



# Hydra-Models

A way to assess the influence of climate change and river programs on future dike heights and the probability of dike failure.

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# Probabilistic versus deterministic approach

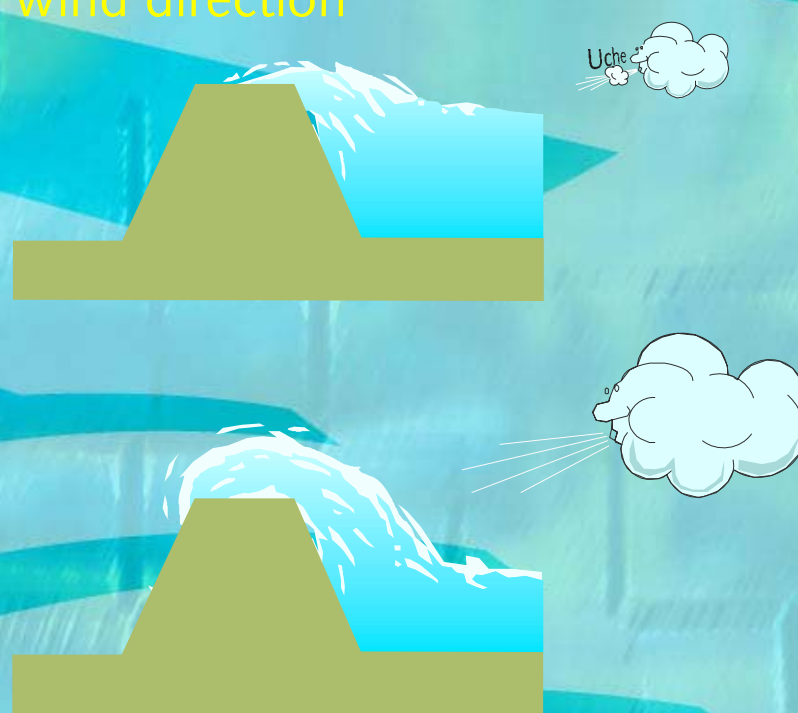
## Deterministic

a design water level,  
a design wind speed and  
wind direction



## Probabilistic

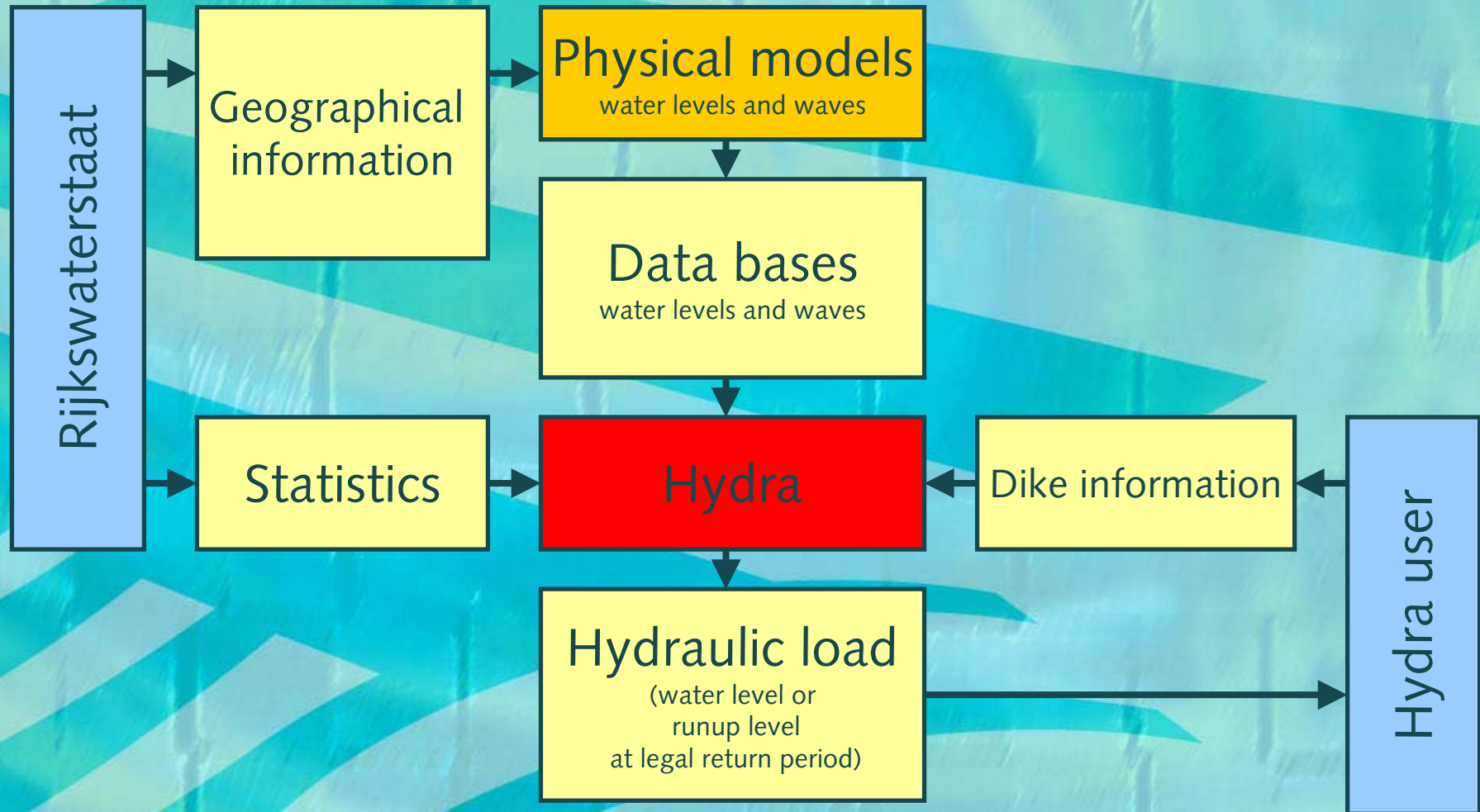
Infinite number of  
combinations of water  
levels, wind speed and  
wind direction





