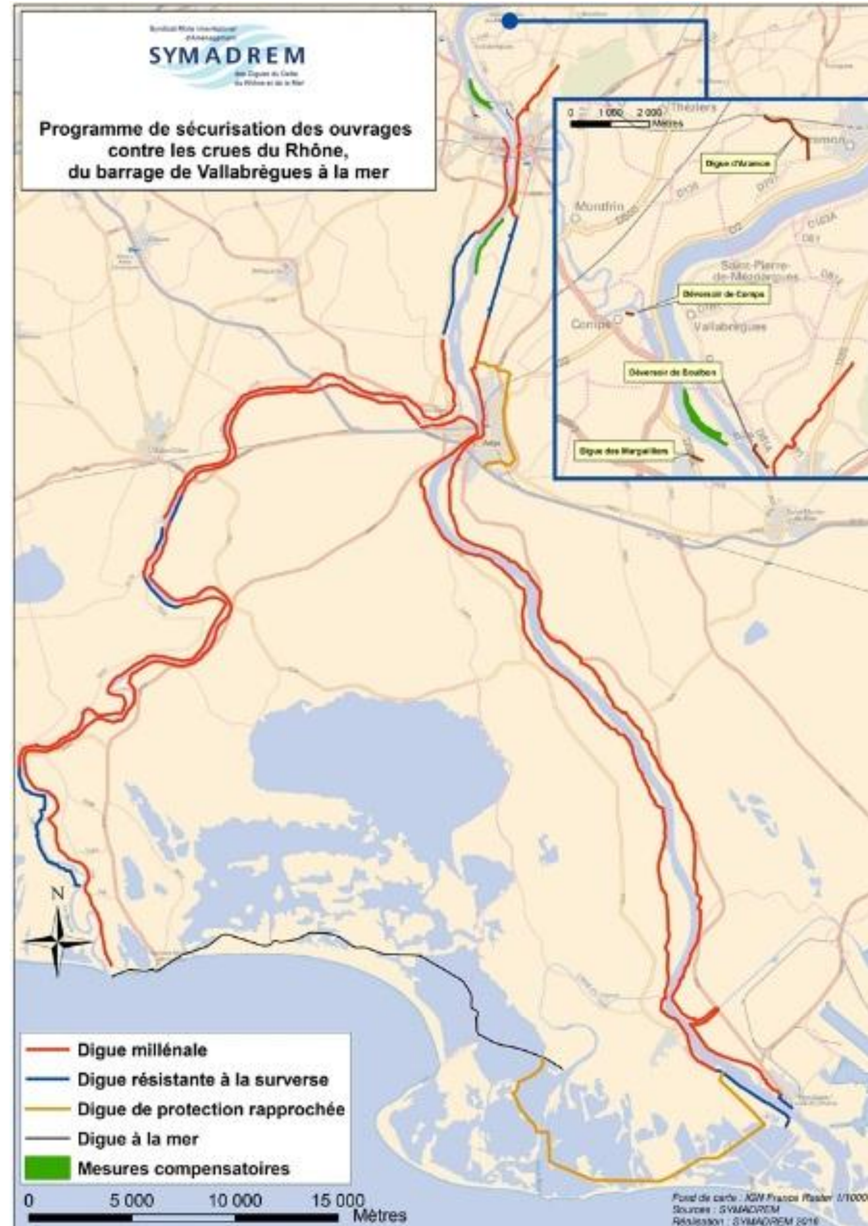




25 km of levees resistant to overflow
Crest level between 10 and 100 years floods



200 km of levees non resistant to overflow
Crest level = 1000 years flood + 50 cm



TOTAL COST : 400 millions of euros

150 millions of euros realized from 2007 to 2017 (achievement excepted for 2028)

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Old embankments are dismantled and new levees are rebuilt with all components of a safe and substainable levee

Annual probability of failure for new levees ≤ 10^{-4}

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Better understanding of overflowing is not our main need

For old levees : according to our feedback, it is a success when there is no breach before water reaching the crest

For new levees : modern spillways are built with concreted rocks (probability of failure by overflowing is acceptable)

Our need would be to get some tools to better predict the development of breaches (size, kinetic).

