CHAIRE INDUSTRIELLE EN EAU POTABLE

CREDEAU

POLYTECHNIQUE MONTRÉAL

Assessment and prioritizing of combined sewer systems using Bayesian networks

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Conseil des bassins versants des Mille-Îles

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Presentation outline

1. Motivation:

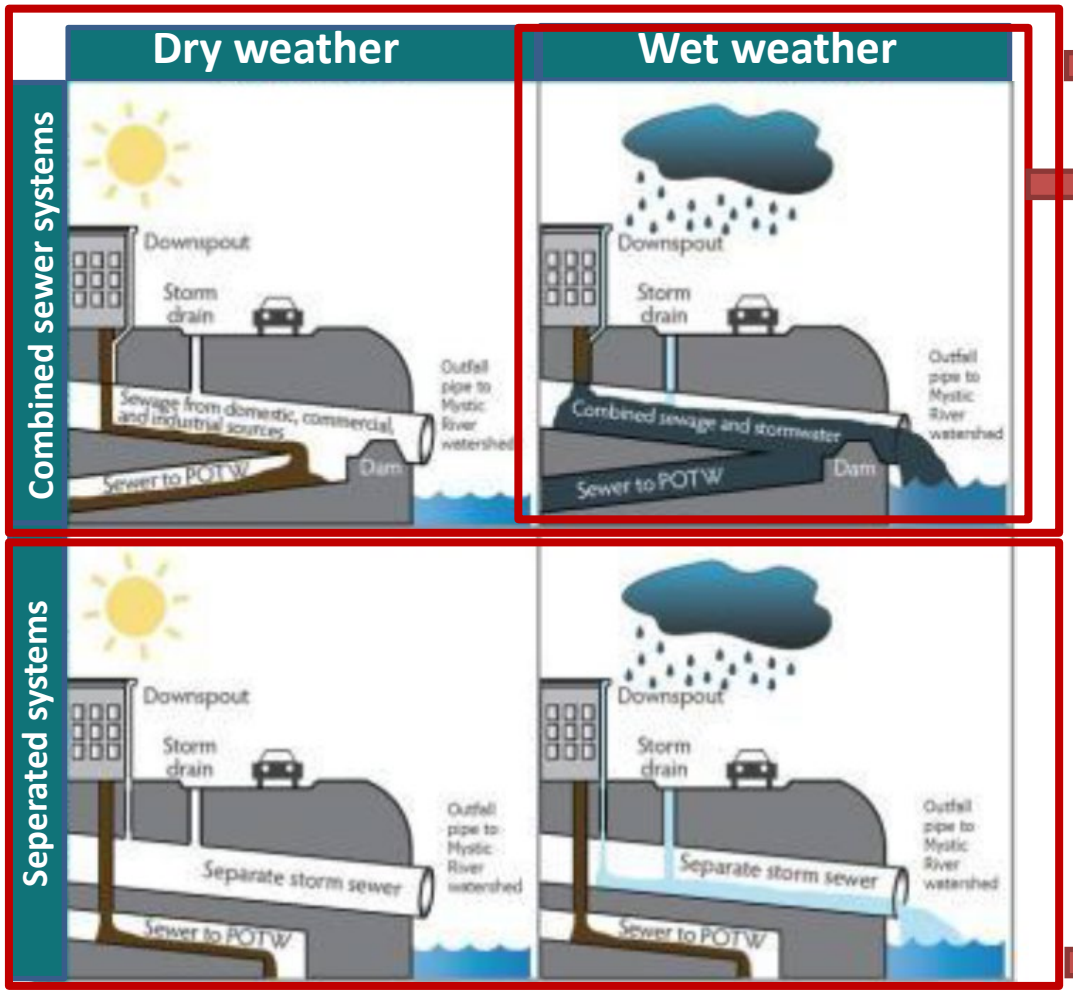
- Definitions
- Provincial regulation and limitations
- Objectives

2. Risk assessment approaches

3. Results and discussion

4. Conclusion

Sewerage system



Source: USEPA

Combined sewer systems (CSSs)

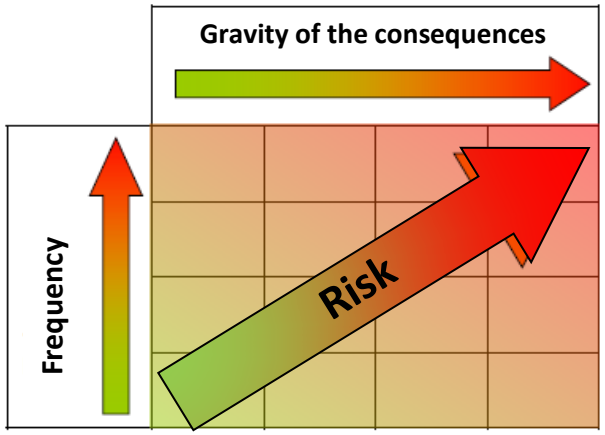
Combined sewer overflows (CSOs)

- Exceeding the wastewater treatment plant's capacity
- Untreated discharge of a combination of wastewater and urban runoff
- Microbial pathogens, physico-chemical contaminants and emerging contaminants

Separated systems

Provincial regulation and limitations

- **Approach required by the regulation: deterministic approach**



Anthropogenic risk assessment

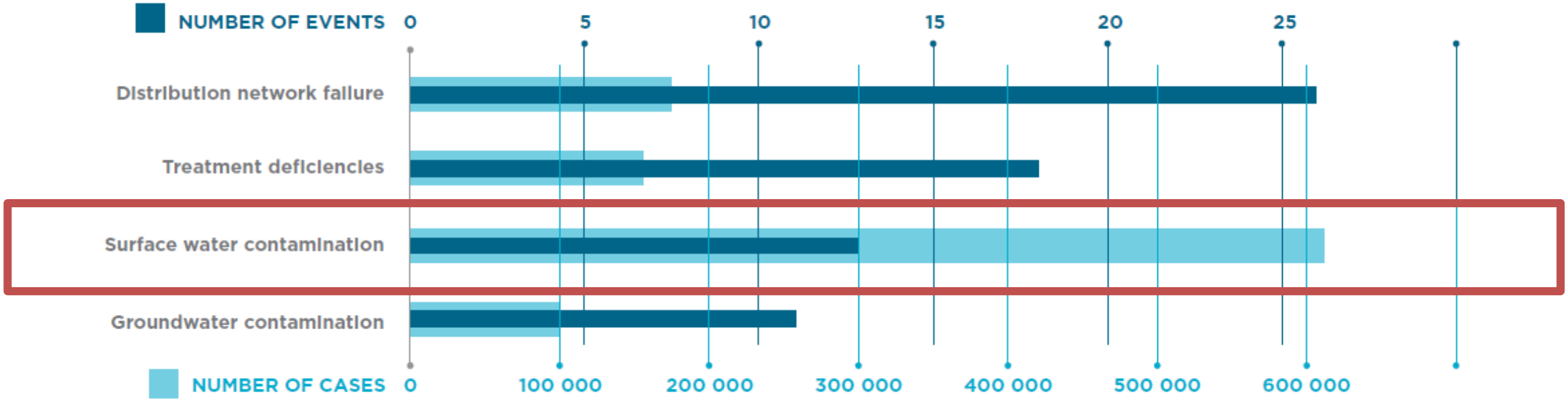
Frequency	Gravity of consequences			
	Minor	Serious	Critical	Catastrophic
Very frequent (≥ 1 time/ week)	Medium	High	Very high	Very high
Frequent (≥ 1 time/ year)	Low	Medium	High	Very high
Occasional (> 1 time/ 5 years)	Very low	Low	Medium	Very high
Rare (≤ 1 time/ 5 years)	Very low	Very low	Low	High

Water withdrawal and protection Regulation

(MELCC, 2018)

Frequency VS Risk level

Contamination of water sources: intrusion of animal faeces due to heavy rain and discharges of wastewater.