# What are Hydra-models?

A method to weigh possible physical events (water levels and waves)



# Hydra's

- \* 1998 –1999  
Hydra-M, for the IJssel lake area
- 2001  
Hydra-B  
for the Rhine and Meuse Estuaries  
extended in 2004 to the borders  
with Germany and Belgium
- 2006  
Hydra VIJ for the Vecht and IJssel  
delta area



Boundaries between the sea/lake dominated, transitional and river dominated areas

- Urban area
  - Water
  - Forest
  - Area protected by dykes
  - High areas and areas outside the dykes
- S = Sea dominated area  
T = Transition area  
R = River dominated area  
L = Lake dominated area

0 10 20 30 Kilometers  
Schaal (A4) 1 : 1.000.000

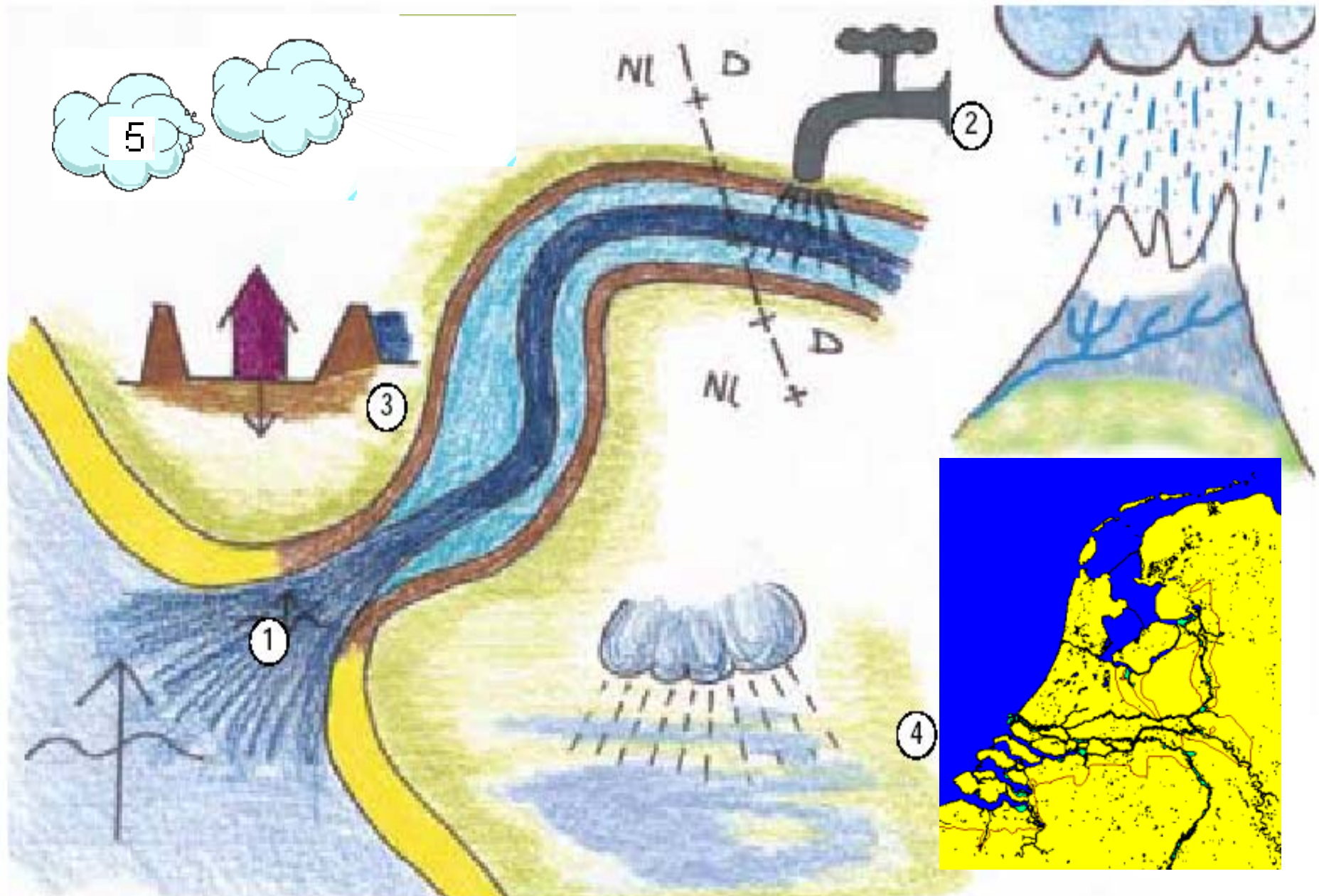


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Directoraat-Generaal Rijkswaterstaat  
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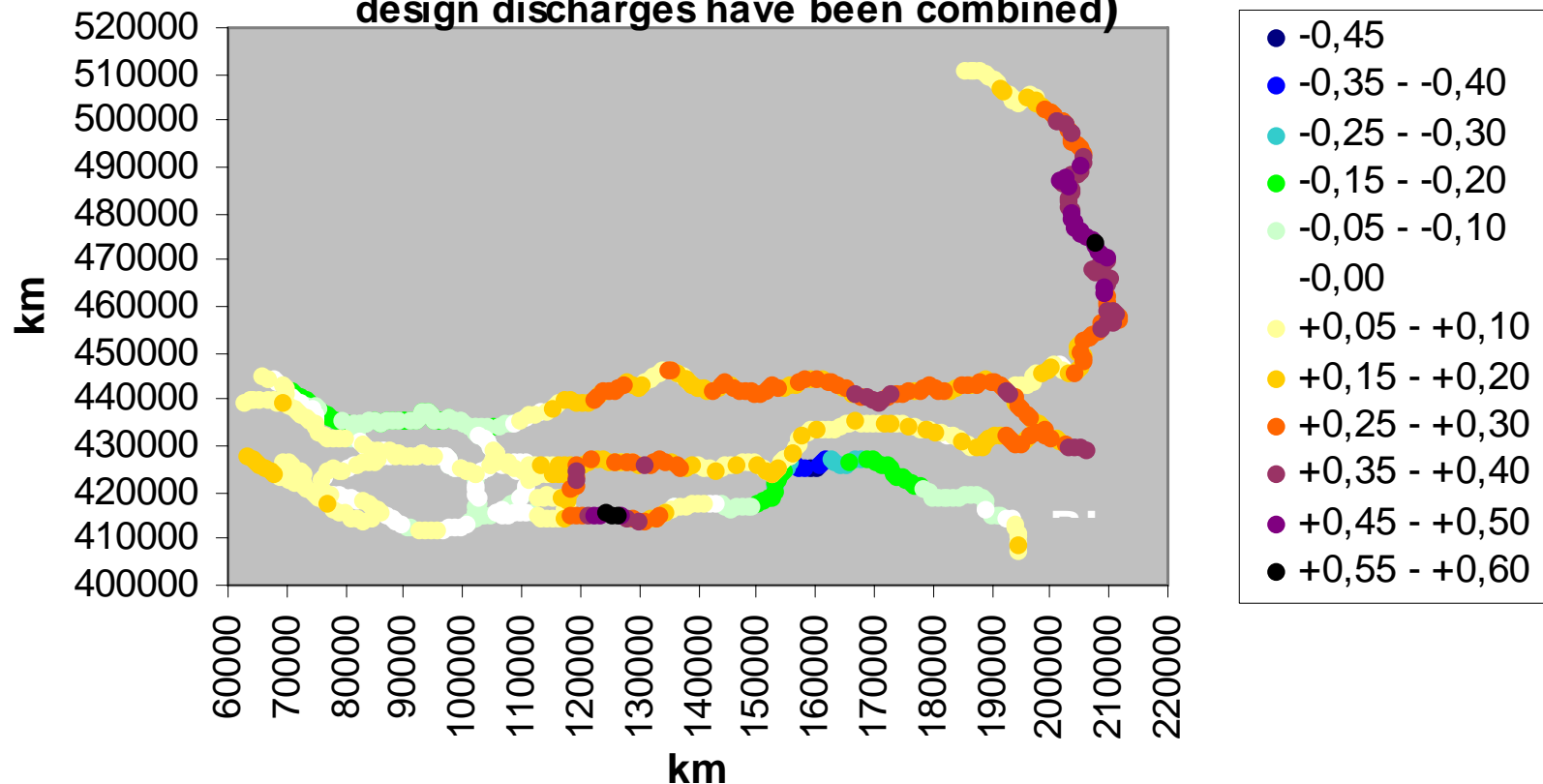
# Climate change and soil subsidence