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French Regulation

Since 2007: dams, dikes and levees managers must realize hazards studies for their hydraulic structures

Since 2015, a new regulation applies to levees :

- ✓ Levees must be organized in hydraulically coherent systems,
- ✓ One unique manager by system,
- ✓ Hazards study (risk assessment) is unique and realized for all structures composing the levees system,
- ✓ Hazards study must determine the protection level within the protected area by the levees system,
- ✓ Protection level of a protected area is defined as the maximum level (guaranteed level) that river can reach without this area being flooded by overflowing, breaches or bypass,
- ✓ Protection level is defined with a maximum probability of failure of 5 %,
- ✓ Over protection level, levees managers must inform local authorities and state for rescue operations,
- ✓ Inundation modeling corresponding to a probability of 50 % must be realized by the manager, for rescue services

Hazards study

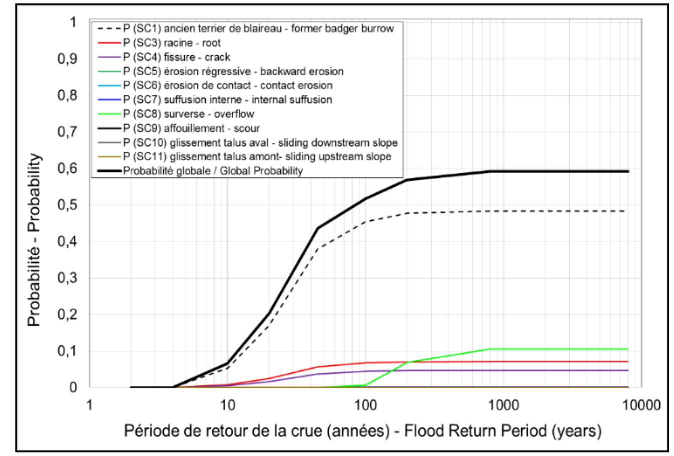




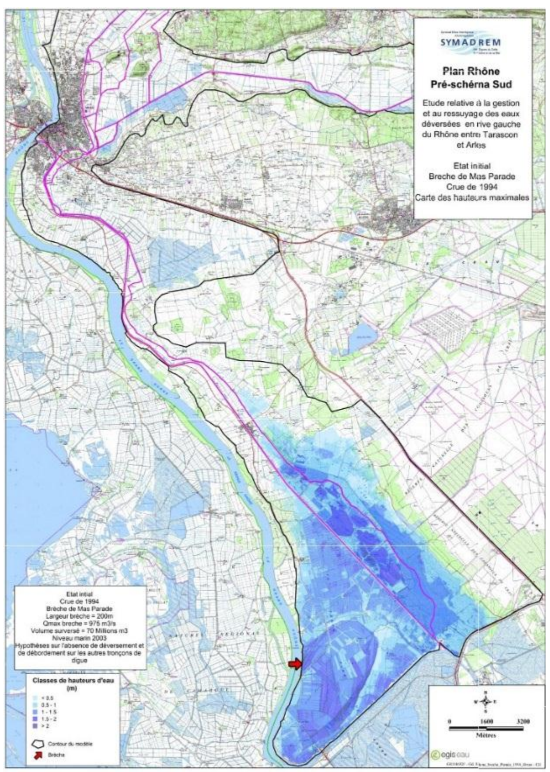


The hazards study contains :

