STANDARDIZED DAM BREACH ASSESSMENT

Australian Water School Webinar - Advances in dam breach assessment

Learn how past mistakes and advances in modelling are improving our ability to estimate dam failure parameters and impacts

Presenter : **Mayari Bernard-Garcia, Eng., M.Sc., PhD.**

8th May 2024 (Australian time)
7th May 2024 (Eastern time)

AtkinsRéalis

Presentation Plan

1. Introduction
2. Review of Dam breach Framework
3. Problematic
4. Methodology
5. Results and Discussion
6. Conclusion

1.1. Introduction - Dam breach Assessment

Uncertainties of various kinds:

Dam failure modeling uncertainties:

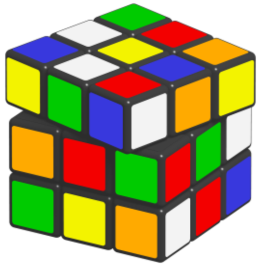
- ❑ Inflow reservoir hydrograph **(Design Flood)**
- ❑ Storage curve
- ❑ Downstream boundary condition

Algorithmic/Numerical uncertainties :

- ❑ Numerical scheme
- ❑ Interpolation uncertainties
- ❑ Discretization of a continuous land surface into cross sections or 2D mesh

Knowledge uncertainties :

- ❑ Roughness coefficient (Manning values)
- ❑ Hydraulic modeling
- ❑ **Dam breach parameters**



1.2. Introduction – Dam breach Regulation

The current Regulation tries, via the classification of dams, to frame :

- **Hydrological uncertainties**
- **Hydraulic uncertainties**
- **Operation uncertainties**

However,

→ **Dam breach uncertainties are NOT included / framed.**

→ **In practice, the failure scenario is define using Guidelines and/or Standards Framework.**

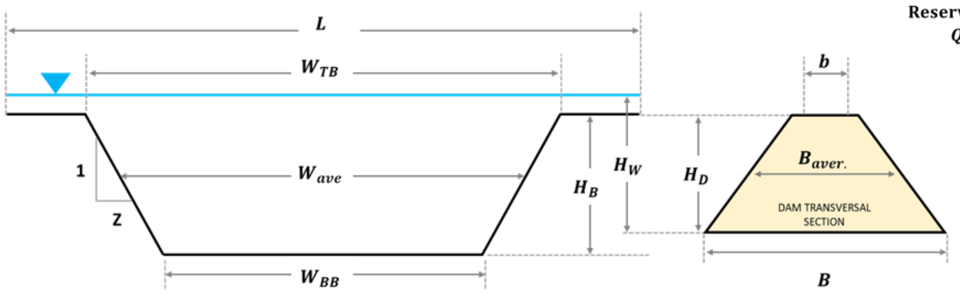
→ Dam Breach Models Chronology

2. Review of Dam Breach Framework

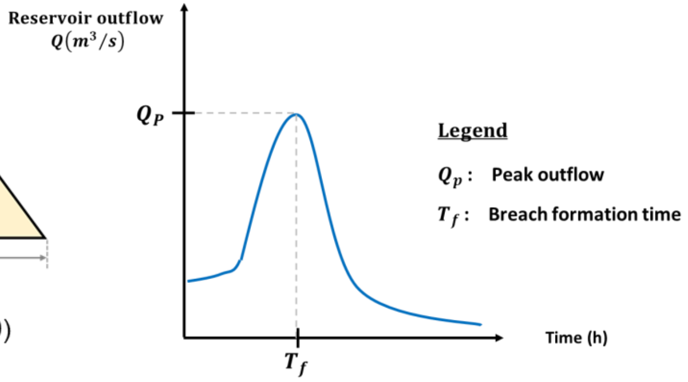
In practice, the standardized dam failure scenario is defined by the following three (3) failure parameters :

1. **Dimensions of the final breach (W_{BB}/H_D or W_{ave}/H_D)**
2. **Slope of the final breach** (1:Z)
3. **Final breach formation time** (T_f)

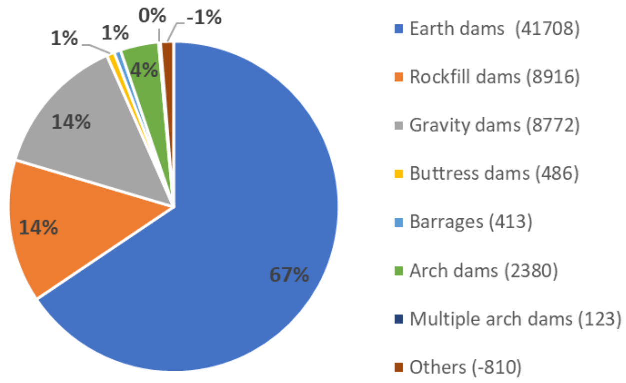
→ A standardized dam failure hydrograph.