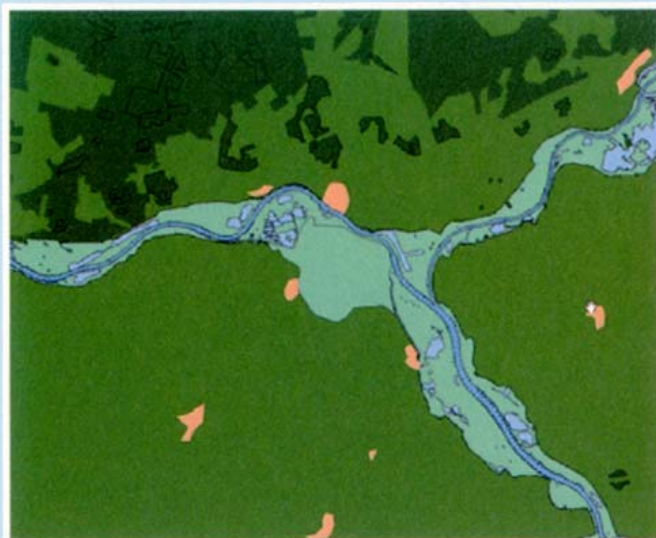
# Room for the River objective: to deminish the increase in design water levels

increase in design waterlevels in m  
from 1996 to 2001

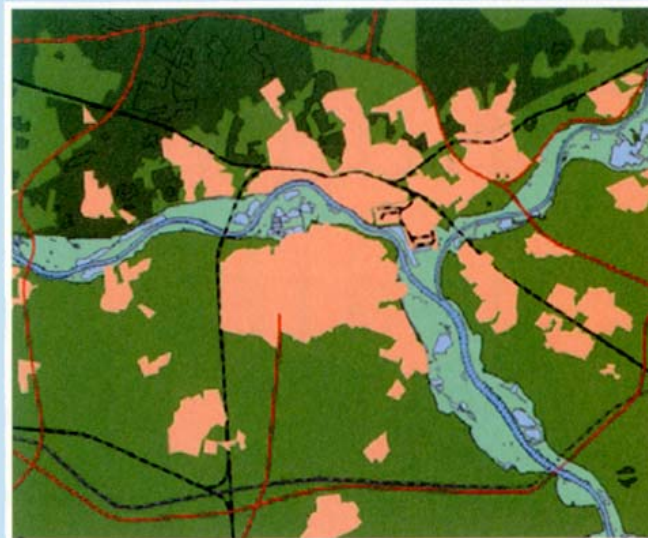
(effects on account of model issues and  
design discharges have been combined)