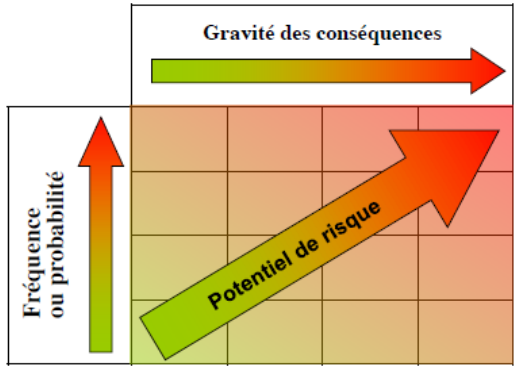
The number of events of waterborne disease outbreaks and the number of cases of illness among consumers in Europe, North America and New Zealand, 2000–2014

(World Health Organization (WHO), 2019)

Regulation VS Research

Regulation

Deterministic method: Risk matrix



(Prévost et al., 2017; Prévost et al., 2011)

Research

- **Targeted water sampling and laboratory analysis**

(Al Aukidy and Verlicchi, 2017; Calderon et al., 2017; Madoux-Humery et al., 2015; Passerat et al., 2011)

- **Real-time measurement of biochemical indicator of fecal pollution using ColiMinder**

(Burnet et al., 2021; Sylvestre et al., 2021)

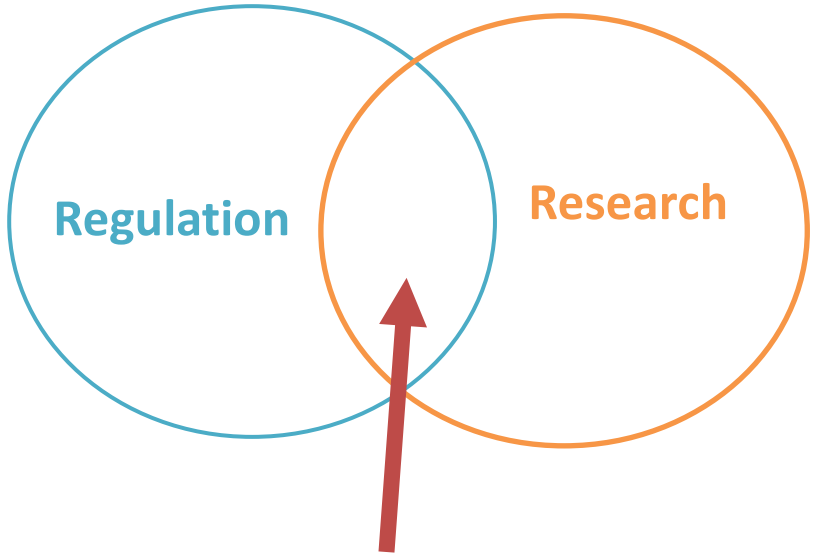
- **Quantitative Microbial Risk Assessment (QMRA) with Monte Carlo simulations**

(Sylvestre et al., 2020; Taghipour et al., 2019)

- **Contaminant transport modeling**

(Taghipour et al., 2019)

Objective

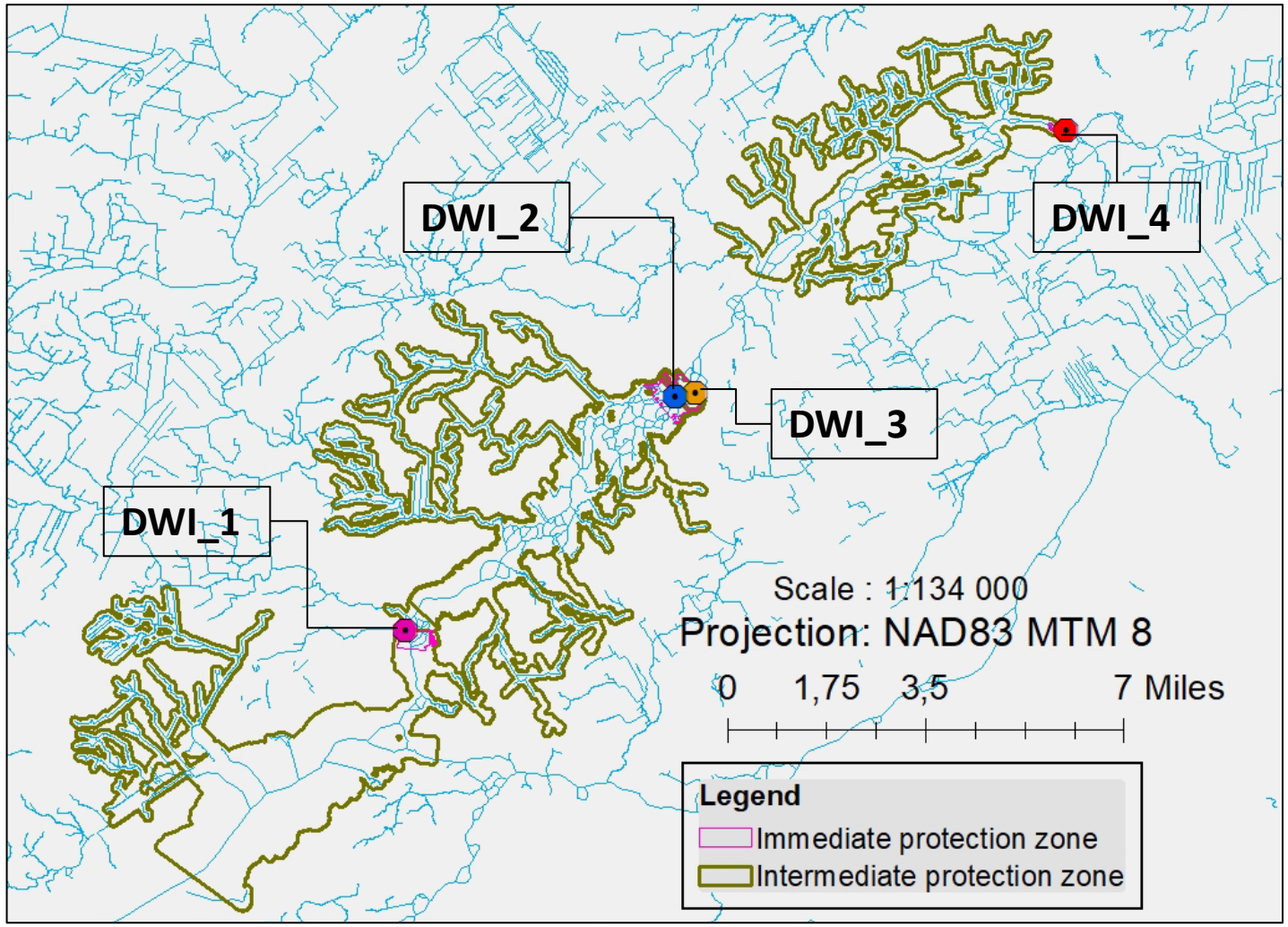


The purpose of this research is to bridge the gap between the regulatory oversight and the research fields to establish a method for assessing the risk posed by CSOs upstream drinking water intakes (DWIs)

Specific criteria

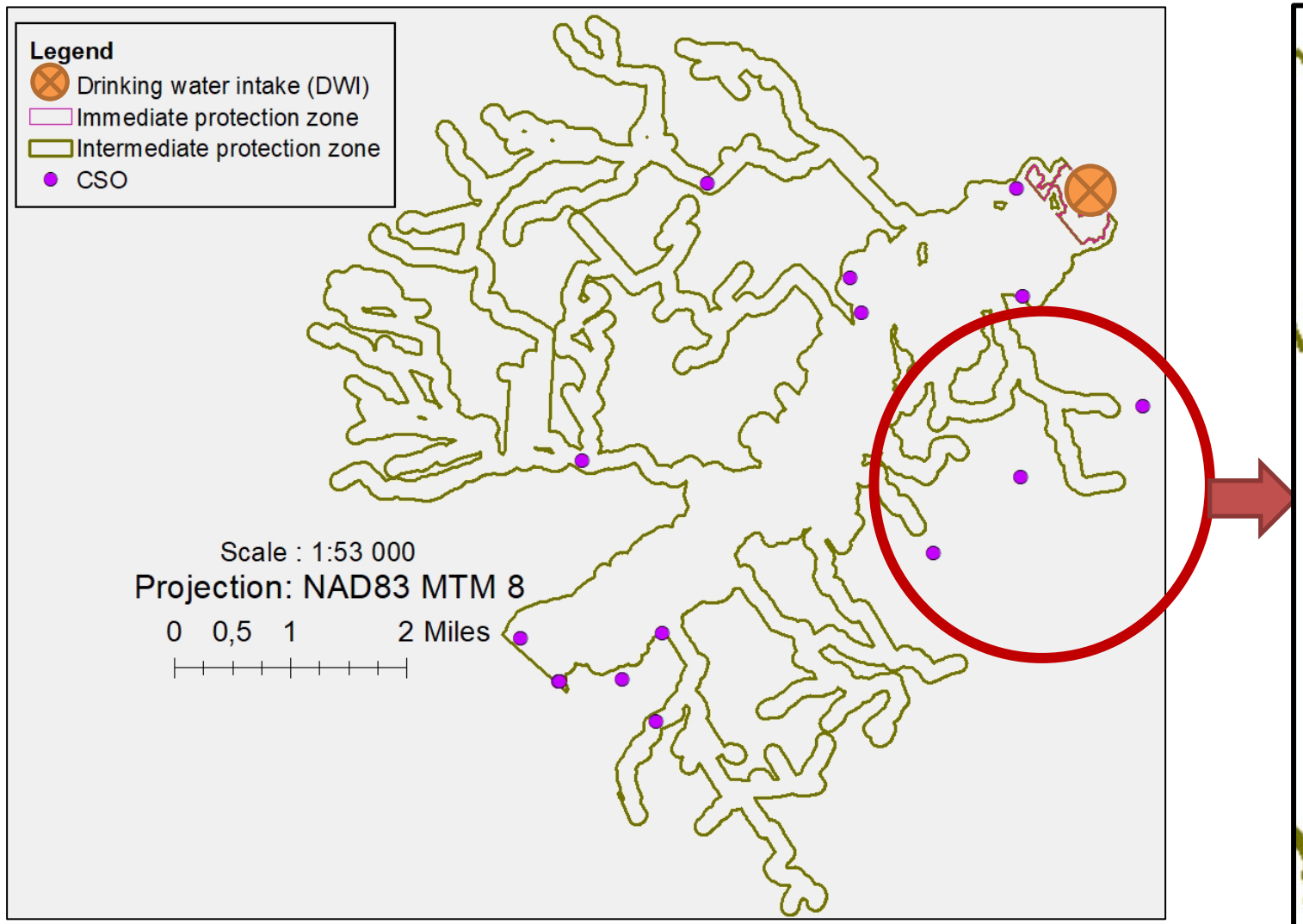
- Approach must be **easily applicable** in practice by managers of drinking water treatment plants
- Use **only data available** in provincial and federal databases
- Provide a **range of potential risk level** outcomes linked to **uncertainty and variability** rather than providing a single risk level estimated for a single hazard scenario