Idealized trapezoid dam breach geometry (Bernard-Garcia and Mahdi, 2020)



2. Review of Dam Breach Framework



(ICOLD, 2020)

International Frameworks (adapted from Marche, 2008)

Dam Type / Standardized rupture parameters	Hydro-Québec (HQ 60-00-00)	NWS (USA)	MEQ	Cadam	France	Switzerland
Barrage en béton, type Gravité ; Concrete, Gravity dam (CON ; GR)						
Bottom Width W_bb	4*H	adapted	4"H	0.5*W	Total	Total
Average Width W_ave	4*H	adapted	4"H	0.5*W	Total	Total
Formation Time tf	0,1 h	0,1 – 0,5 h	0,1 h	0,2 h	0,01 h	0
Barrage en béton, type Arché ; Concrete, Arch dam (CON ; ARC)						
Bottom Width W_bb	4*H	Total		0.9*W	Total	Total
Average Width W_ave	4*H	Total		0.9*W	Total	Total
Formation Time tf	0,1 h	0.01 h		0,01 h	0,01 h	0
Barrage en remblai ; Embankment dam ; Erthfill and Rockfill (EFL+RFL ; NO FD)						
Bottom Width W_bb	**4*H**	0.9*H – 2.9*H	3*H	Model	Pipping	2*H
Average Width W_ave	**5*H**	1*H – 3*H	3*H		Total	3*H
Formation Time tf	**0,5 h**	0,1 – 0,5 h	0,5 h		some h	0
Barrage en remblai, type masque amont ; Embankment dam, Face dam (EFL+RFL ; FD)						
Bottom Width W_bb	4*H		3*H		Total	2*H
Average Width W_ave	5*H		3*H		Total	3*H
Formation Time tf	**0,5 - 2 h**		0,5 hr		0,01 hr	0

H : Dam height

Remarks :

The distinction between EFL+RFL (Earhtfill and Rockfill excluding facedam ; NO FD) and EFL+RFL (FD ONLY) is in the formation time of the breach, which can be up to 2 hours in the case of "Facedam (FD)"

3. Problematic

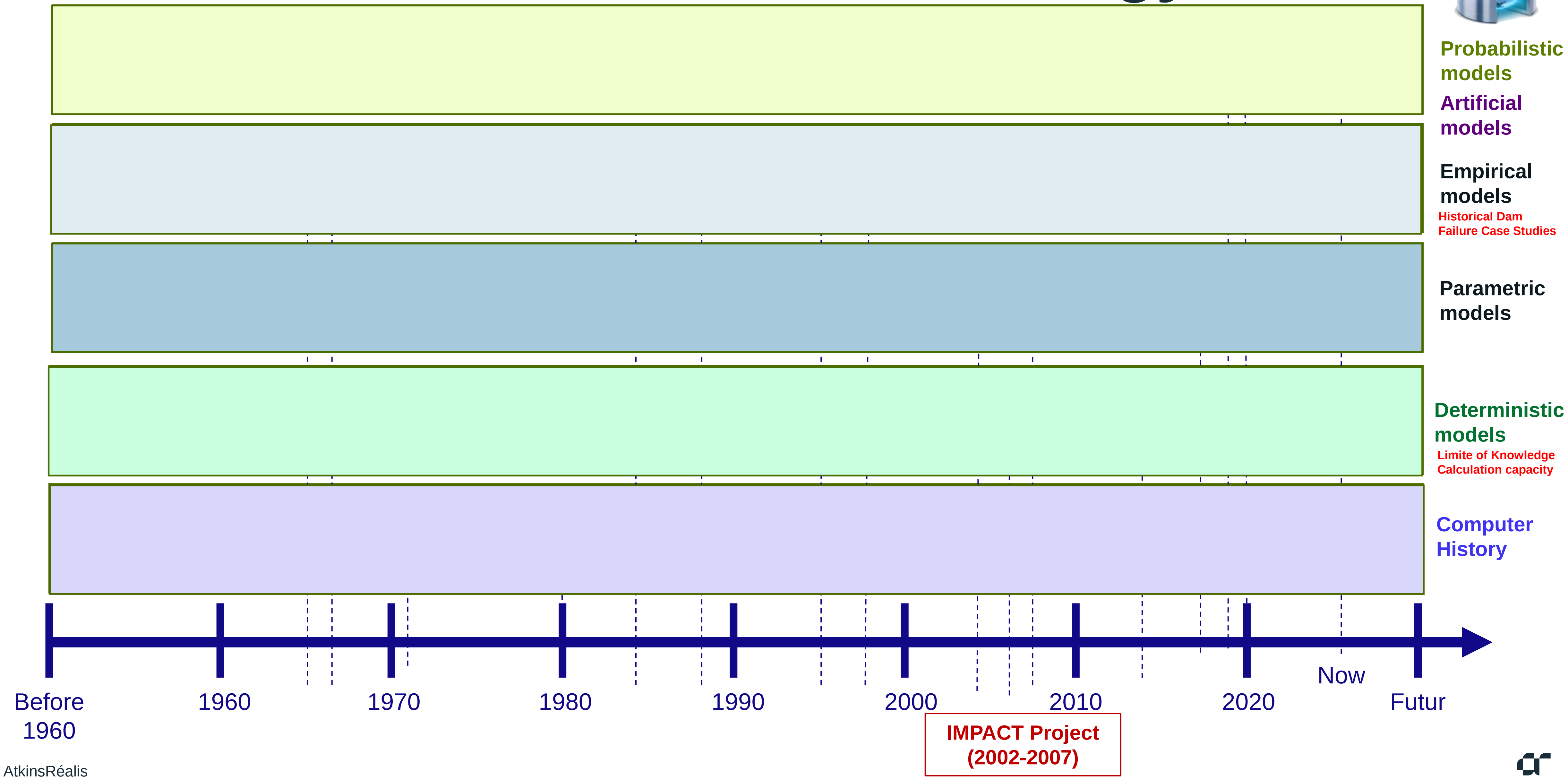
Dam breach Framework Limitation :