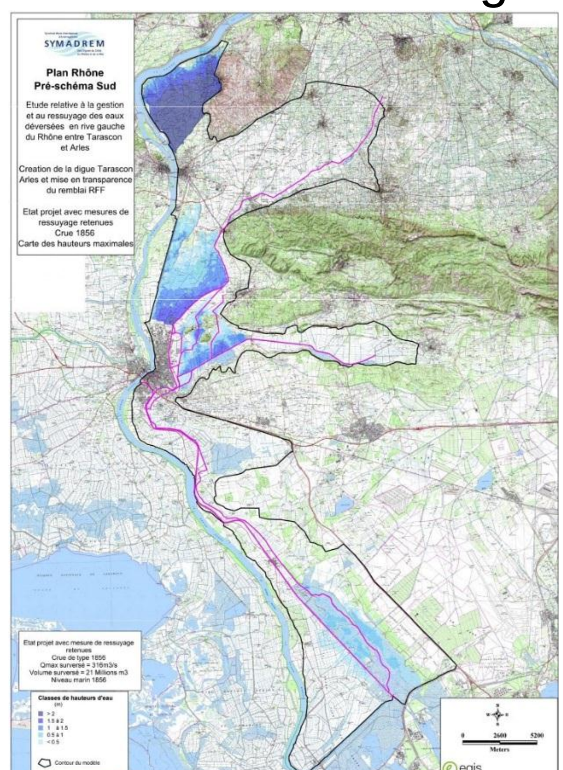
- ✓ Estimation of loading event probability,
- ✓ Levee performance (assessment),
- ✓ Levee system failure probability,
- ✓ Determining the protection and safety levels of the system,
- ✓ Inundation modeling to determine protection levels withing the protected area