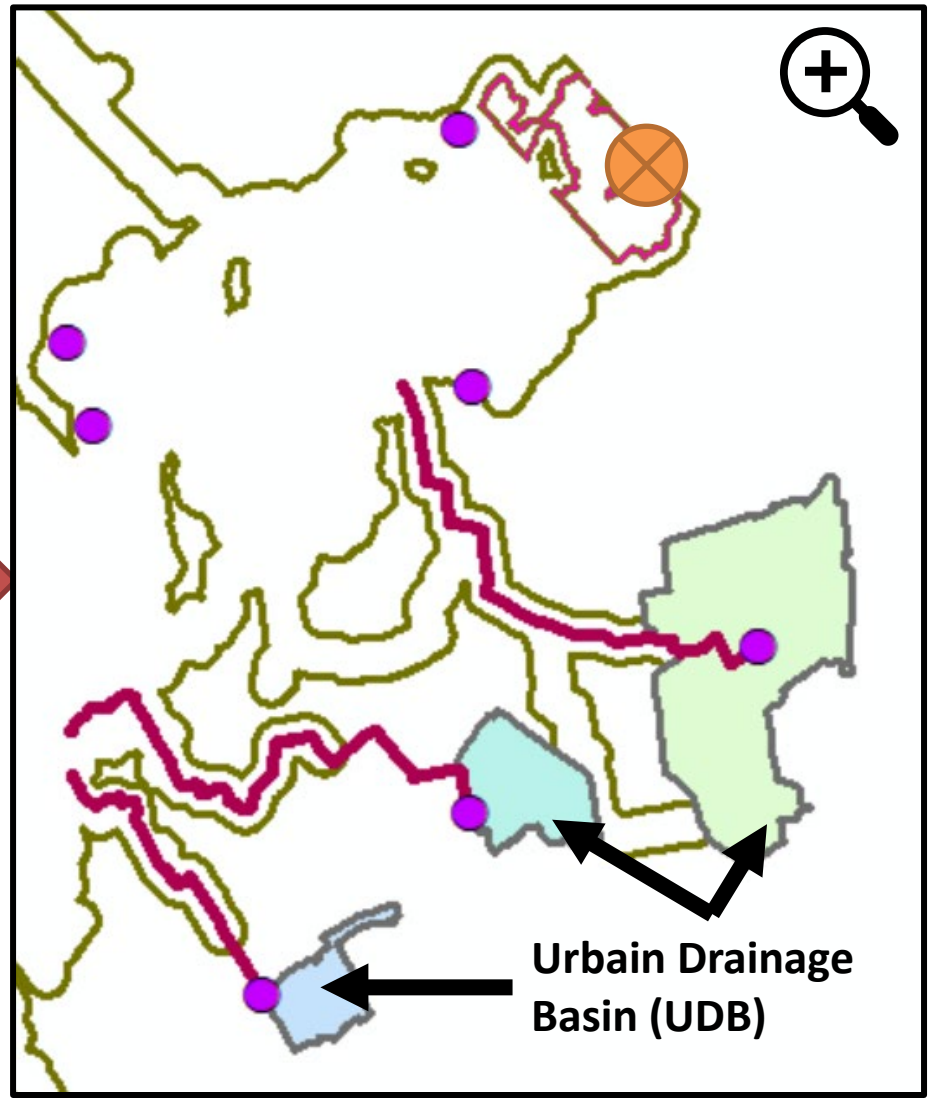
Study site



- Highly urbanized source water
- Four drinking water intakes (DWIs) located in southern Quebec
- Inventory of CSOs in the immediate and intermediate protection zones
- Total of 89 CSO outfalls

Urban Drainage Basin (UDB)

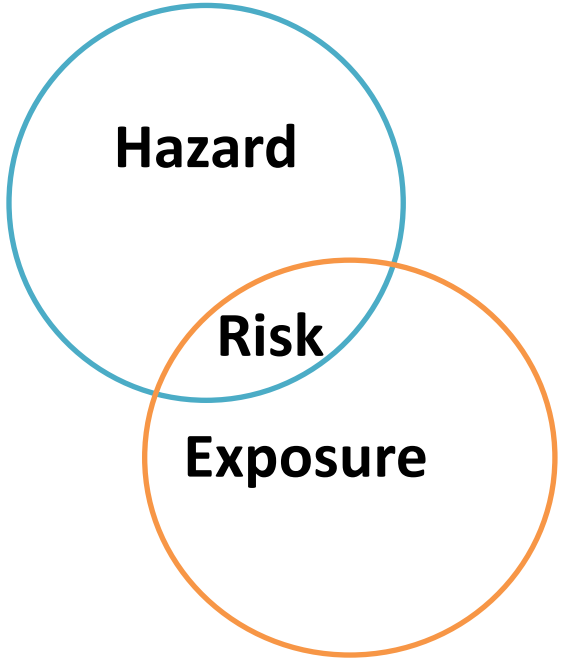




Deterministic approach

$$\boldsymbol{DEU-1} = D^2 \; x \; MAX \sum_{i=i}^{n} Overflow\ duration \; x \; \text{Pop UDB}$$

$$\boldsymbol{DEU-2} = \frac{DEU-1}{\ln(dist\ riv)}$$



$$\boldsymbol{DEU-1F} = D^2 \; x \; MAX \sum_{i=i}^{n} Number\ of\ overflow \; x \; \text{Pop UDB}$$

$$\boldsymbol{DEU-2F} = \frac{DEU-1F}{\ln(dist\ riv)}$$

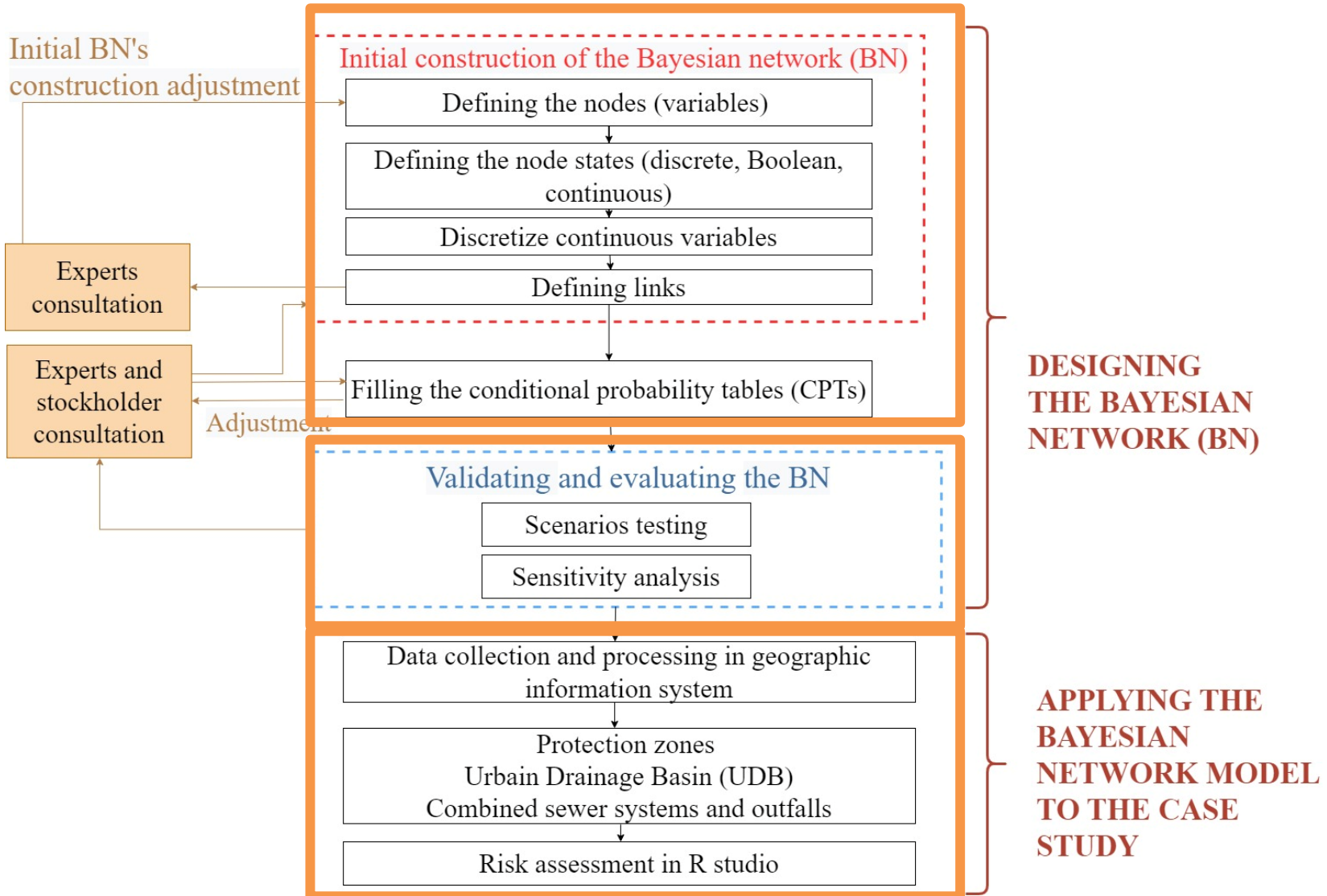
(McQuaid et al., 2019)

