

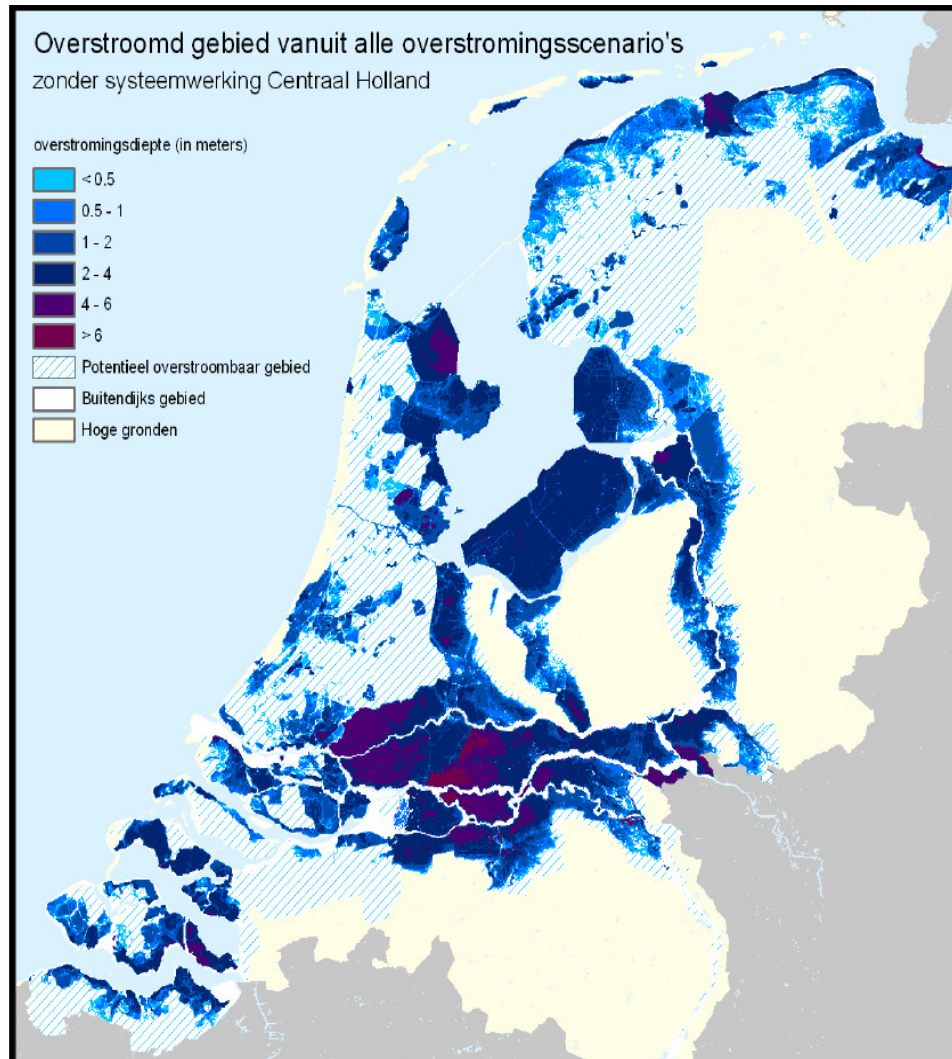
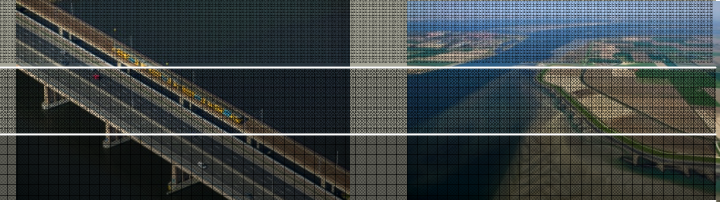


Dutch Approach to Levee Reliability and Flood Risk

Timo Schweckendiek
Deltares & Delft University of Technology

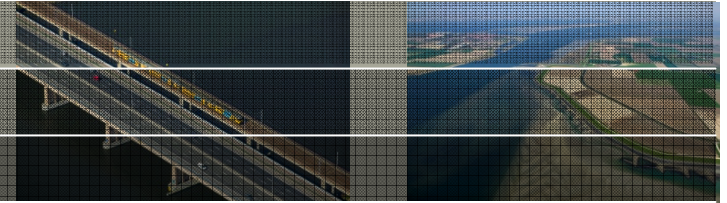
PFHA Workshop, Washington DC, January 29-31, 2013

Outline



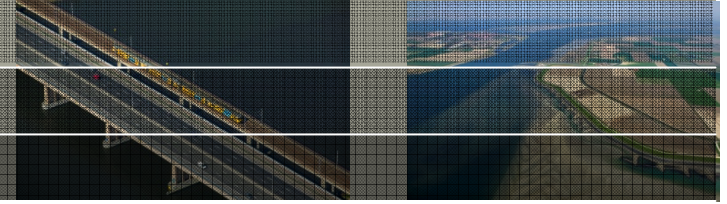
1. Historical Background
2. Reliability and Risk Analysis
3. System Effects

1953 Flood

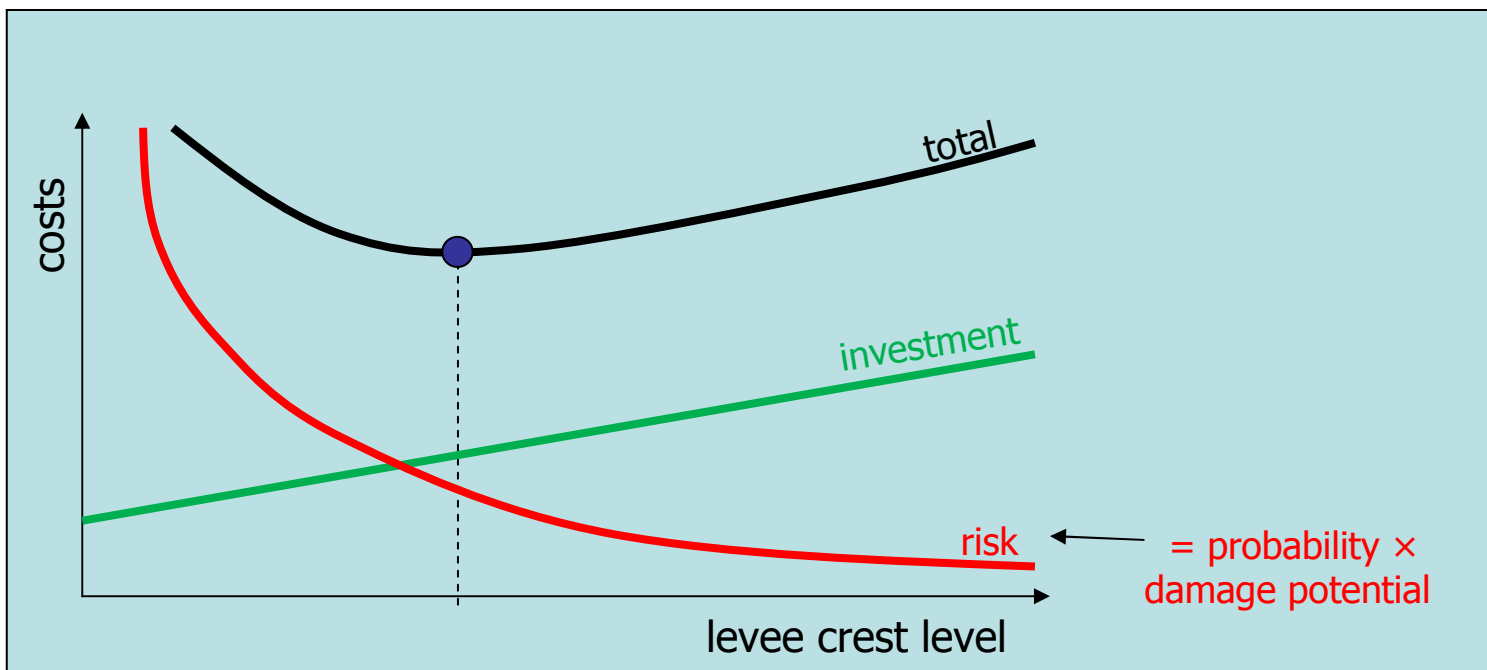


Deltares

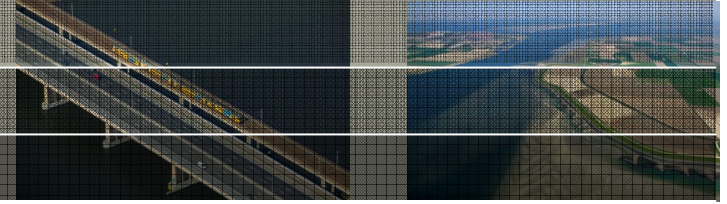
Risk-based optimization



Van Dantzig, D. (1953). "Economic Decision Problems for Flood Prevention." *Econometrica* 24(3): 276-287.