- Specifications provided in most current safety standards were established on historical dam failures recording these parameters.
- The “accuracy” of these specifications is directly related to the number of dam failure cases available.

Objective :

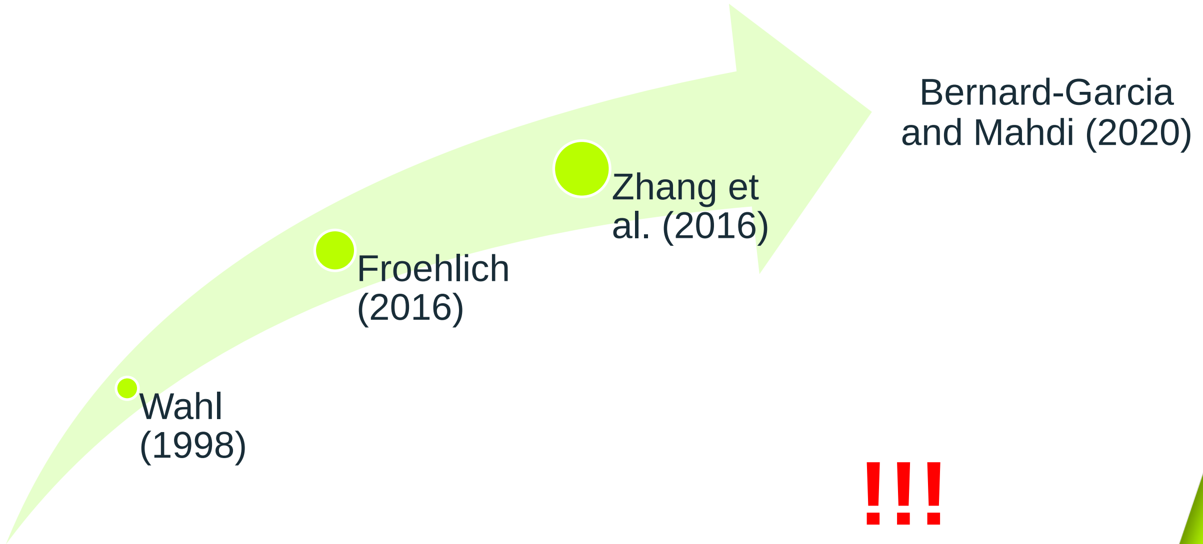
- Provide a probabilistic strategy/approach allowing :
    - To identify the controlling dam breach parameter(s) and their influence on the downstream flooding.
    - To define a range of « possible » using historical dam failure case studies.
    - To **quantify uncertainties on the dam breach parameters,** using a probabilistic approach, on the dam failure hydrograph.

3.1. Dam Breach Models Chronology



4. Methodology

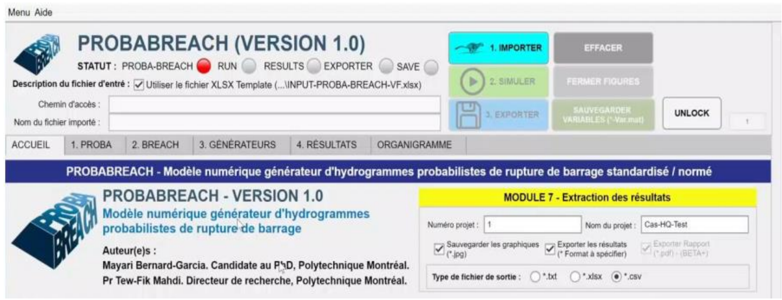
Bernard-Garcia and Mahdi (2020) database recording 3 861 worldwide historical dam failure case studies



!!!