Deterministic approach

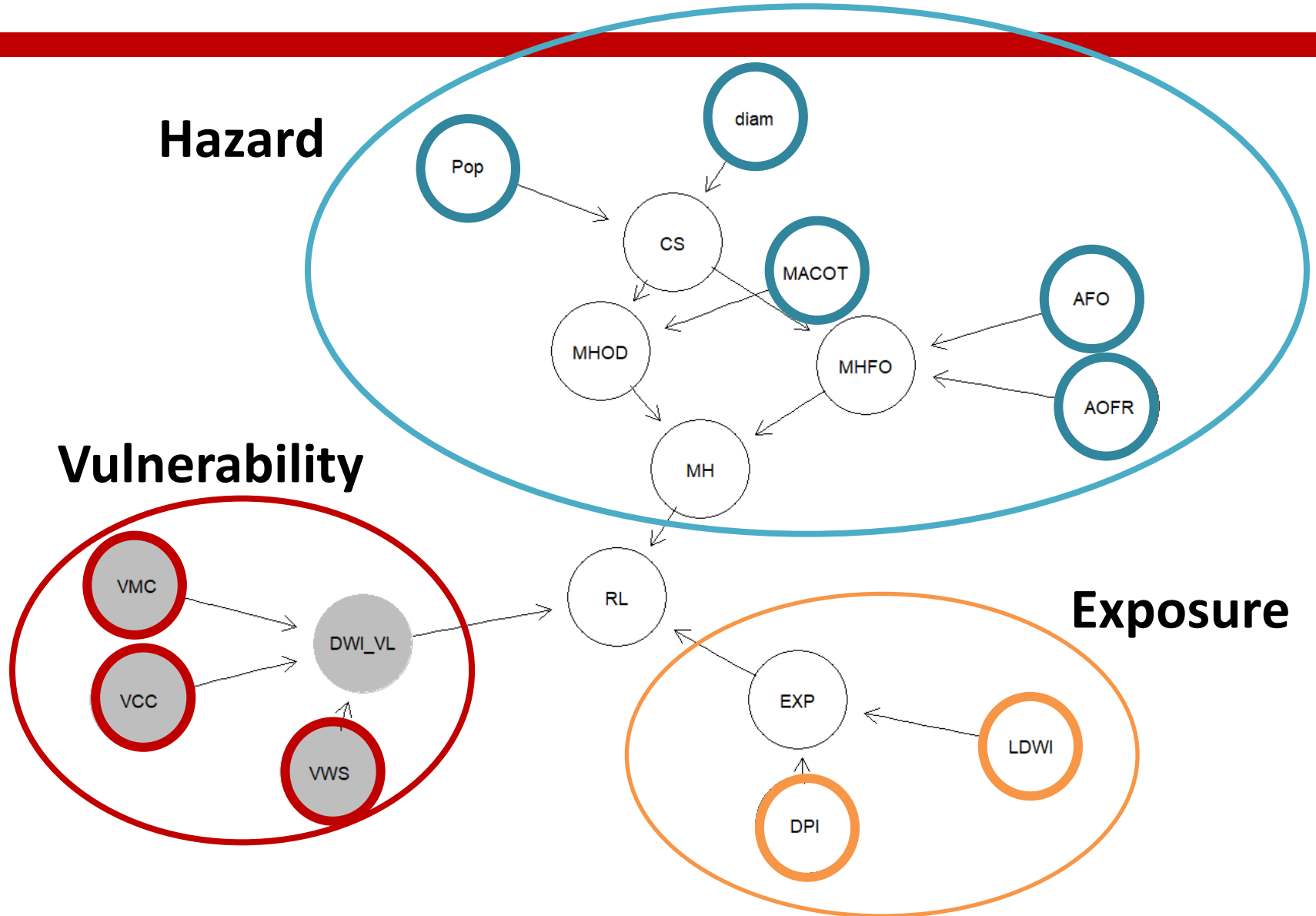
Risk level	Very low	Low	Medium	High	Very high
DEU-2	<5	5-2 700	2 701-46 000	46 001- 475 000	> 475 000
DEU-2F	<5	5-235	236-2 400	2 401-25 000	> 25 000

(McQuaid et al., 2019)

Probabilistic approach

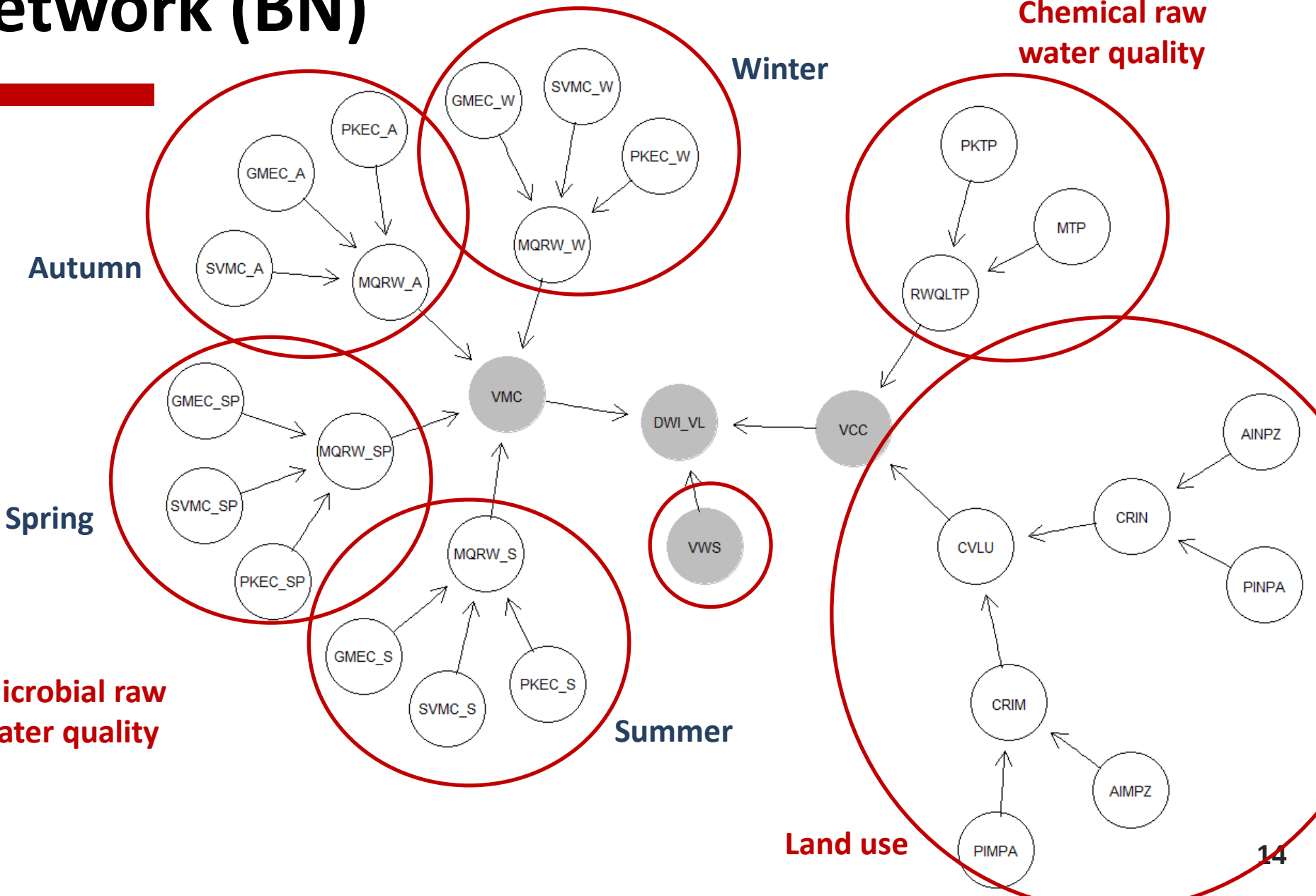


Bayesian network (BN)