Delta Committee 1953-1955



1. Delta works

2. **Reliability target**
(for Central Holland):

1/125,000 or 8×10^{-6}
(annual probability)



Deltares

Storm surge barriers (delta works)

Risk-based approaches in
Design and Construction Planning:

- hydraulic loads
- structural elements
- geotechnics
- operation and maintenance

Oosterschelde Dam, 1970



Maeslant Barrier, 1990

Safety Standards (Water Act, 1990)

3600km of “primary” flood defenses

57 polders (“dike rings”)

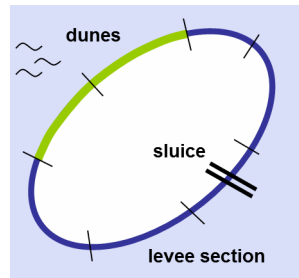
reliability targets per polder

safety assessments every 5 years

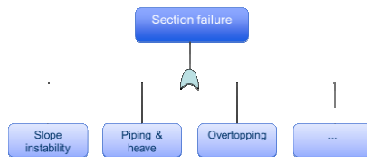
RISK ANALYSIS PER POLDER / DIKE-RING



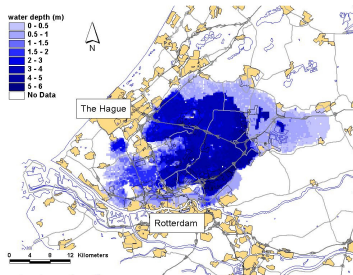
Risk Analysis – Basic Steps (VNK2)



1. Define homogeneous reaches

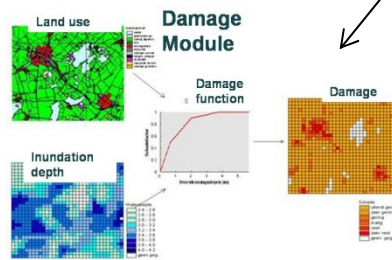


2. Probability of failure per reach



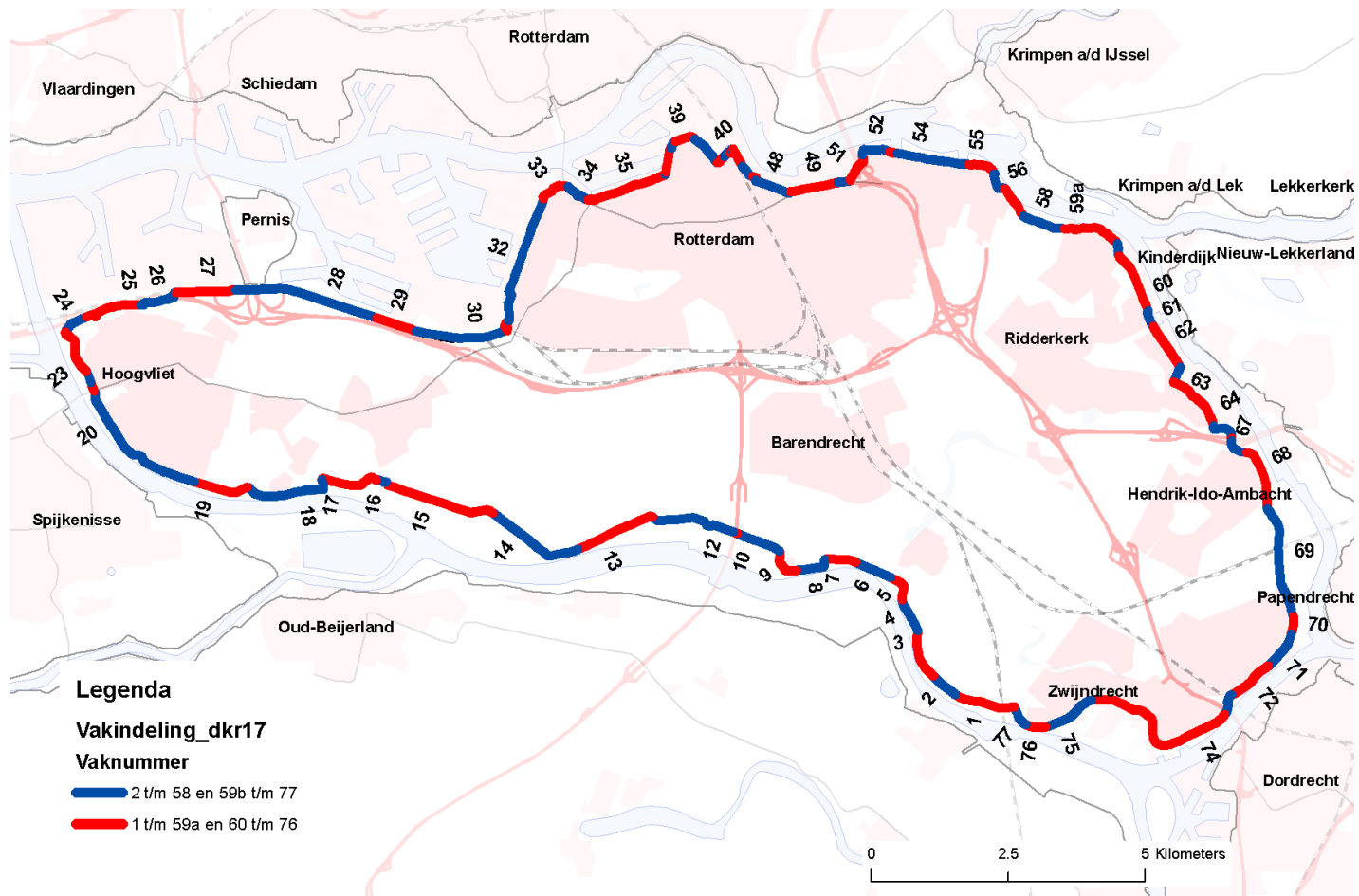
3. Flood scenarios

4. Damage estimates



5. Combine probabilities and consequences

Define homogeneous reaches



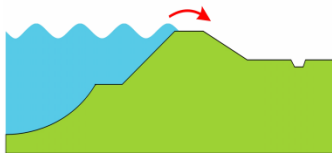
Failure Modes



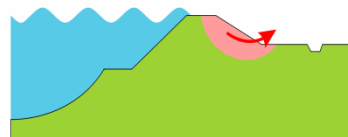
Most important:

Levees

Overtopping



Slope instability



Piping



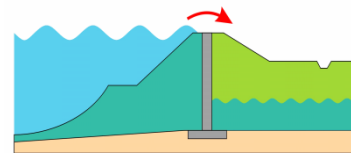
Erosion outer slope



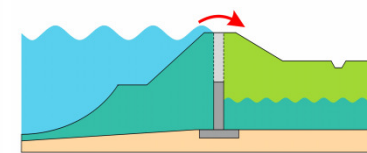
Dunes: Dune erosion

Hydraulic structures

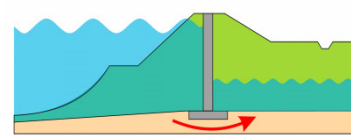
Overtopping



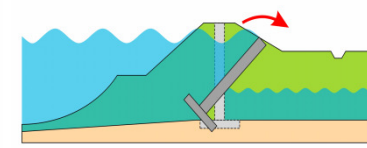
Non-closure



Piping

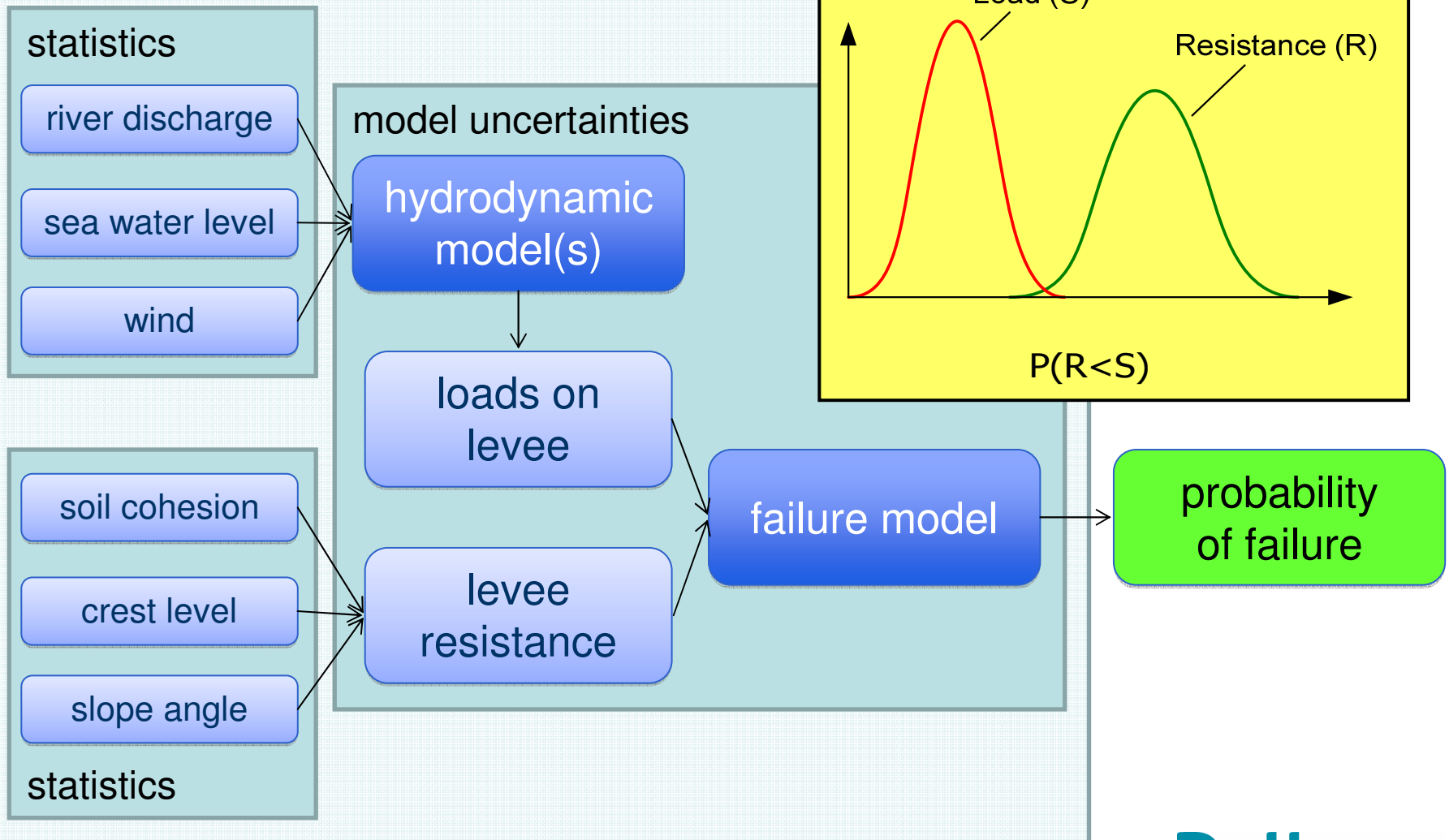


Structural failure

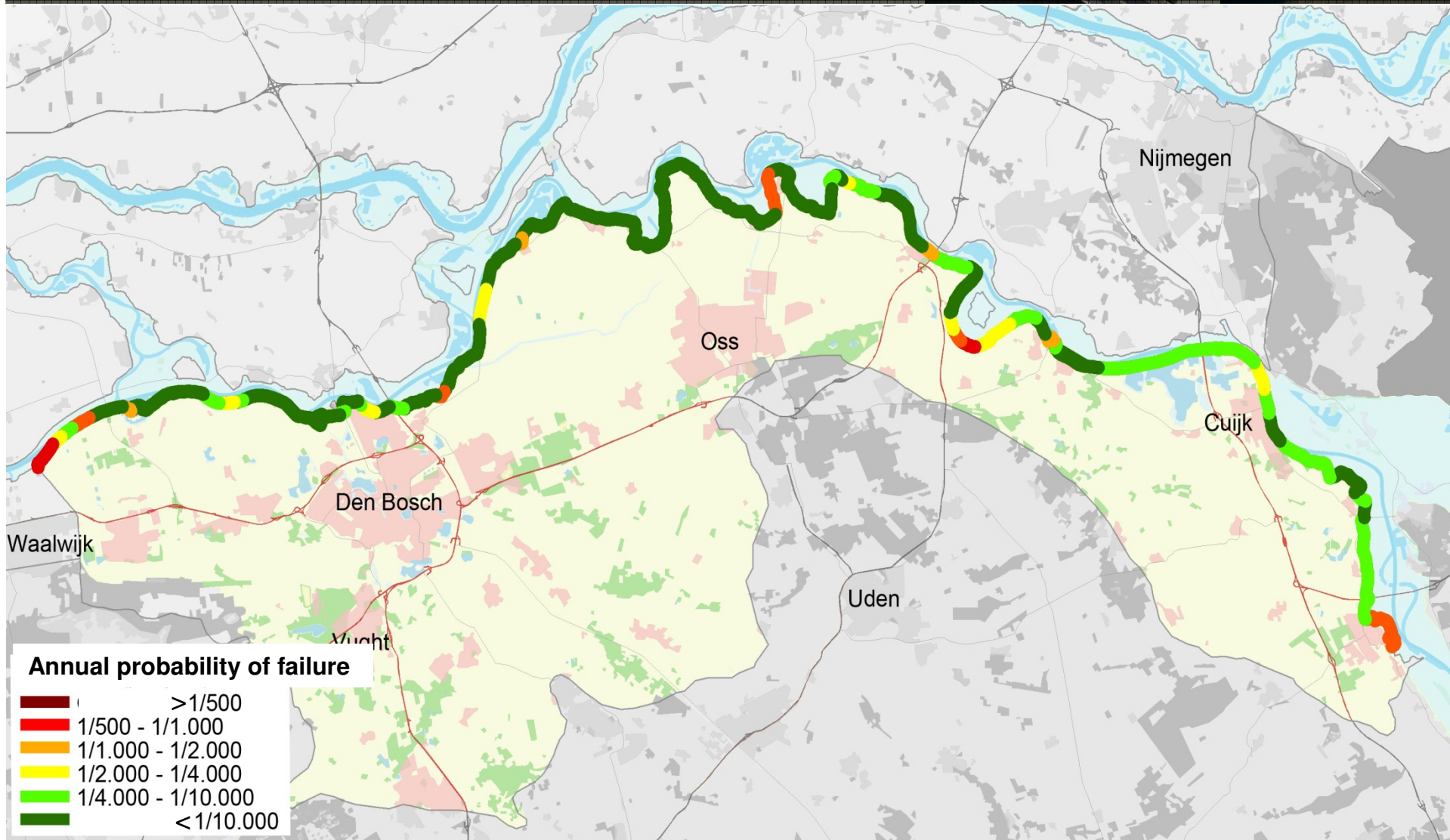


Reliability per Failure Mode (per Reach)