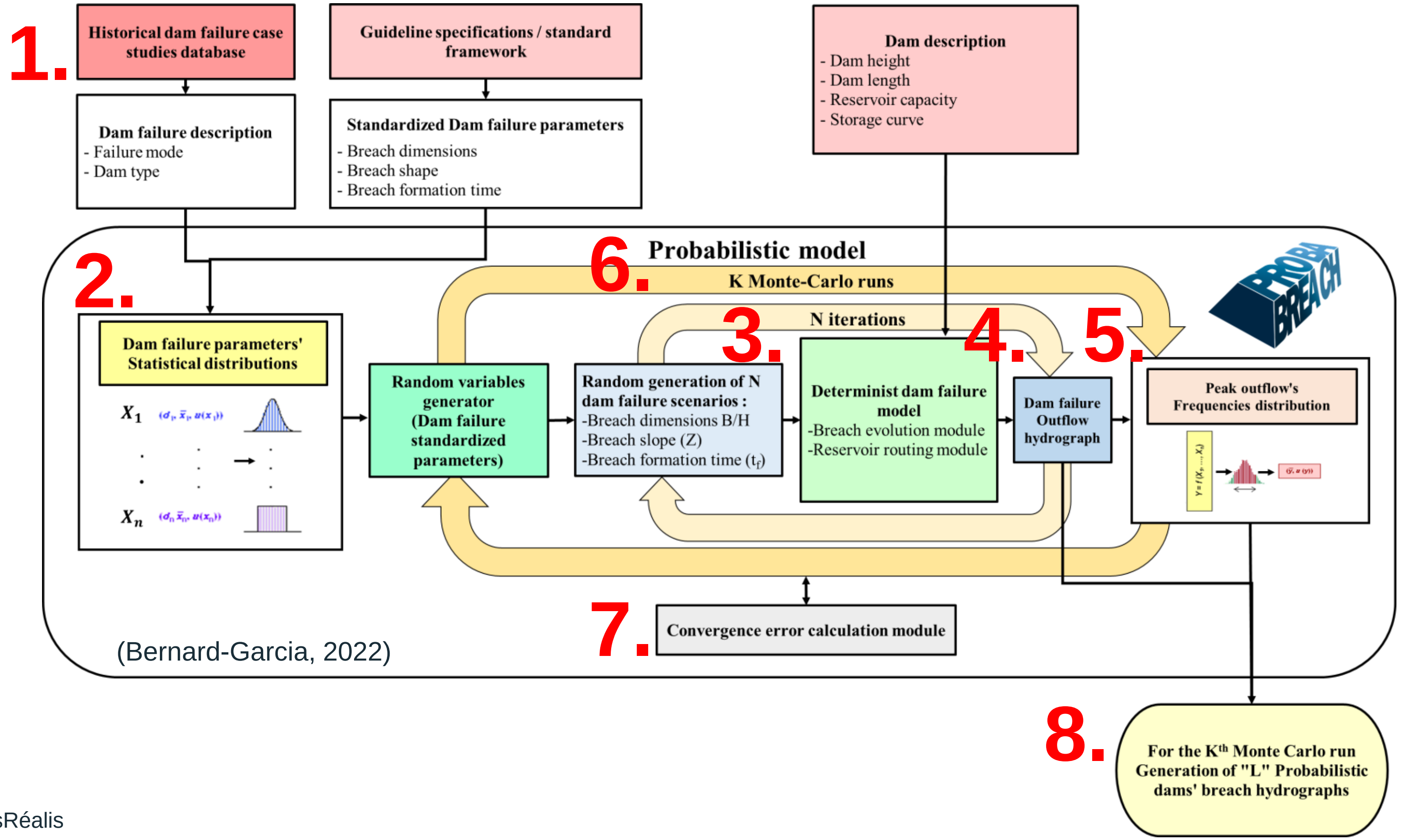
4. Methodology

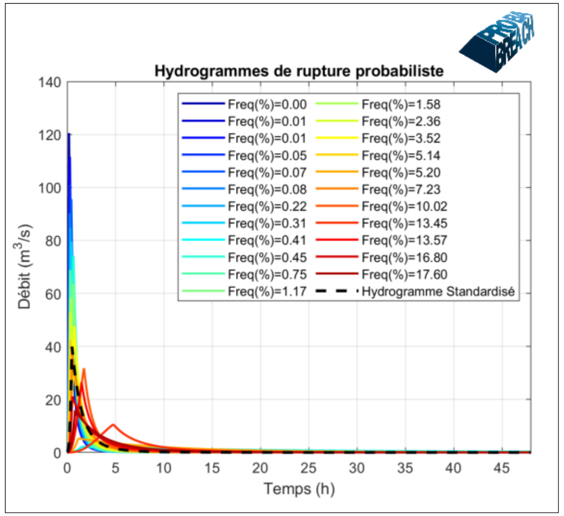
(Bernard-Garcia, 2022)