Bayesian network (BN)

Drinking water intake vulnerability level (DWI_VL)

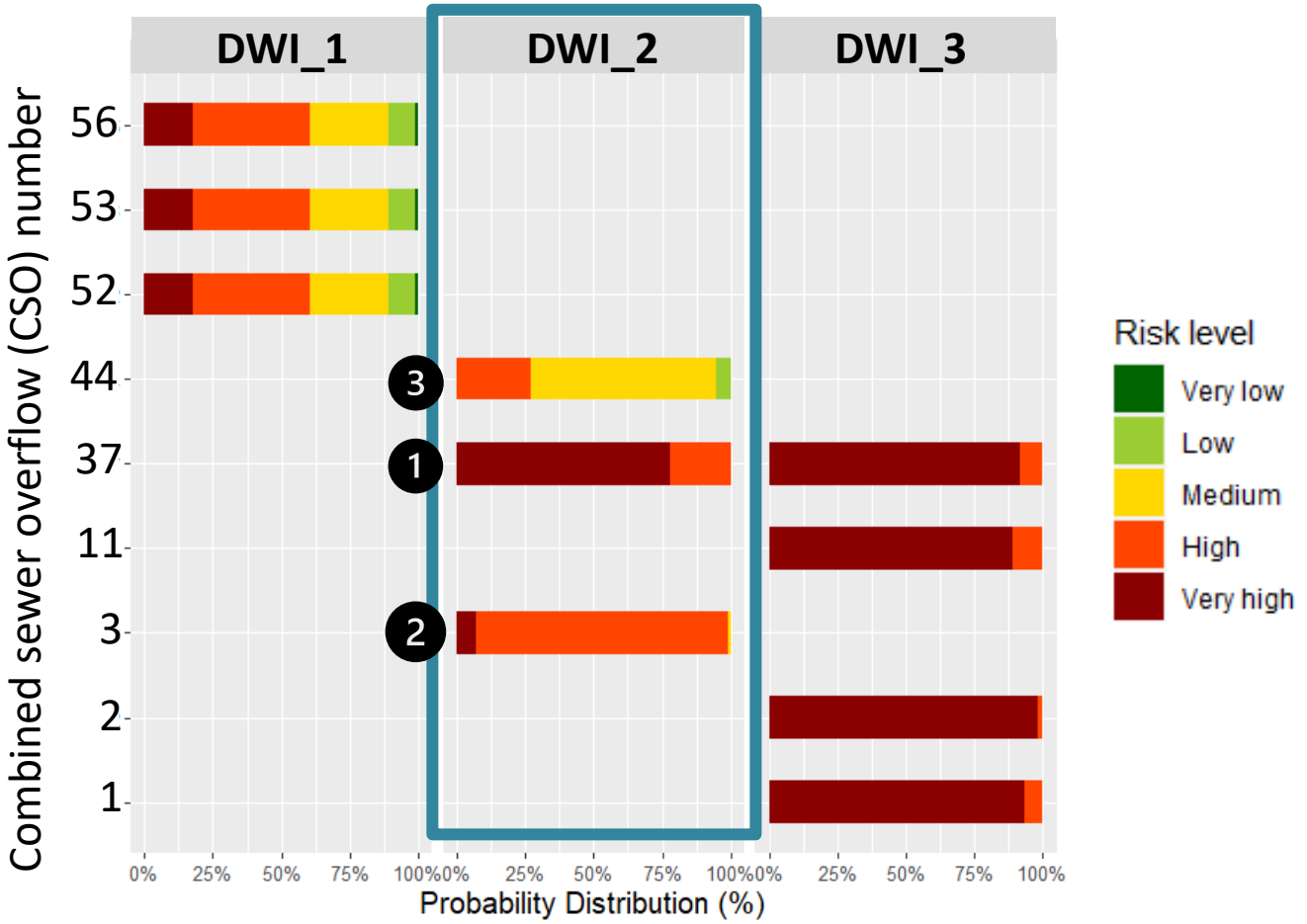


Results and discussion

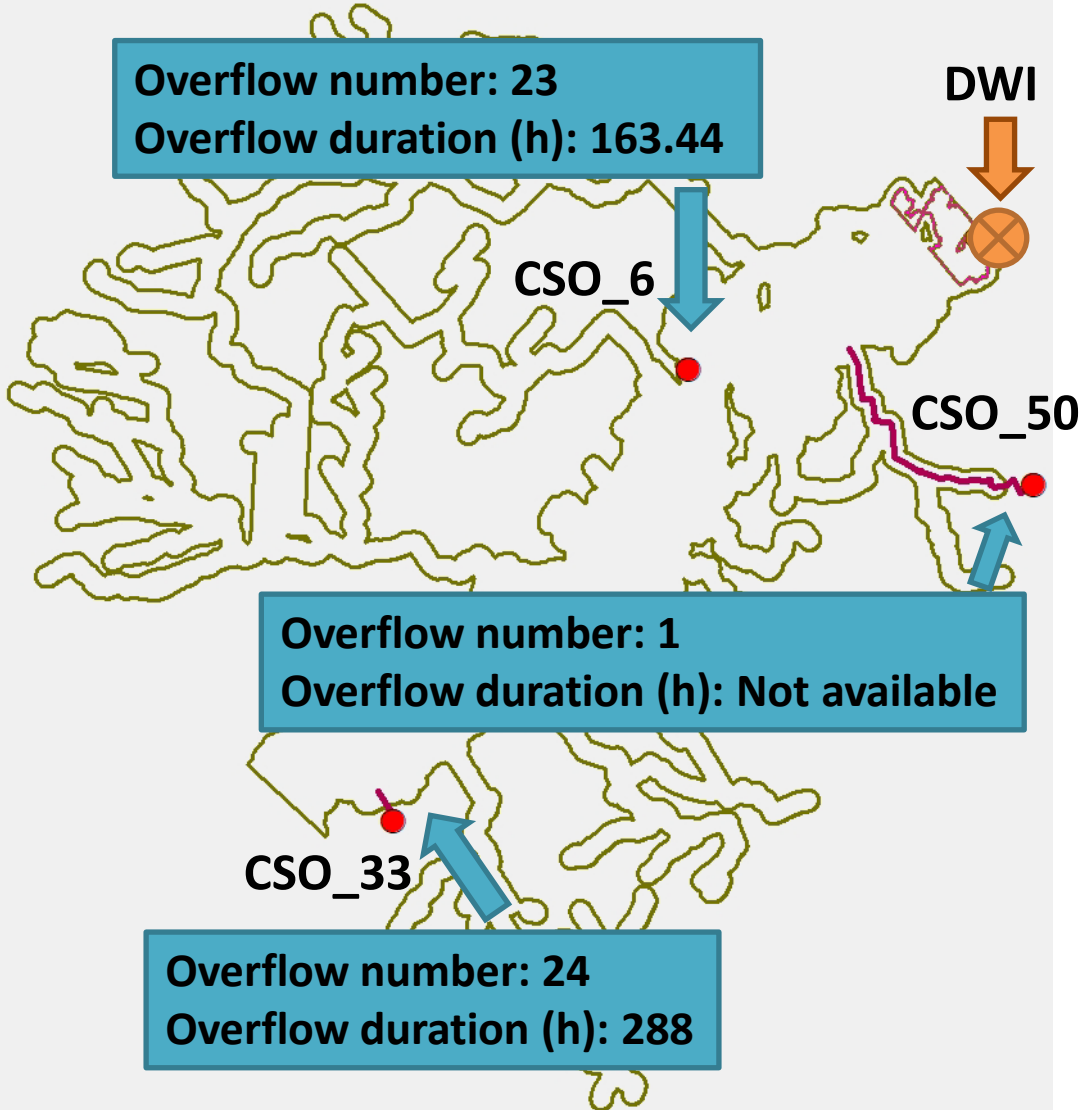
Deterministic approach

CSO	DWI downstream	Risk level
CSO_56	DWI_1	Very high
CSO_53	DWI_1	
CSO_52	DWI_1	
CSO_44	DWI_2	
CSO_37	DWI_2	
	DWI_3	
CSO_11	DWI_3	
CSO_3	DWI_2	
CSO_2	DWI_3	
CSO_1	DWI_3	