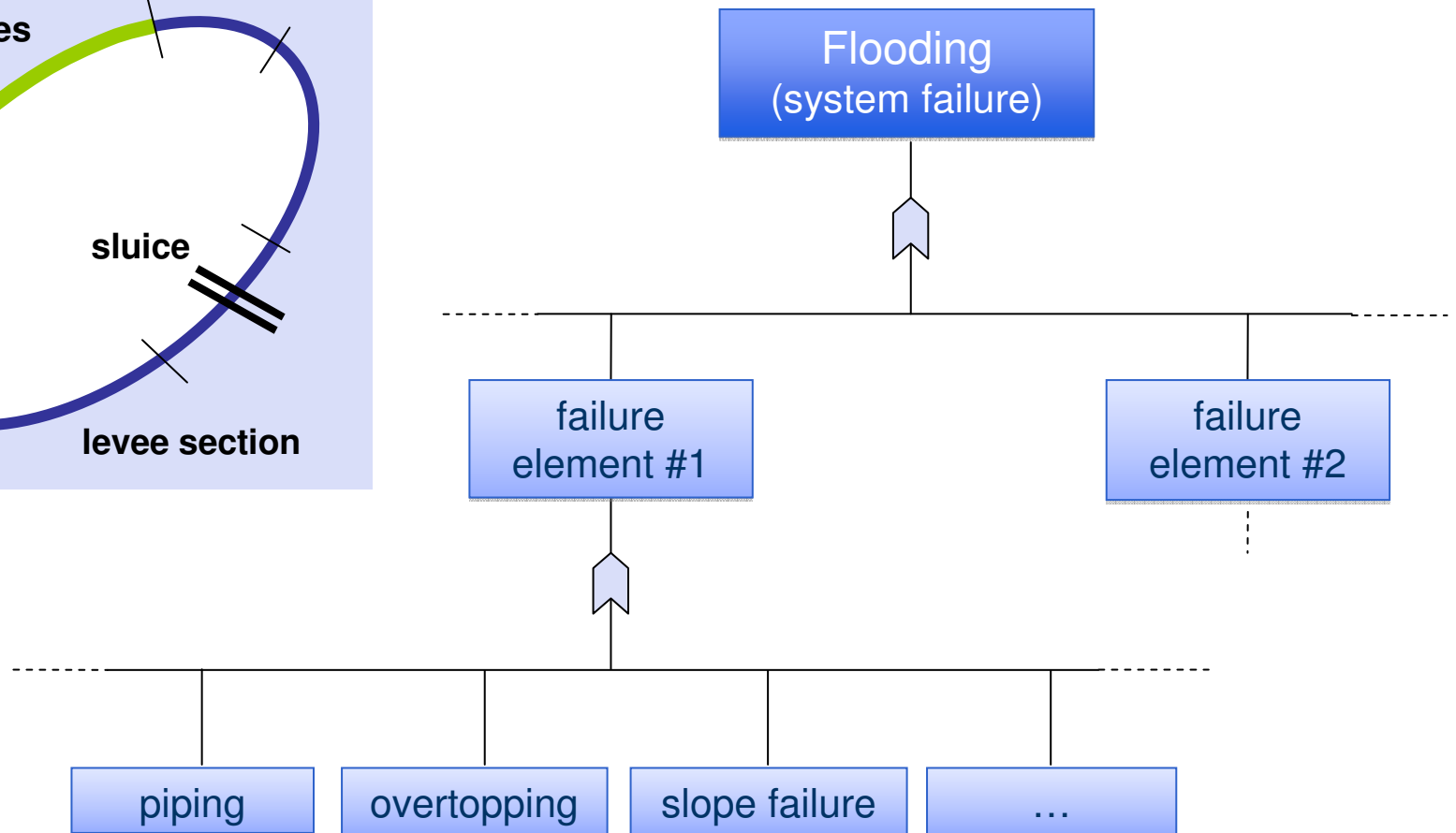
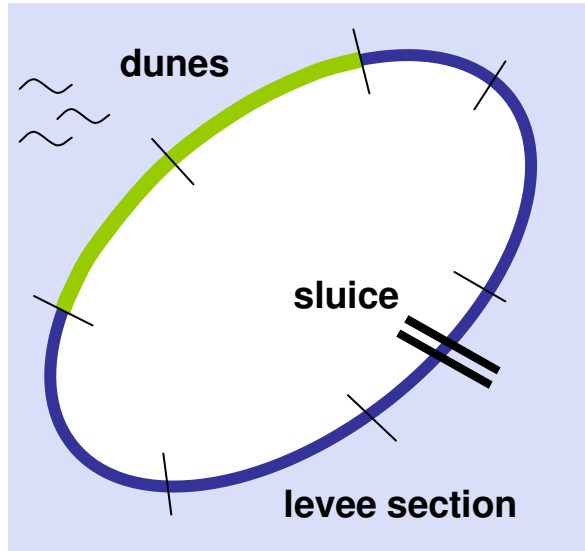
Probabilistic Framework



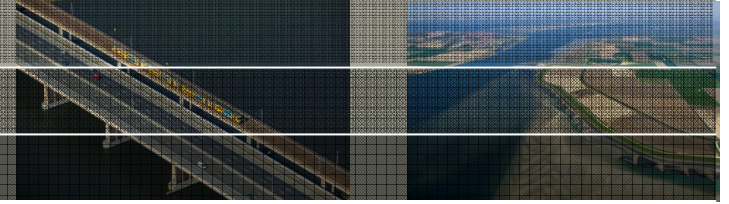
What do the results look like?



System Modeling & Fault Tree

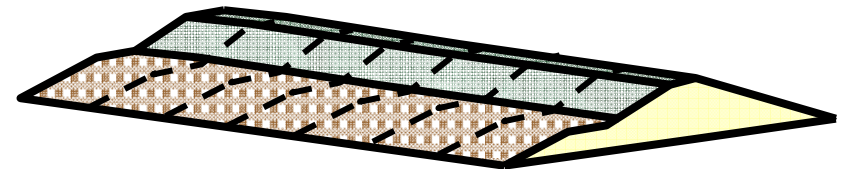


Correlations / Length-Effect



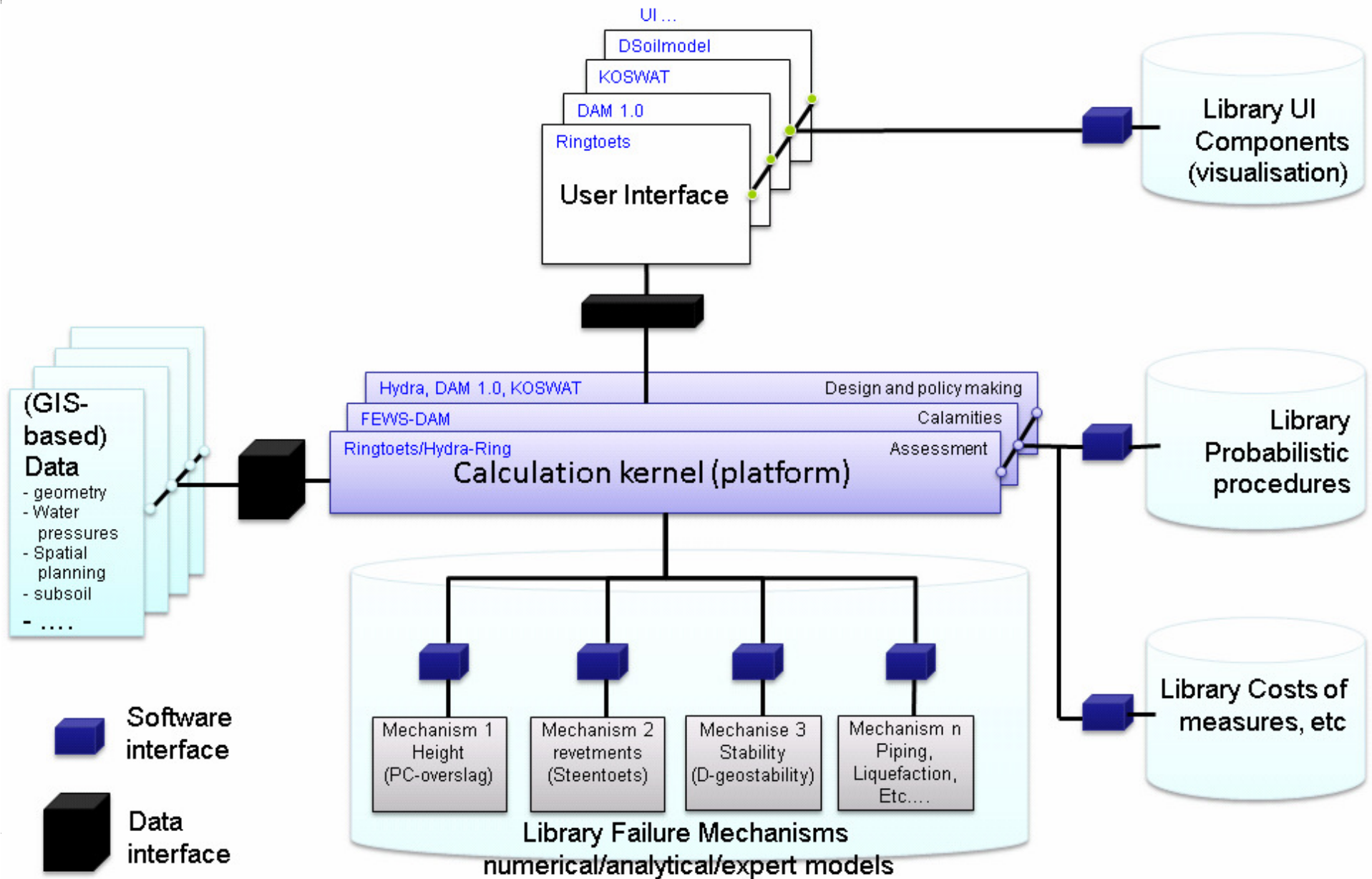
1. BETWEEN FAILURE MODES
(correlated through common variables)