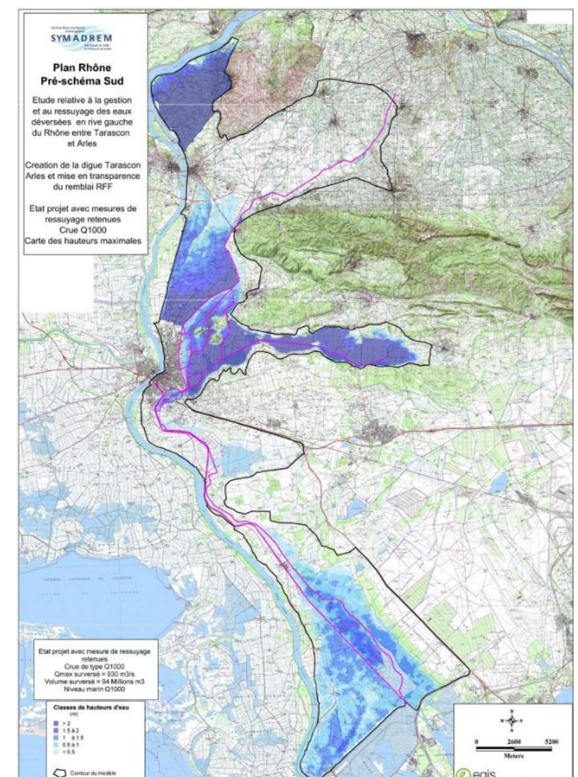
Inundation modeling



By breach



By overflow



By overflow and breach

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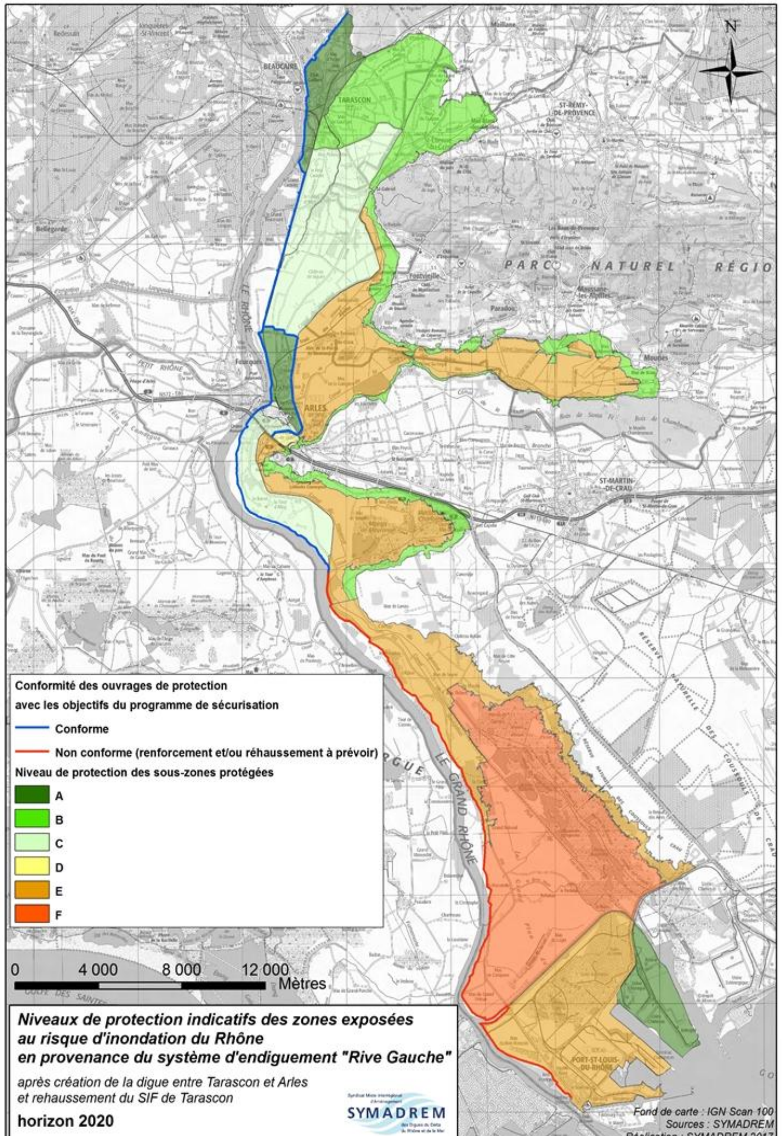
Protection levels within a area protected by a levees system



Level Protection	Discharge upstream Delta (m3/s)	Sea Level (m NGF IGN 69)	Return Period (years)
A	14 160	1,50	800
B	12 500	1,30	200
C	11 500	1,00	100
D	10 500	0,80	50
E	9 500	0,95	20
F	8 500	0,40	10

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Our need

Bibliography to estimate failure modes has developed considerably since 10 years (ILH, ICOLD Bulletins, FloodProbe…).
Today we have developed probabilistic methods to estimate system failure probabilities.
Results corresponds to our feedback.
It need to be improved, but we are on the good way

We have good inundation modeling but we lack precision and relevance for determining breaches characteristics :
bibliography about breach predicting, stays low developed.
Models are mostly local, concern old embankment levees or are adapted only to dams.

- ✓ SL Hunt & al. (2005)
- ✓ JR Courivaud (SHF 2014)
- ✓ Visser after Hanson (Windam 2015)
- ✓ IMPACT Project
- ✓ SOBEK model ….
- ✓ SYMADREM local model

We need to better understand the process of breach development :

- depth of scour pit,
- regressive development,
- side development,
- flow through the breach (submerged or free)

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Better understanding breaches development