Probabilistic approach



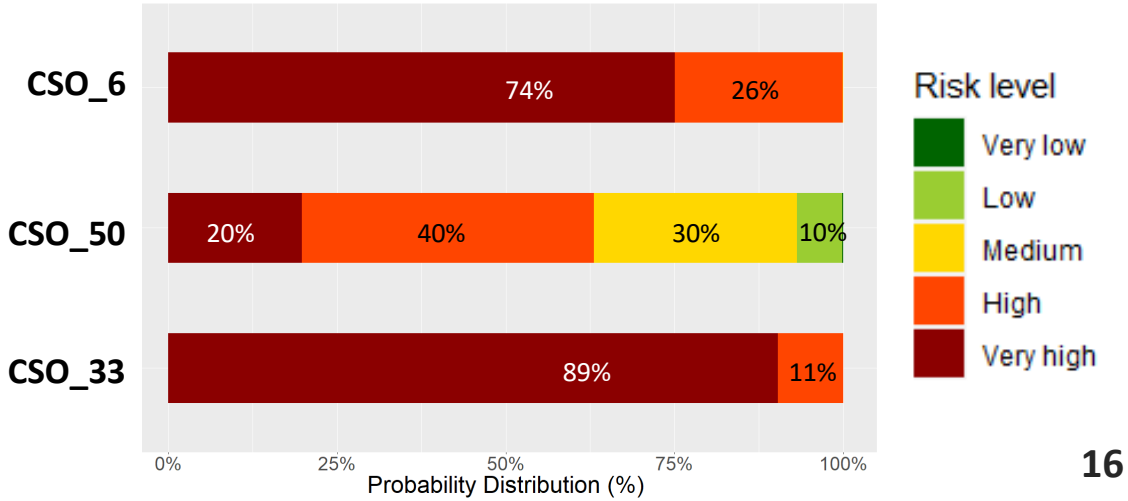
Probabilistic VS Deterministic



Deterministic approach

CSO	Risk level
CSO_6	High
CSO_50	
CSO_33	

Probabilistic approach



Lack of data

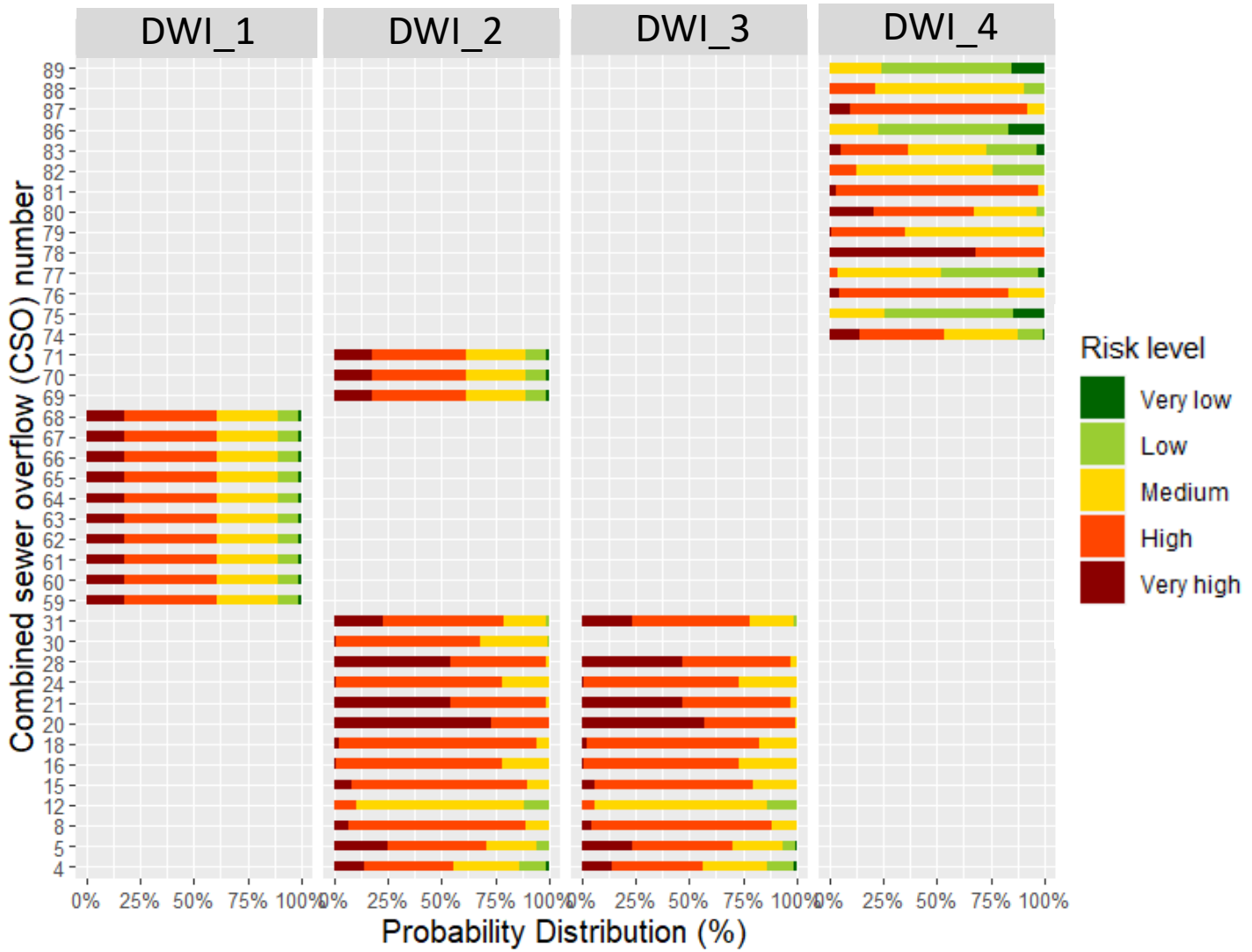
40 CSOs couldn't be assessed using the deterministic approach

Lack of data such as :

- **Diameter of the pipe**
- **Delineation of UDB**
- **Duration and frequency of overflows**

Annual frequency of overflows

AFO	CSO
0 to 1	0.200
1 to 2	0.200
2 to 5	0.200
5 to 14	0.200
>=14	0.200



Conclusion

- Deterministic approach **cannot reflect all possible scenarios** in the final outcome;
- Deterministic approach has **limitations** for **risk prioritization** in a densely urbanized watershed
- The deterministic approach could lead to a **misplaced risk management decision**, as it only considers the impact of a **single risk scenario**
- The Bayesian network (BN) is a valuable tool for conducting a probabilistic approach **under uncertainty** and integrating **different types of knowledge**
- The findings also show that this probabilistic model can handle an **incomplete input dataset**
- Probabilistic outcomes can be used to assist stakeholders in **designing more efficient sampling campaigns** for quantifying microbiological contaminants, in particular CSSs.

Acknowledgements

- Partner municipalities

- Watershed organization

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Thank you and Questions ?