2. BETWEEN REACHES (LENGTH-EFFECT)



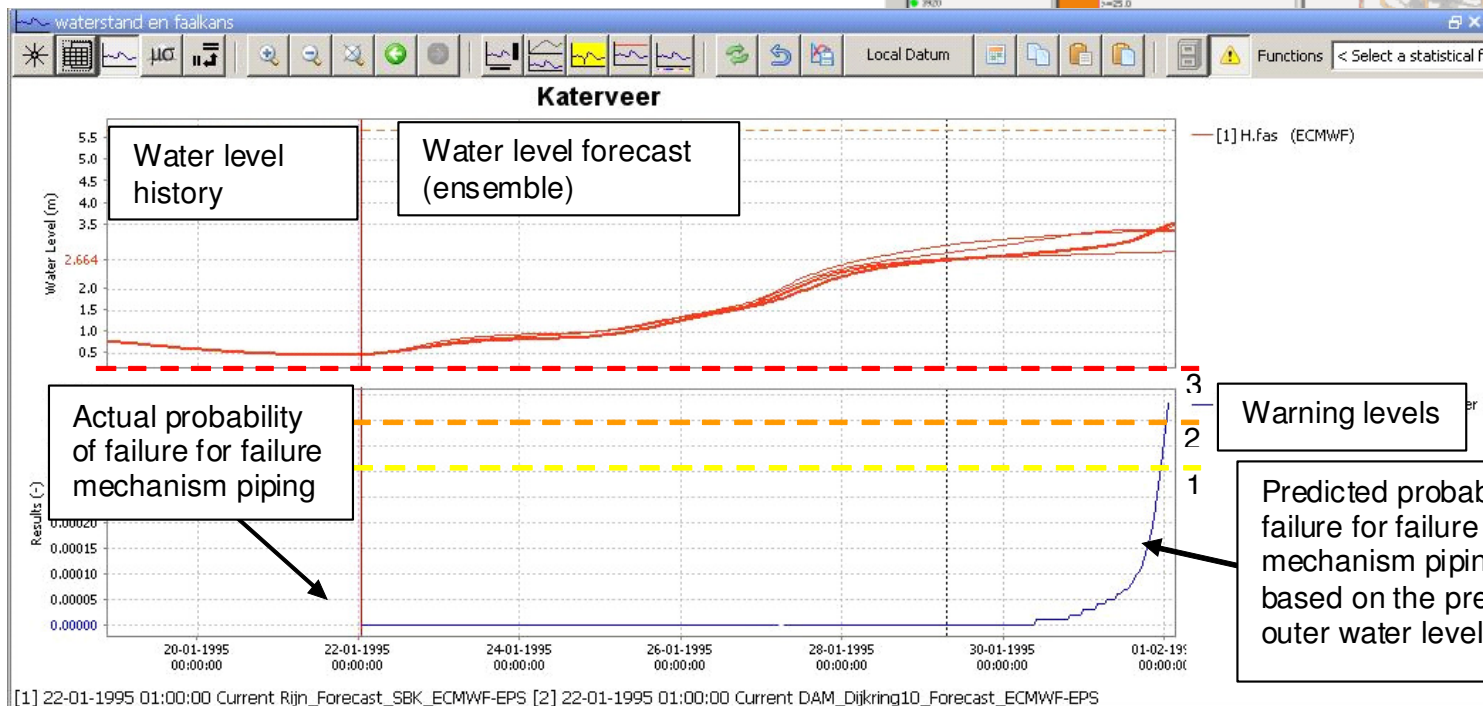
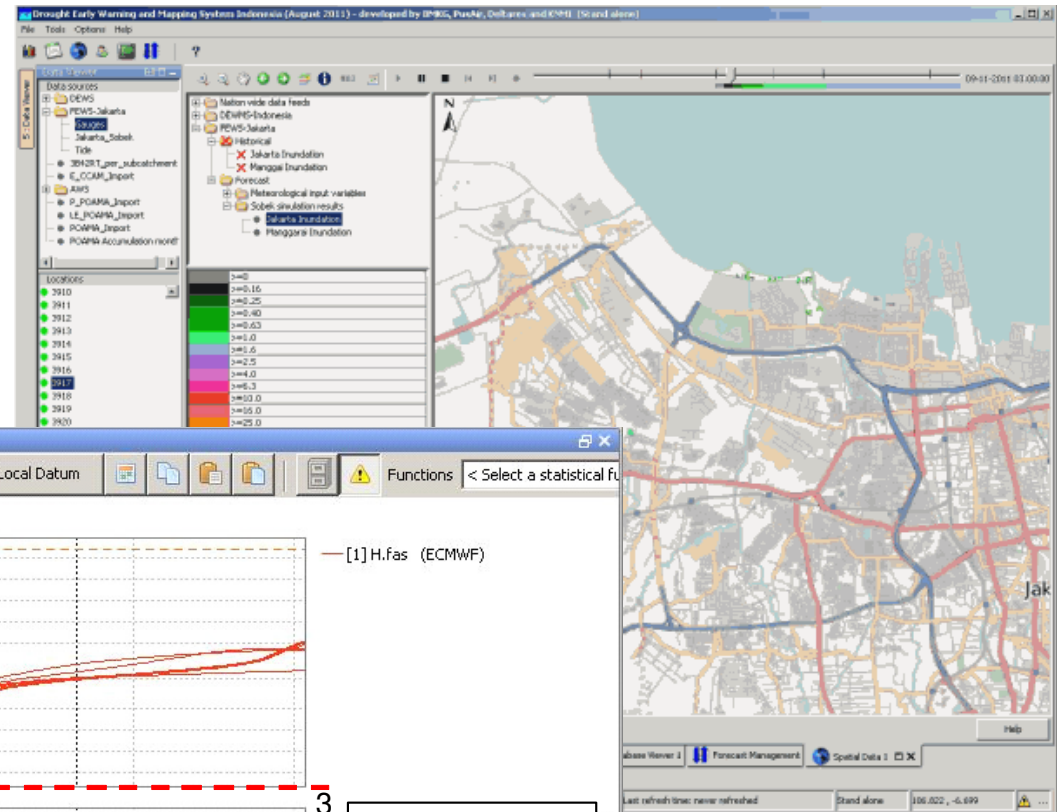
3. IN TIME

Hydra-Ring / DAM / FEWS / ...



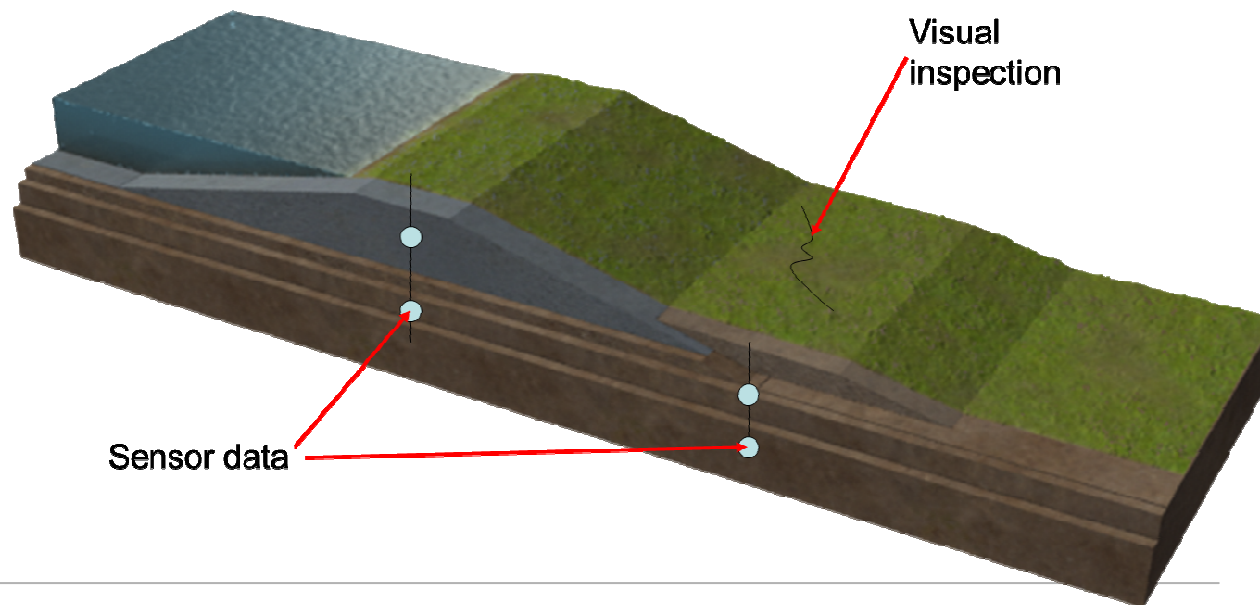
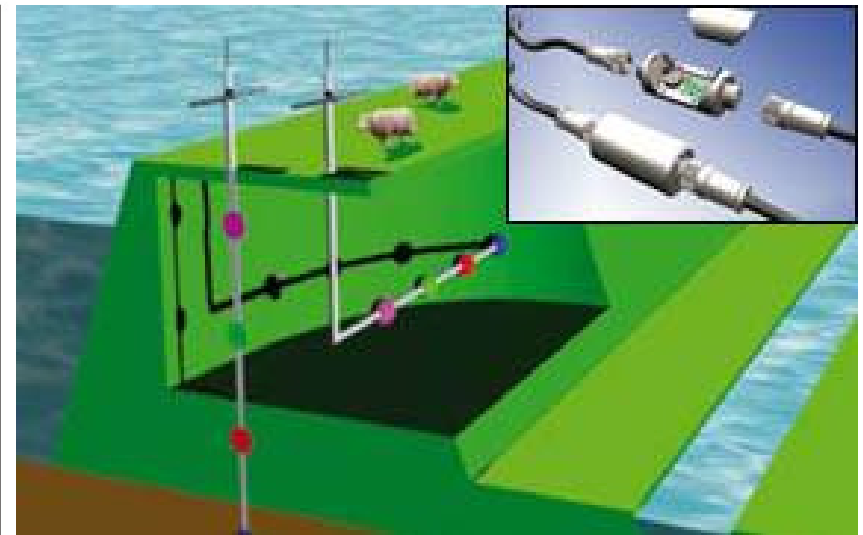
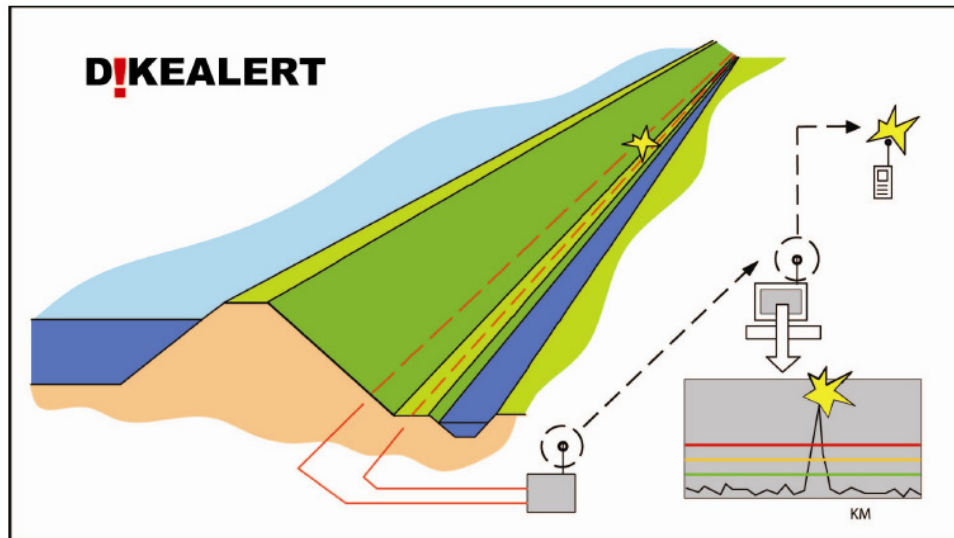
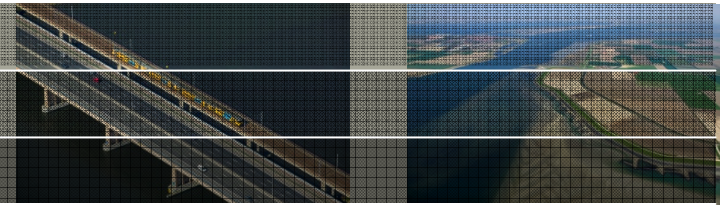
FEWS-DAM: Real-time Levee Safety