"Main" model results:

- Distribution of frequencies of appearance of deterministic Qp
- Probabilistic hydrographs
- Range of "standardized" probabilistic rupture scenarios
- Frequency of non-exceeding of Qp_standardized and parameters





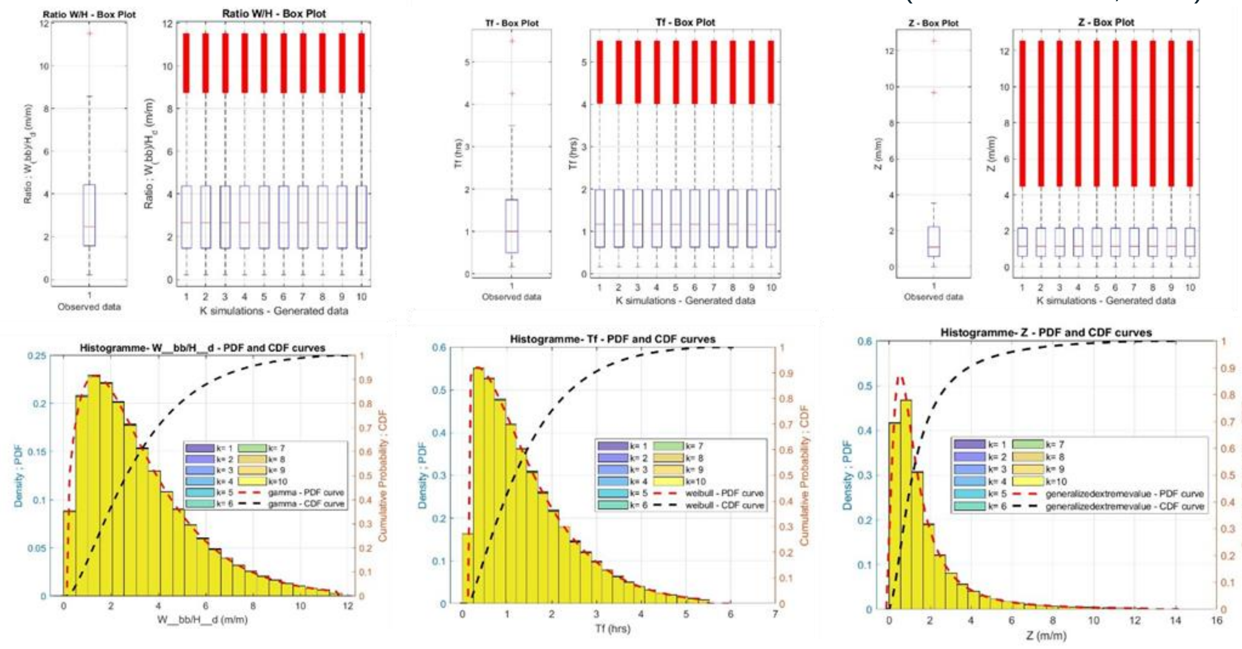
(Bernard-Garcia, 2022)

5. Generate random dam failure scenarios

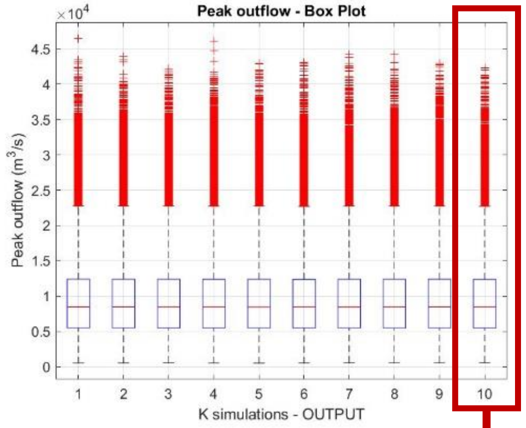
10 Monte Carlo runs of 1 000 000 scenarios

From Step 3 :

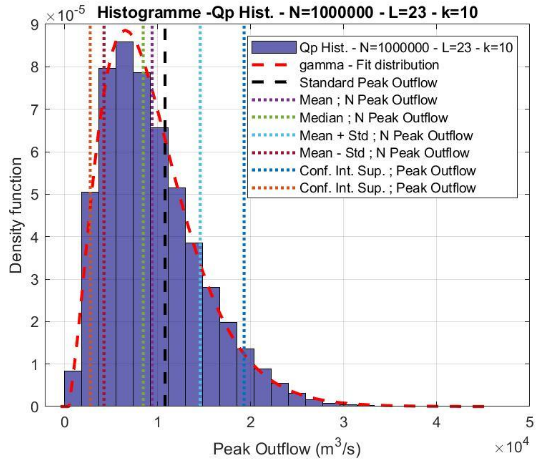
(Bernard-Garcia, 2022)