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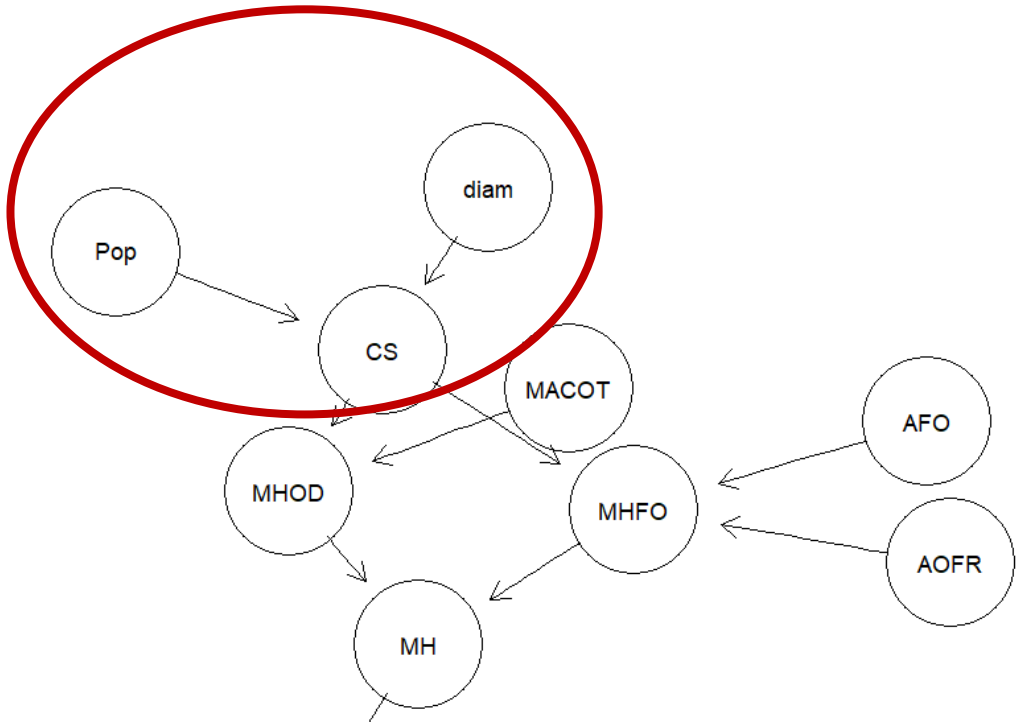
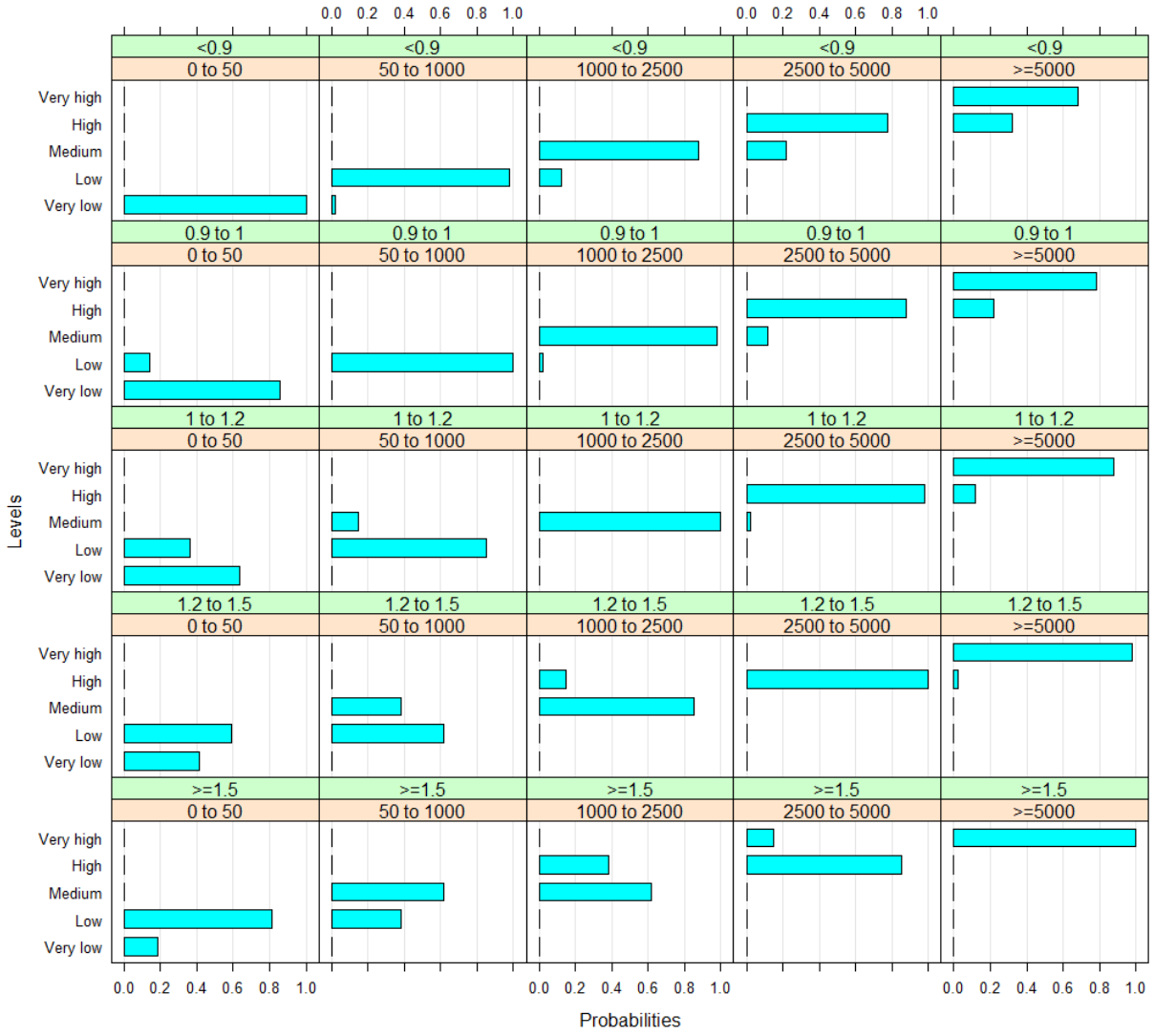
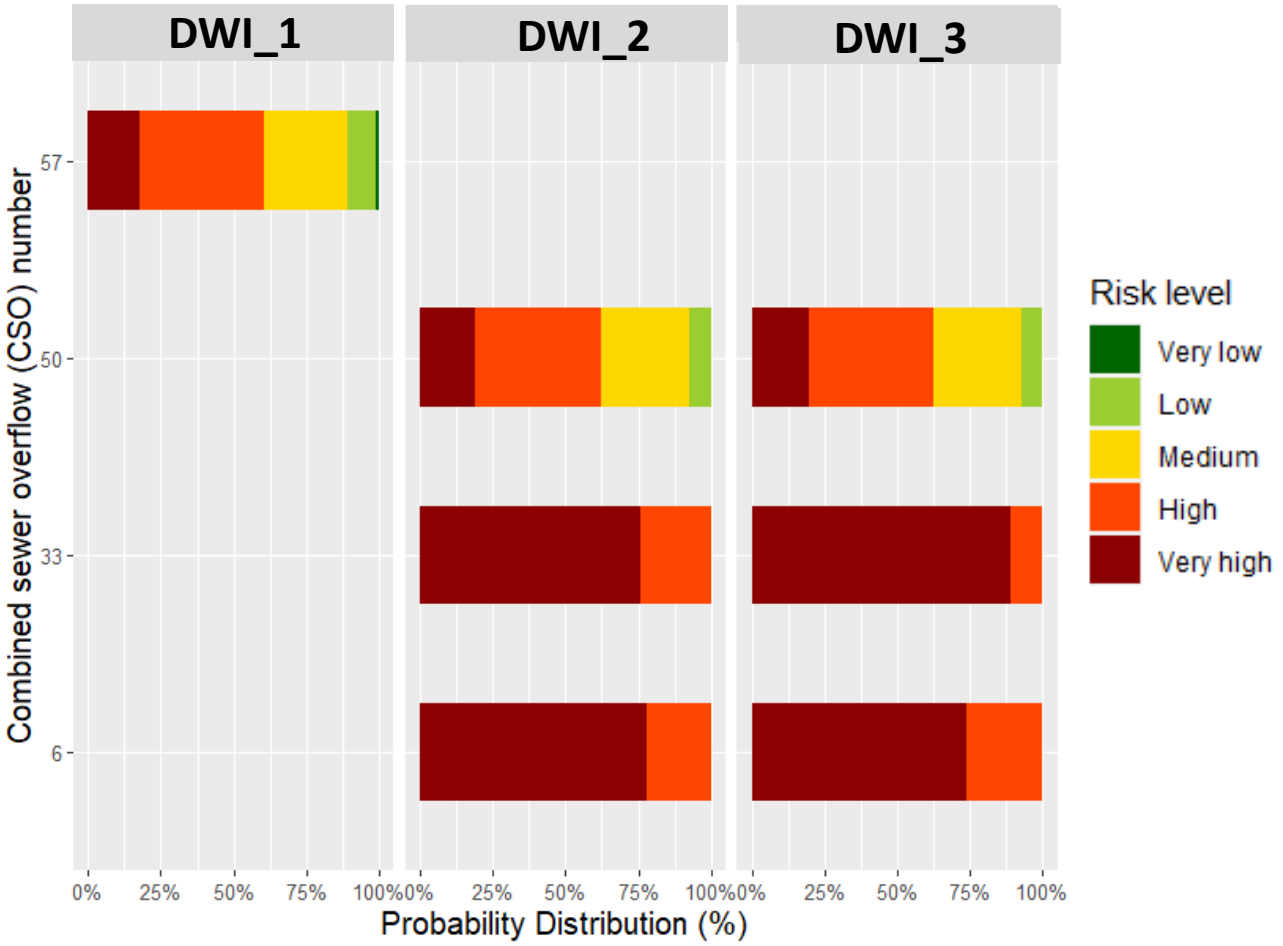
Conditional probability distribution (CPD)