Flood Forecasting System in Indonesia



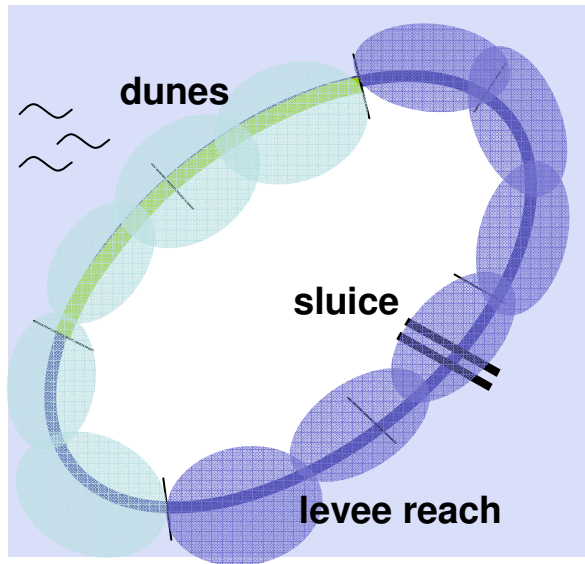
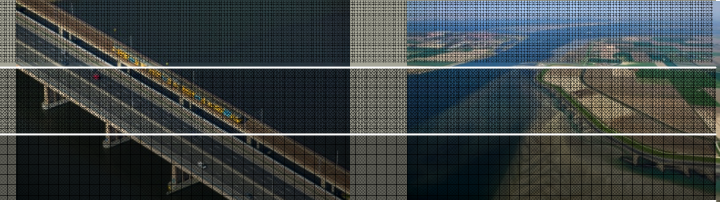
[1] 22-01-1995 01:00:00 Current Rijn_Forecast_SBK_ECMWF-EPS [2] 22-01-1995 01:00:00 Current DAM_Dijkkring10_Forecast_ECMWF-EPS

Real-time Levee Monitoring



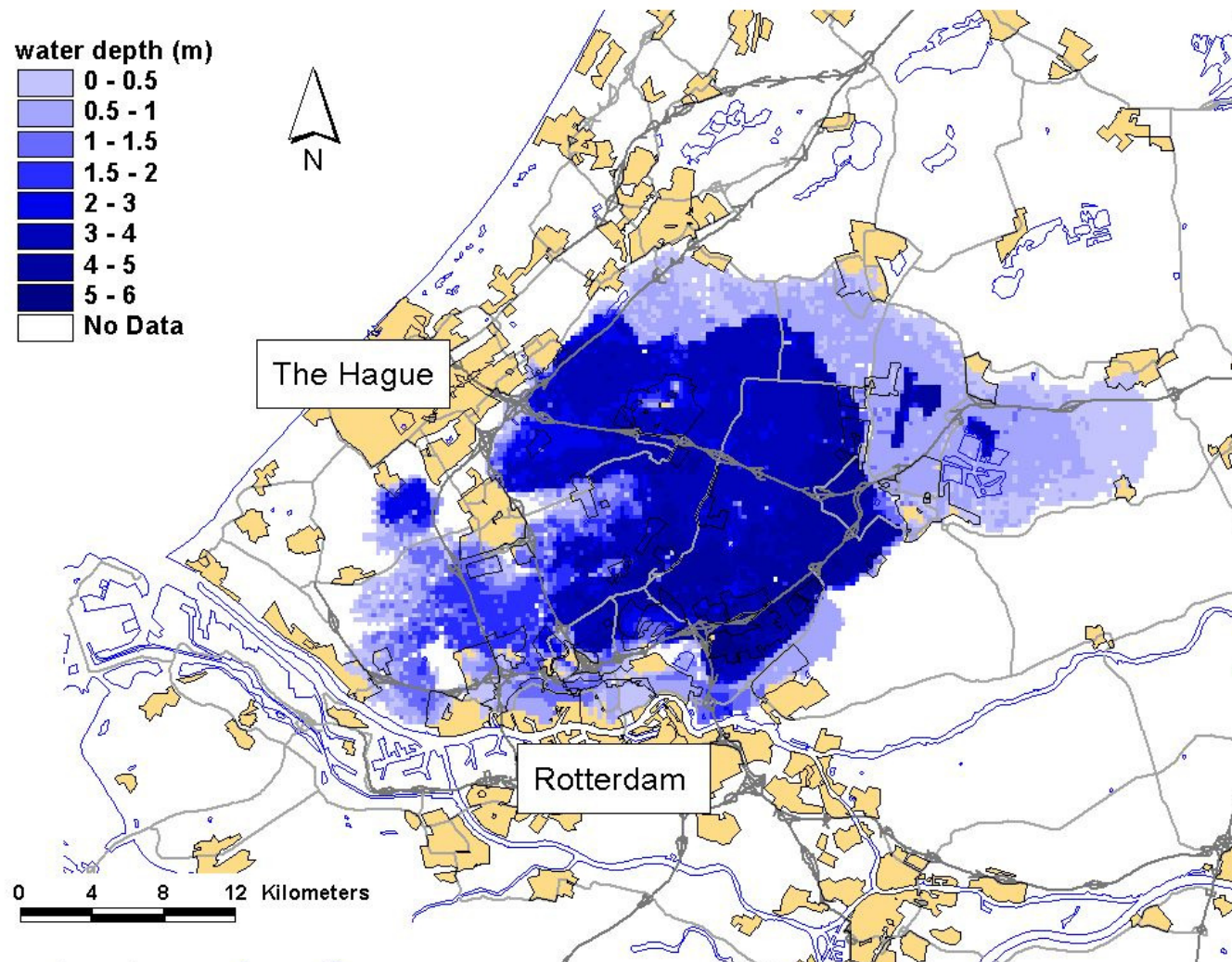
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Inundation Scenarios