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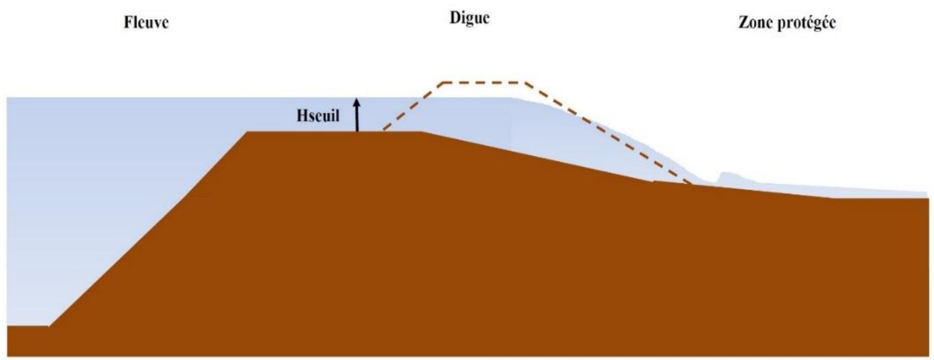
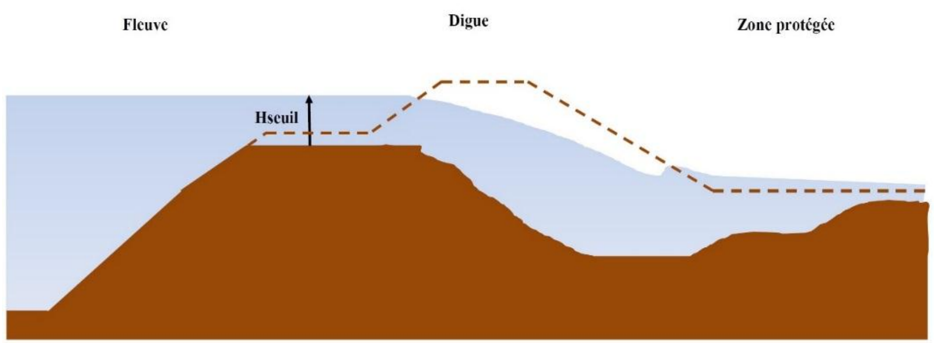
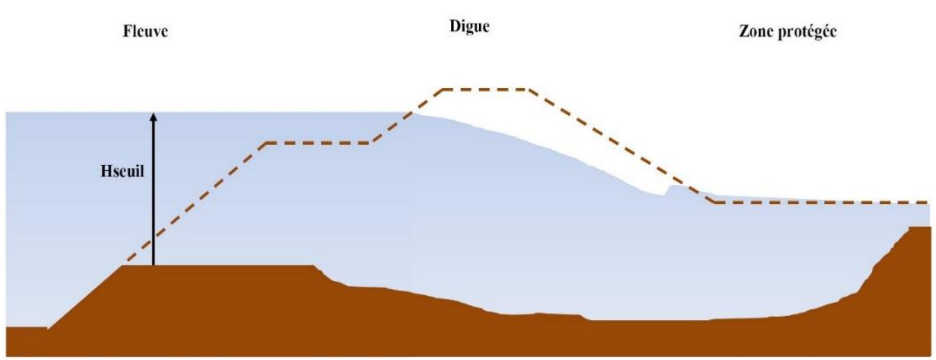
Better understanding breaches development







Loading can evolve greatly, according to the levee location (far or close from river)

The flow can be controlled by the breach (weir and width) (free flow)

But the flow through the breach can be submerged and controlled downstream scour pit (flow width is not the same and superior to breach width)