From Step 4 :

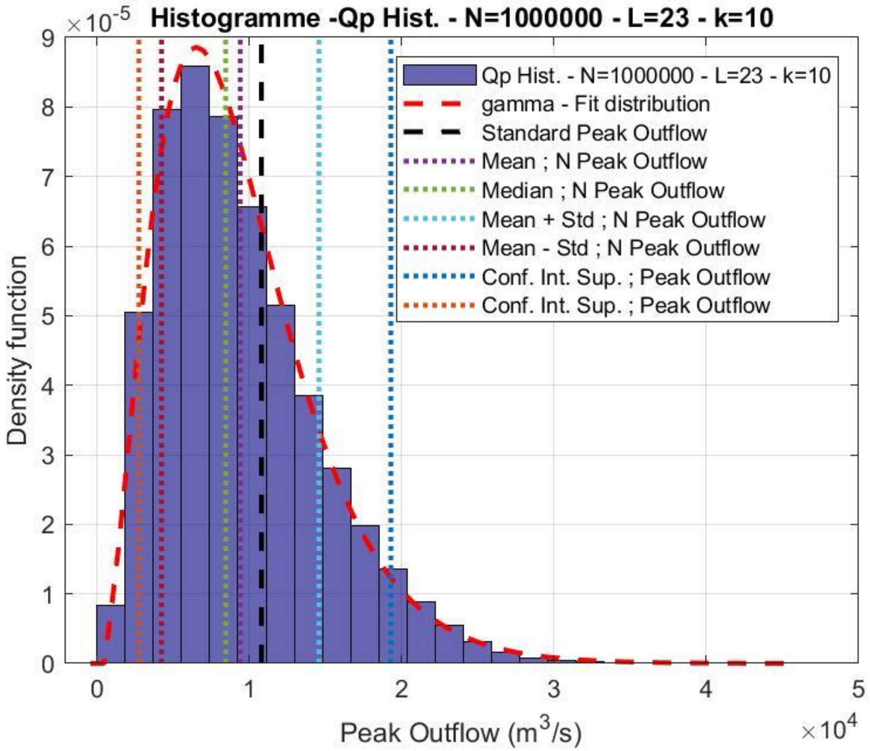


From Step 5 :