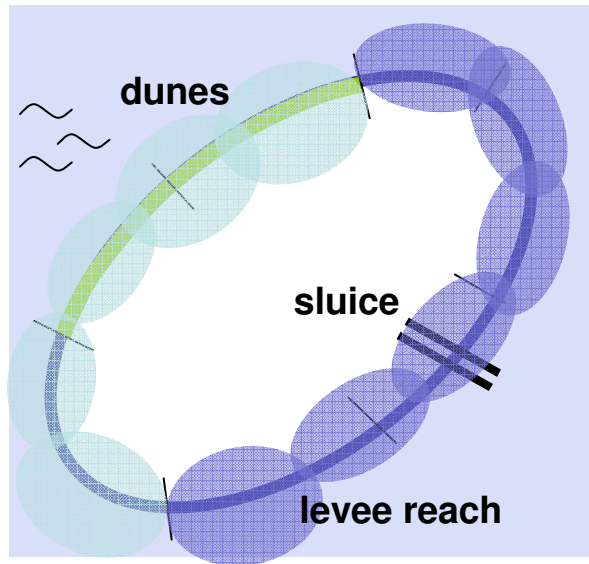


scenario	Reach		probability
	1	2	
scenario 1	X		P_1
scenario 2		X	P_2
scenario 3	X	X	P_3
			P_{tot}

Inundation Simulation



Risk Integration (e.g. economic damage)



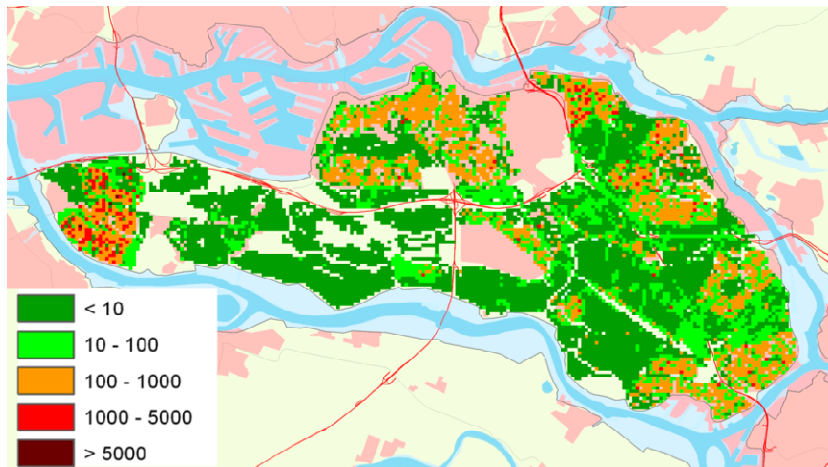
scenario	Reach		probability	damage
	1	2		
scenario 1	X		P_1	C_1
scenario 2		X	P_2	C_2
scenario 3	X	X	P_3	C_3
			P_{tot}	

$$E[C] \approx \sum_i C_i P_i$$

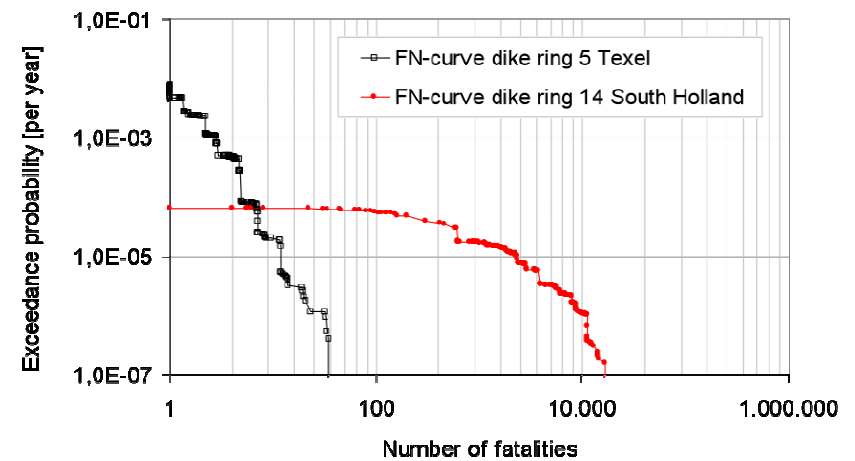
Dimensions of Risk



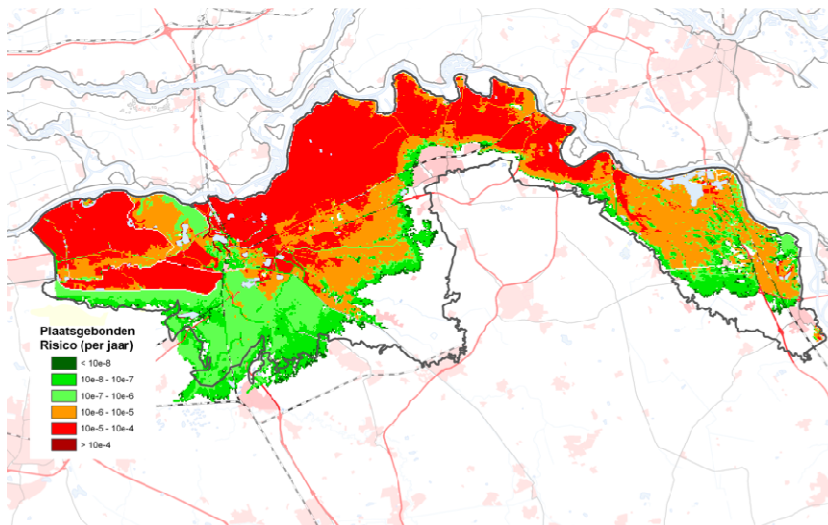
Expected value of economic damage [euro yr⁻¹ha⁻¹]