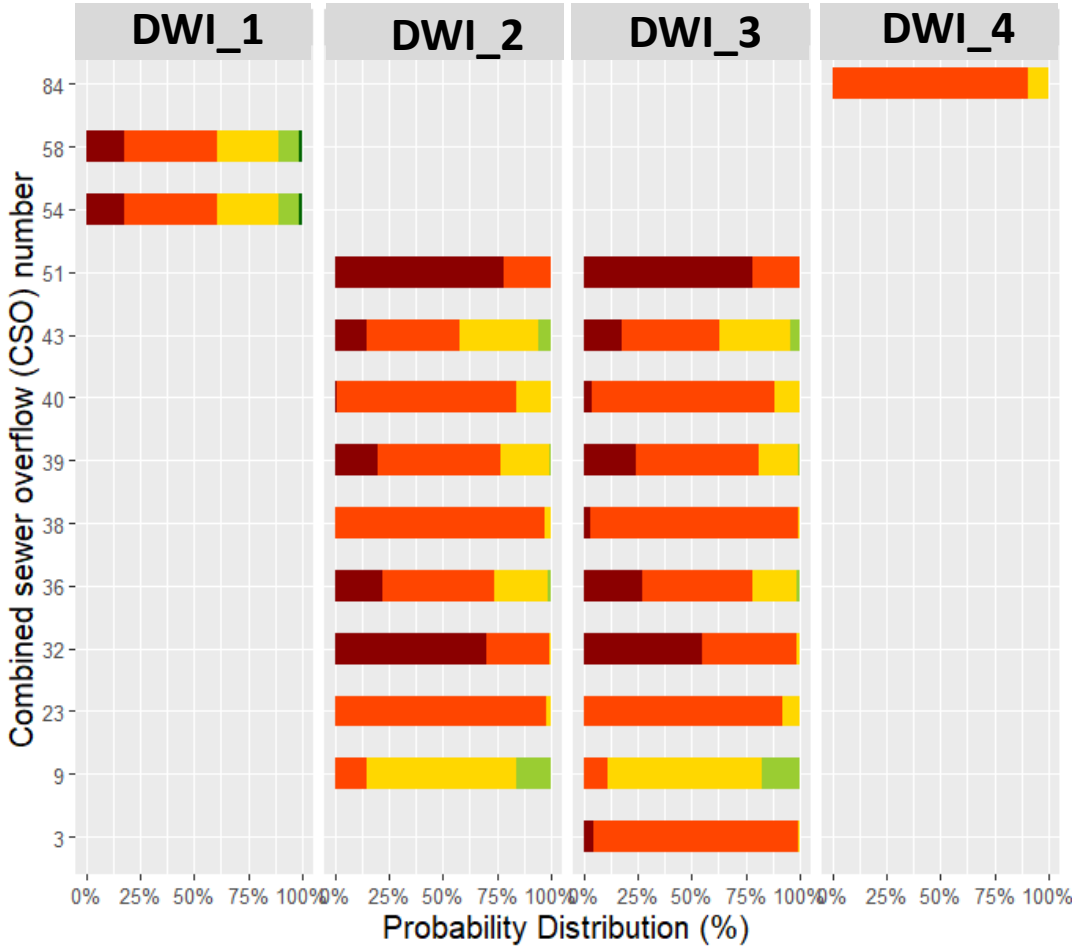


Conditional probability distribution for node ‘consequence severity’

Results and discussion

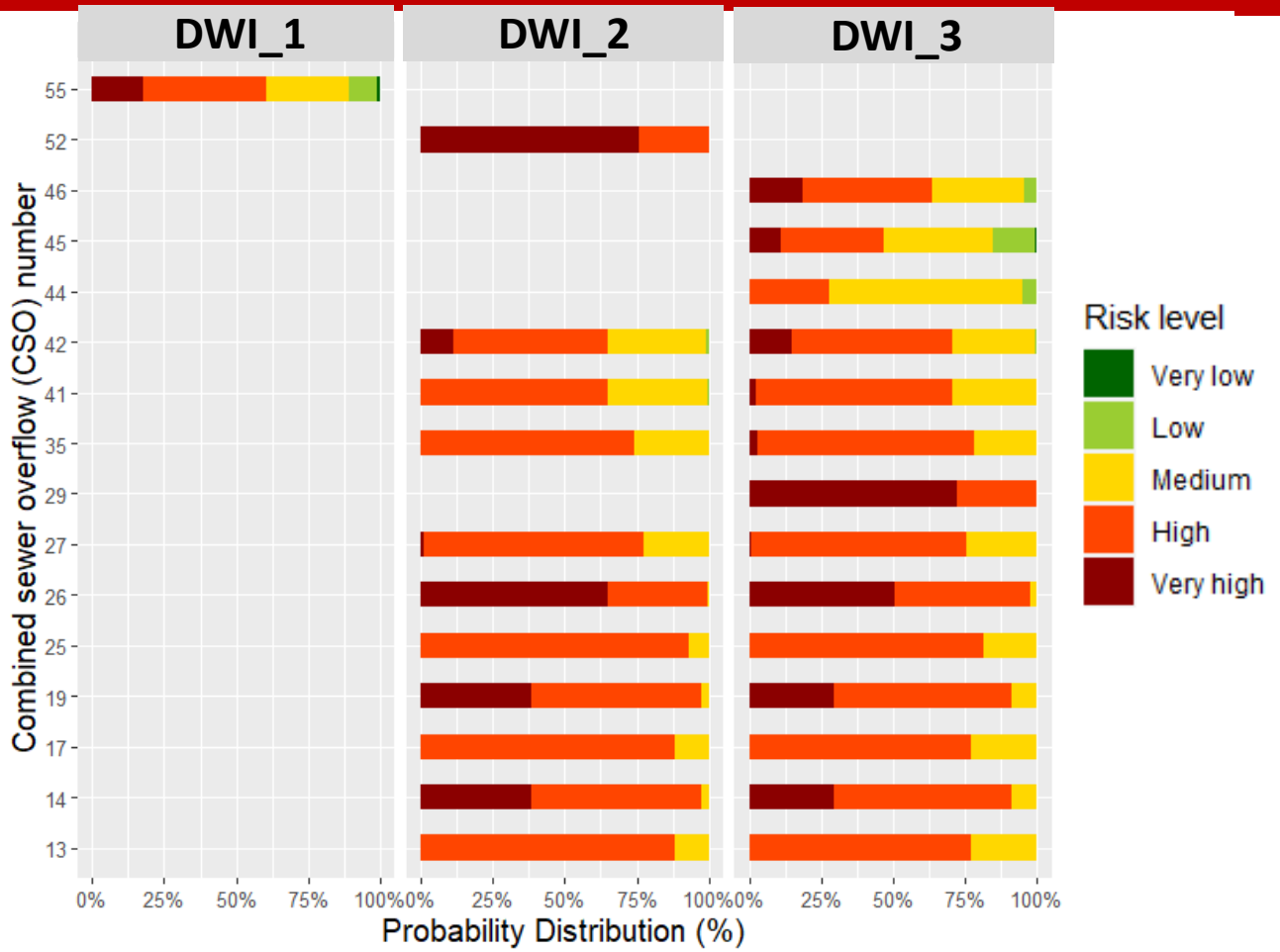


Probabilistic risk of CSO associated with **high risk using deterministic approach**.

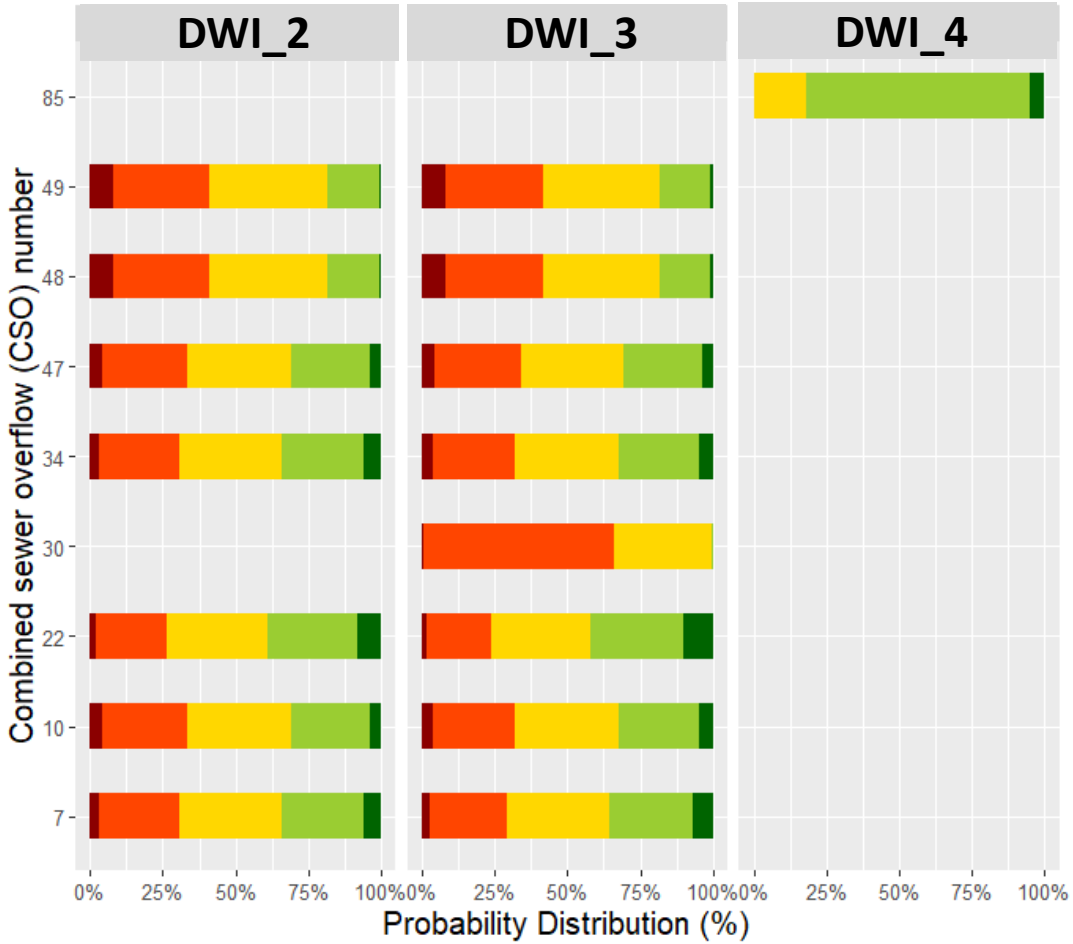


Probabilistic risk of CSOs associated with **medium risk using deterministic approach**.

Results and discussion



Probabilistic risk of CSOs associated with **low risk using deterministic approach.**



Probabilistic risk of CSOs associated with **very low risk using deterministic approach.**