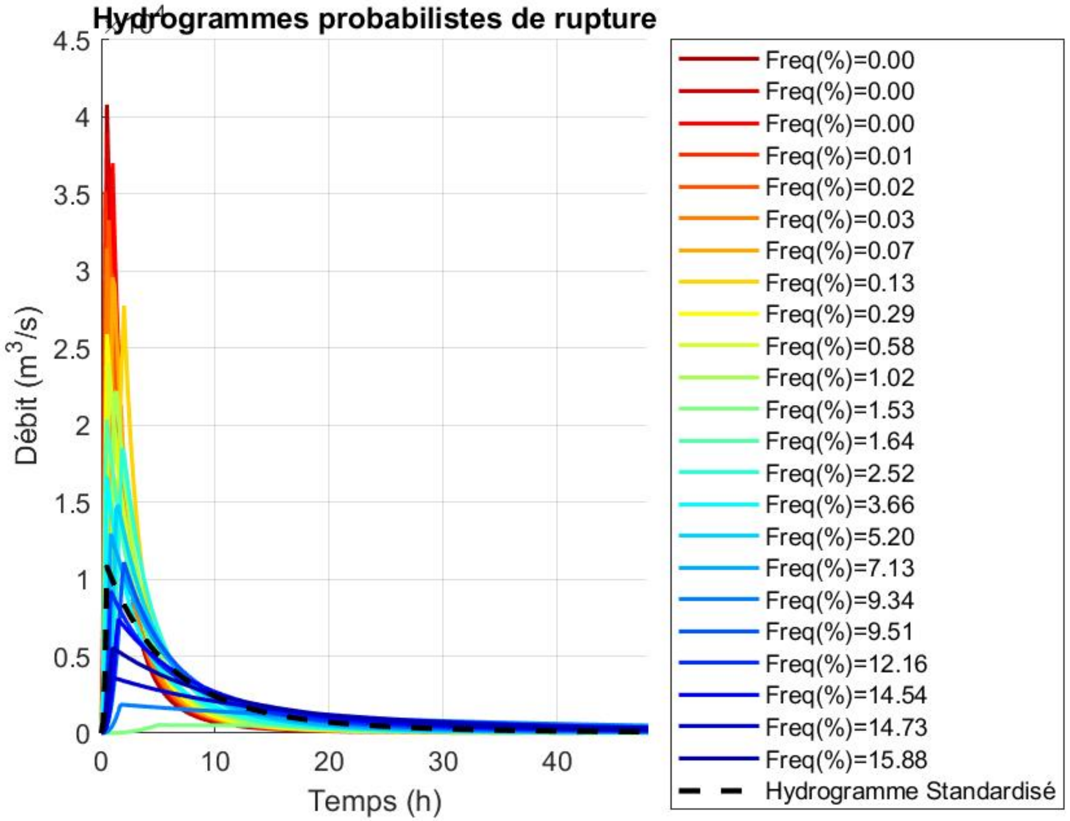


5. Generate probabilistic dam breach hydrographs

Using the last Monte Carlo simulation



23 probabilistic hydrographs are generated



(Bernard-Garcia, 2022)

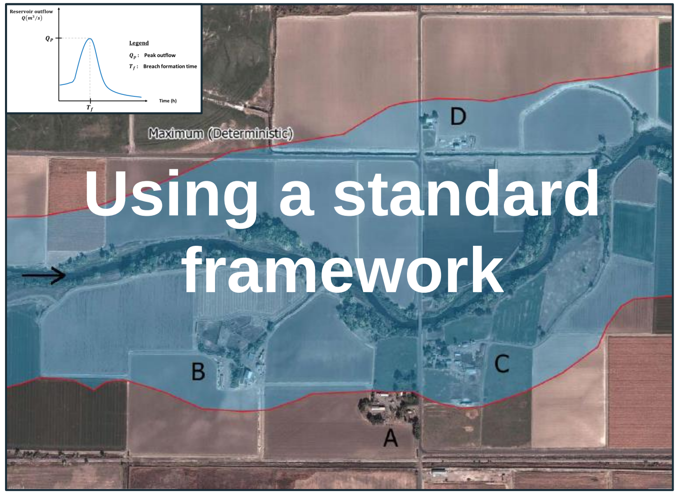
5. Discussion

Evaluate the influence of :

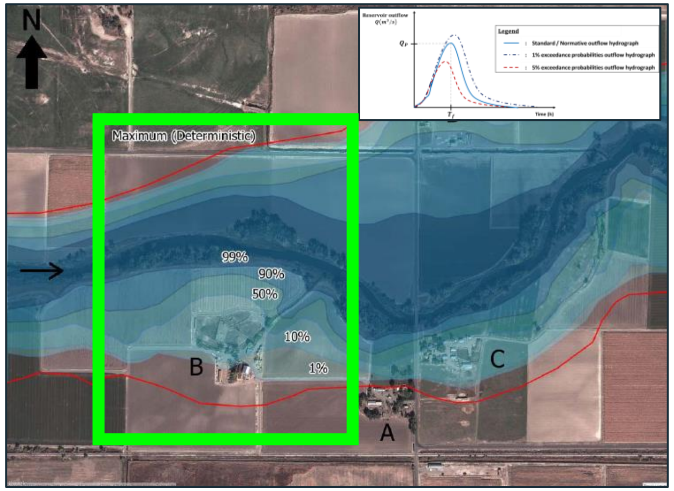
- Dam breach parameters
- Fit distribution consider to generate the dam breach parameters
- Number of simulations per Monte Carlo run to consider
- Number of Monte Carlo runs
- Deterministic dam breach model consider (parametric, deterministic)

6. Conclusion – For dam breach assessment

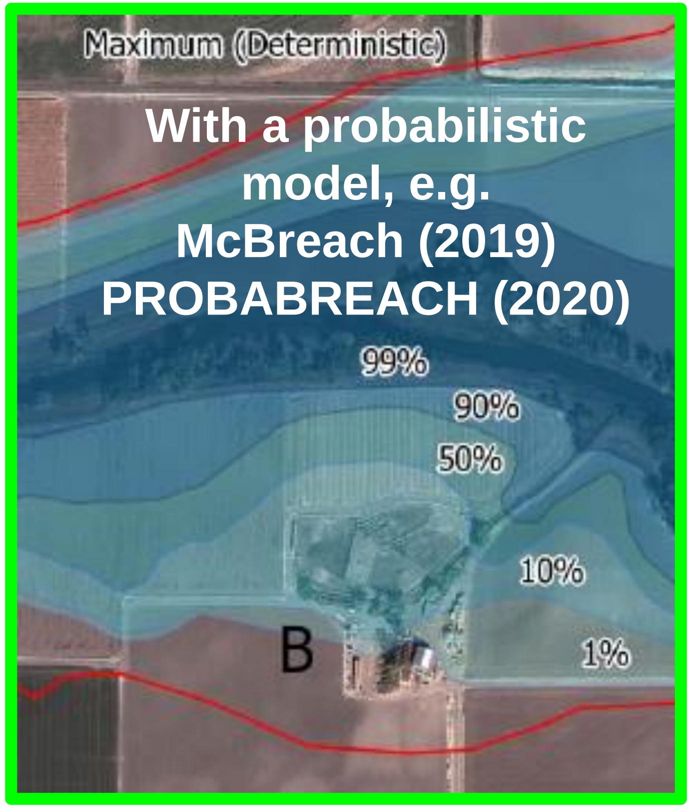
- Associate a level of “uncertainty” to failure hydrograph using an “user-friendly” tool.
- Quantify dam failure parameters uncertainties
- Encountered sensibility analysis on dam breach parameters
- **Improving flood maps by associating probabilities…**



(adapted from WEST Consultants Inc, 2015, p.5).