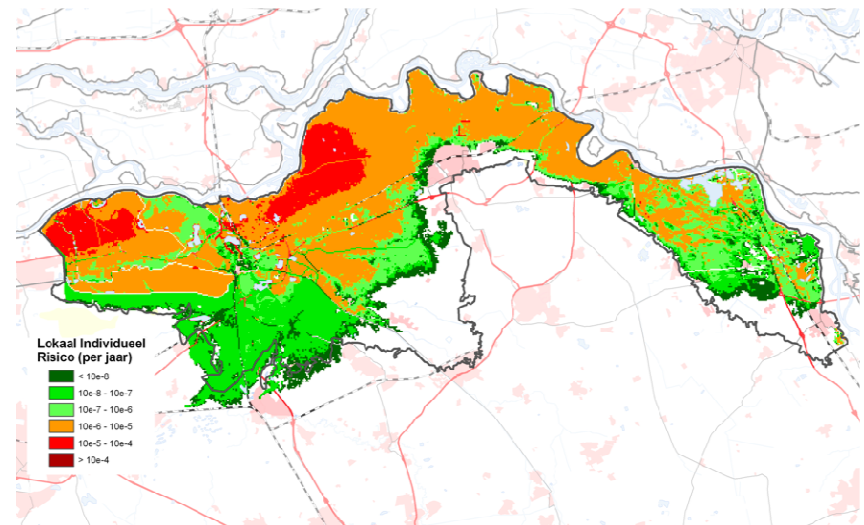
FN-curve



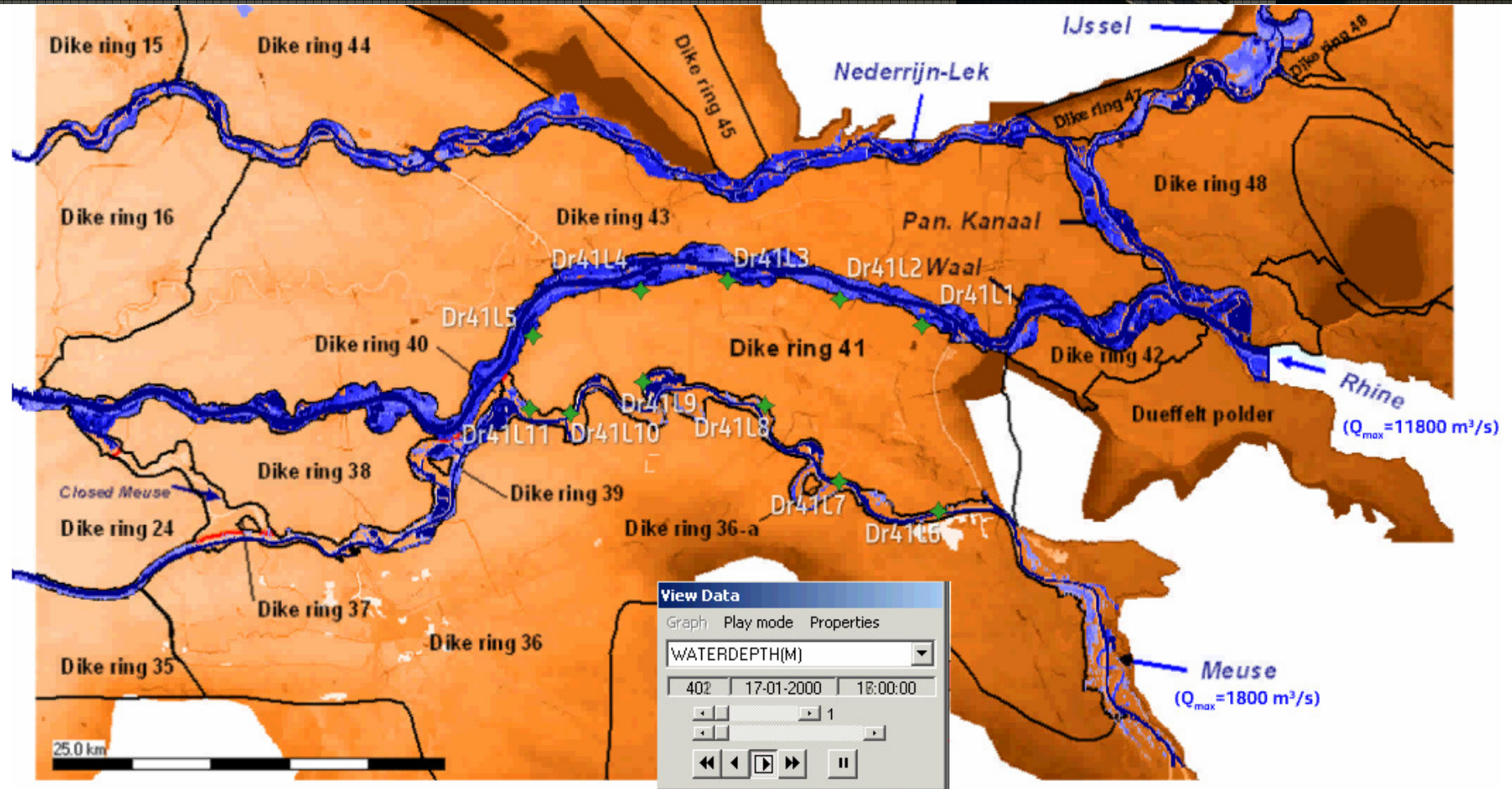
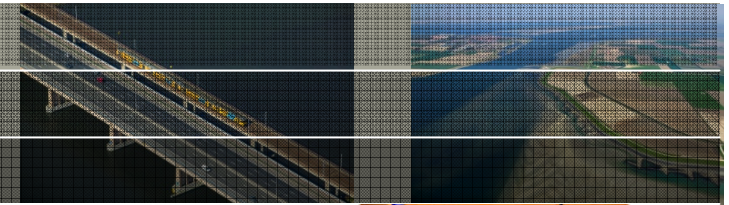
Individual risk excl. the effect of evacuation [yr⁻¹]



Individual risk incl. the effect of evacuation [yr⁻¹]



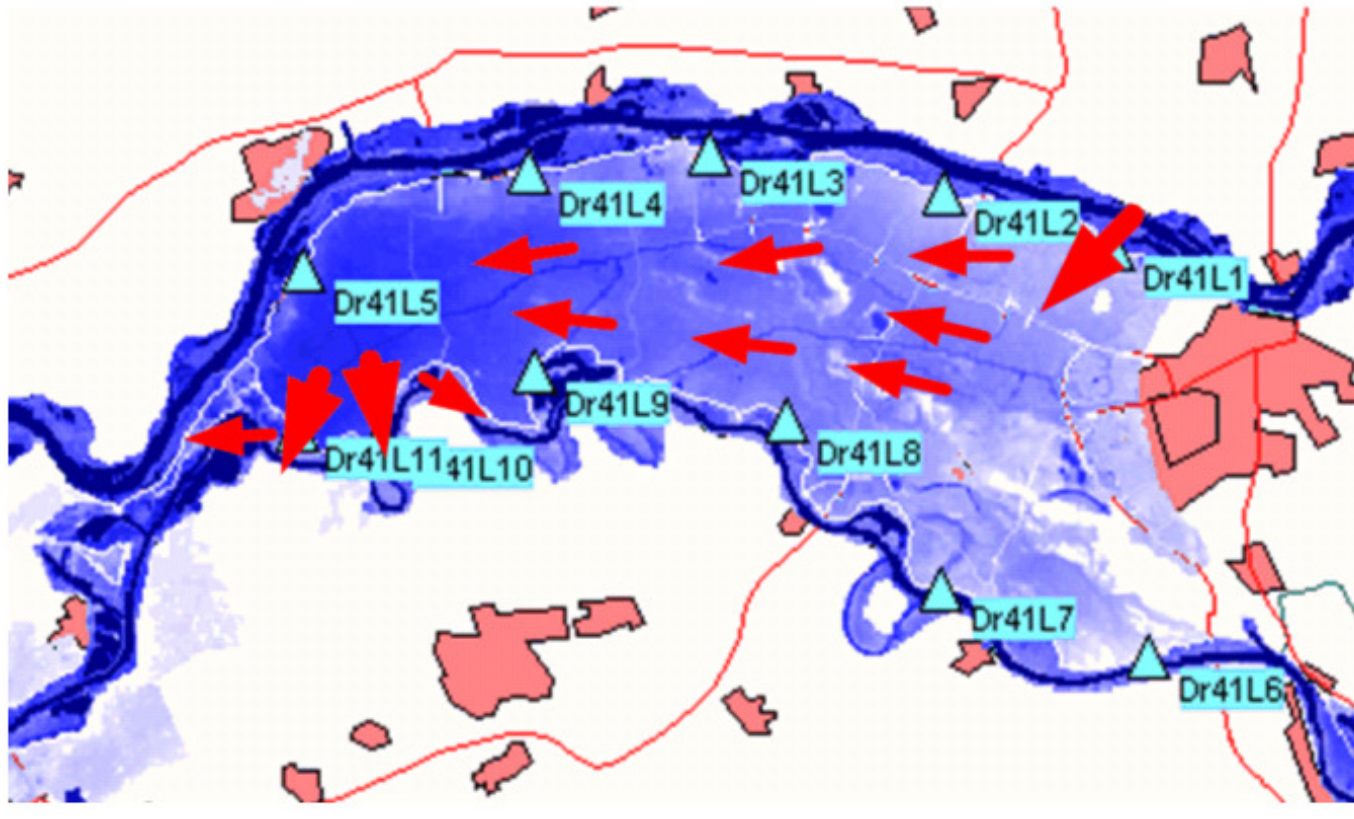
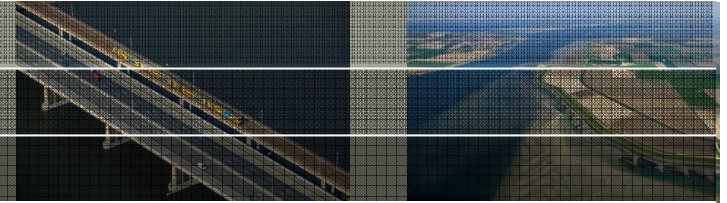
System Effects



- ◆ DR41L1: Failure induced by river; Heave & Piping failure mechanism
- ◆ DR41L11: Failure induced from Dikering, Overflow failure mechanism

- Primary flood protection work, category a (protects so-called dikering areas against flooding)
- Primary flood protection work, category b (connects dikering areas)
- ◆ Considered dike breach location

System Effects

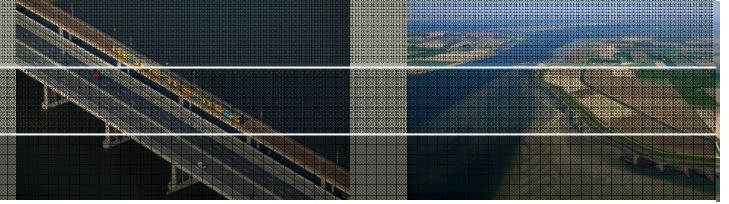


Van Mierlo, M.C.L.M. et al, 2007, Assessment of floods risk accounting for River System Behaviour, *Intl J. River Basin Management* Vol 5, No 2 (2007), pp 93-104.

Courage, W., Vrouwenvelder, A.C.W.M., van Mierlo, T. & Schweckendiek, T. (2013): System Effects in Flood Risk Calculations. *Georisk*, special issue on "Levee Reliability and Flood Risk". (in press)

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In a nutshell



1. Approach **historically grown** since the 1950s.
2. **Risk analyses** for all major flood defenses.
3. Reliability part based on **physics-based computational models**.
4. **Expert judgment** mostly at the level of basic random variables.
5. Account for **dependencies / correlations**.
6. Failure probabilities in the order of **10^{-6}** .
7. Current efforts:
 - **upgrade / revision** (methods and software)
 - improve shortcomings (e.g. **system effects**).
8. **International experience**: Singapore, Germany, Indonesia, US, ...



Dutch Approach to Levee Reliability and Flood Risk

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