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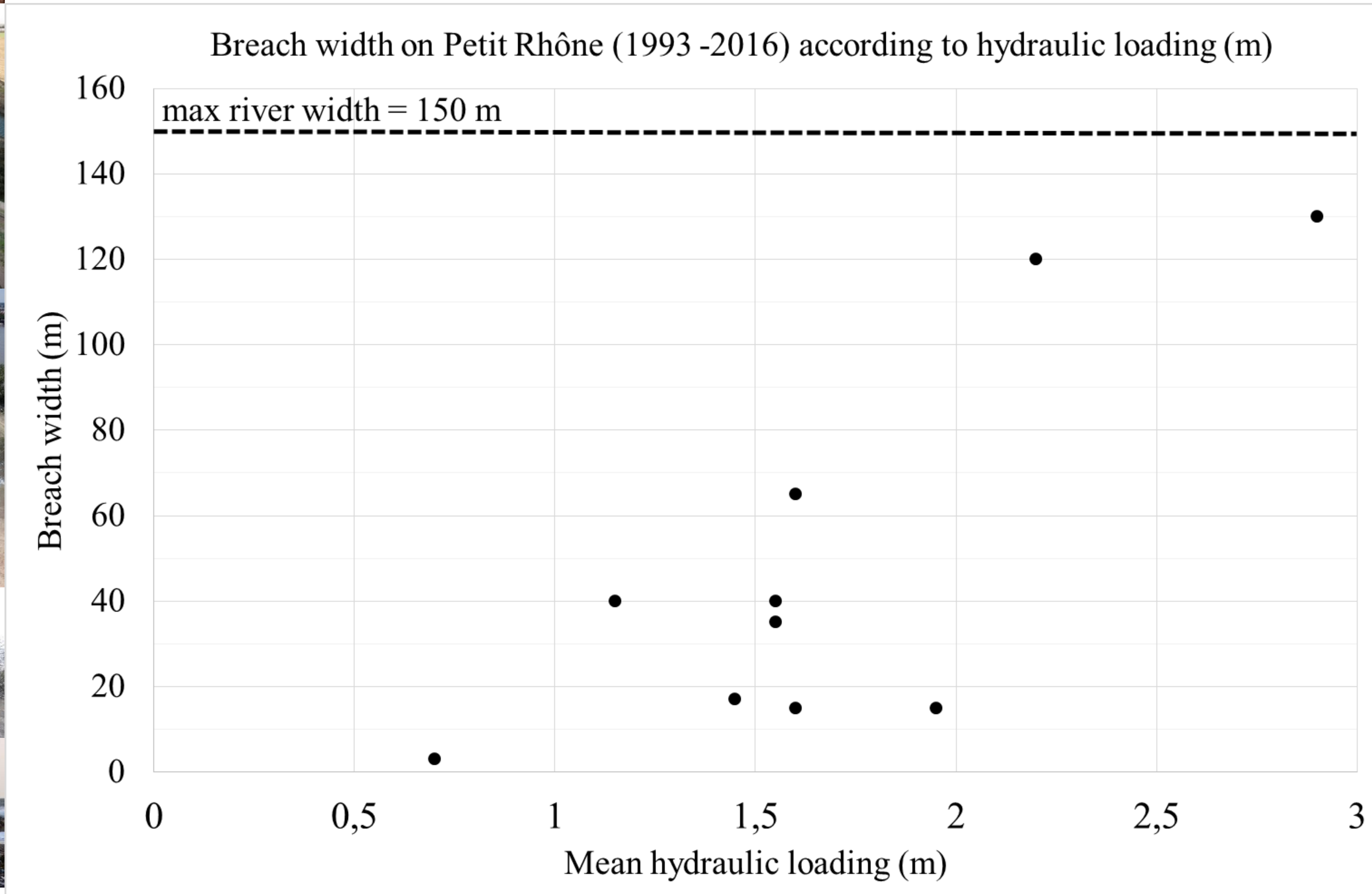
SYMADREM feedback for homogeneous and old embankment on the Petit Rhône river



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Needs for basic datas

Because zero risk doesn't exist, we also need to modelize breach in a safe and substainable levee to evaluate the residual risk

According to Hunt (2005), kinetics of breach widening can be estimated as :

$$\frac{dW}{dt} = 2k_d(\tau_{brèche} - \tau_c)$$

As for CIRIA charts, which gives resistance to overflow according to speed,

We would need to know kd and τc for :

- A homogeneous levee with a poor compacted embankment
- A homogeneous levee with a well compacted embankment
- A zoned levee with riprap (concrete, blocks, concreted blocks)
- A levee with sheet piling ?
- A river wall (quay)
- …

Thank you for attention

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