(adapted from WEST Consultants Inc, 2015, p.25).



7. References

For a complete case study using PROBABREACH (CDA,2023) (in English)

- Bernard-Garcia and Mahdi (2023). Probabilistic standardized dam failure hydrographs / Hydrogrammes probabilistes de rupture de barrage standardisé. Conference: CDA 2023 Annual Conference Congrès annuel 2023 de l'ACB At: Winnipeg, Canada. Octobre 2023. (p.24-37).

For Bernard-Garcia and Mahdi (2020) Database (in English)

- Bernard-Garcia, M. Mahdi, T.-F. (2020). A Worldwide Historical Dam Failure's Database, https://doi.org/10.5683/SP2/E7Z09B, Borealis, V1.

For Bernard-Garcia and Mahdi (ICOLD,2021) Database description (in English)

- Bernard-Garcia, M. Mahdi, T.-F. (2021) A WORLDWIDE DATABASE OF DAM FAILURE CASE STUDIES / UNE BASE DE DONNÉES MONDIALE DE CAS DE RUPTURES DE BARRAGE. 27th CONGRÈS DES GRANDS BARRAGES À MARSEILLE 2021 (Due to CODIV-19 this event has been reported in May 2022). DOI :10.1201/9781003211808-92

For Bernard-Garcia and Mahdi (HYDRO,2020) review of historical Databases (in English)

- Bernard-Garcia, M. Mahdi, T.-F. (2020). "Overview and access to worldwide historical dam failure compilations". Hydropower potential and development opportunities. HYDRO2020 Conference Proceedings. 26-28 October 2020

For Bernard-Garcia and Mahdi (CSCE,2021) a review of Standard Framework (in English)

- Bernard-Garcia, M. Mahdi, T.-F. (2021). "REVIEW AND UPDATED GUIDANCE FOR EMBANKMENT DAM BREACH PARAMETERS". S. Walbridge et al. (eds.), Proceedings of the Canadian Society of Civil Engineering Annual Conference 2021, Lecture Notes in Civil Engineering 250. https://doi.org.10.1007/978-981-19-106504_52

For Bernard-Garcia (2023) PROBABREACH model description (in French)

- Bernard-Garcia, M. (2023). *Nouvelle stratégie de modélisation numérique générant des hydrogrammes probabilistes de rupture par submersion de barrage en remblai adaptée au cadre normatif* . Thèse de doctorat, Polytechnique Montréal. Février 2023.

7. References

- Froehlich, D. 2016a. Predicting Peak Discharge from Gradually Breached Embankment Dam. Journal of Hydrologic Engineering, July 2016, 21(11): 04016041. DOI: 10.1061/(ASCE)HE.1943-5584.0001424
- Froehlich, D. 2016b. Empirical model of embankment dam breaching. The International Conference on Fluvial Hydraulics (River Flow 2016), June 2016, p. 1821-1826. DOI: 10.1201/9781315644479-285
- ICOLD. 2020. Synthèse générale, tiré de : https://www.icold-cigb.org/FR/registre_des_barrages/synthese_generale.asp
- IMPACT. 2004. Risk and Uncertainty (WP5)-Technical Report, Investigation of Extreme Flood Processes & Uncertainty (IMPACT). Tiré de: http://www.impact-project.net/AnnexII_DetailedTechnicalReports/AnnexII_PartD_WP5/WP5_technical_Report_V1_2.pdf
- Marche, C. 2008. Barrages: crues de rupture et protection civile (2e édition éd.). Montréal: Presses internationales Polytechnique.
- Wahl, T. L. 1998. Prediction of embankment dam breach parameters: a literature review and needs assessment (Dam Safety Research Report DSO-98-004). US Bureau of Reclamation.
- WEST Consultants Inc. (2015). A Probabilistic approach to dam breach modelling. Online presentation. Portland (OR), USA.
- Zhang et al. (2016). Dam failure mechanisms and risk assessment. 2016 John Wiley & Sons Singapore Pte. Ltd. Published 2016 by John Wiley & Sons Singapore Pte. Ltd. Nat Hazards (2016) 84:1385–1418. DOI 10.1007/s11069-016-2492-9

thank you