# Little space and more damage potential each year



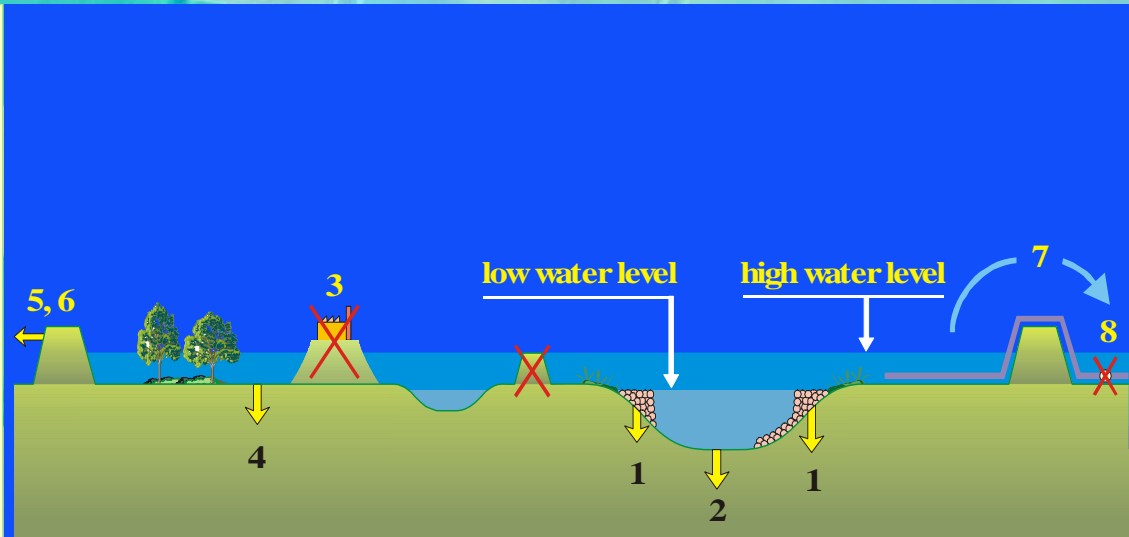
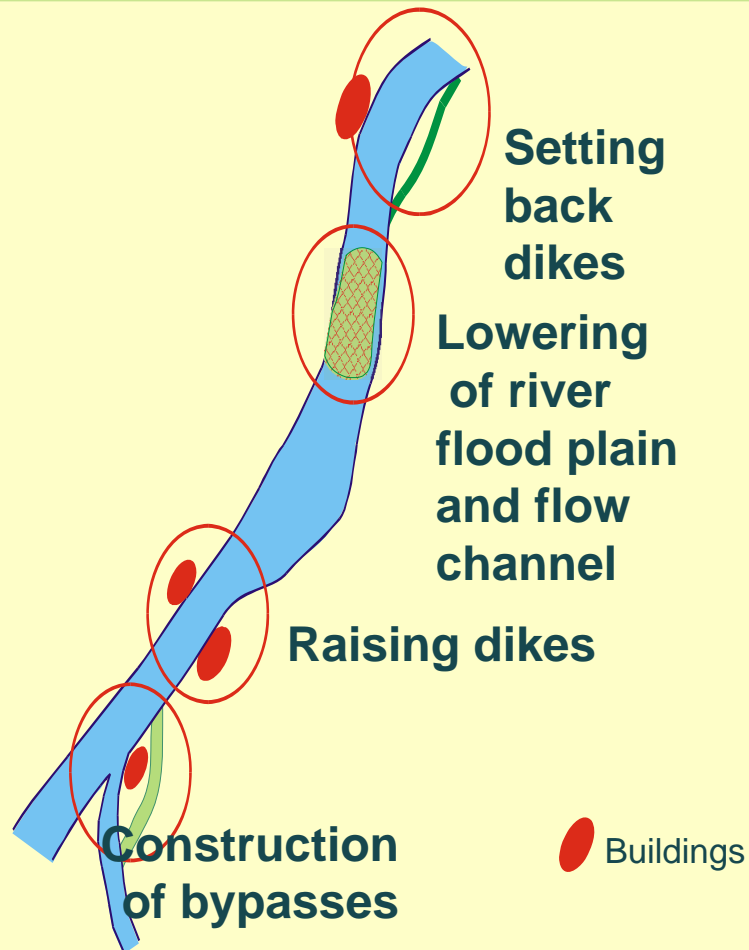
Arnhem, 1830



Arnhem, 2000



# Measures



- 1 - lowering of groynes
- 2 - deepening low flow channel
- 3 - removing hydraulic obstacles
- 4 - lowering flood plains

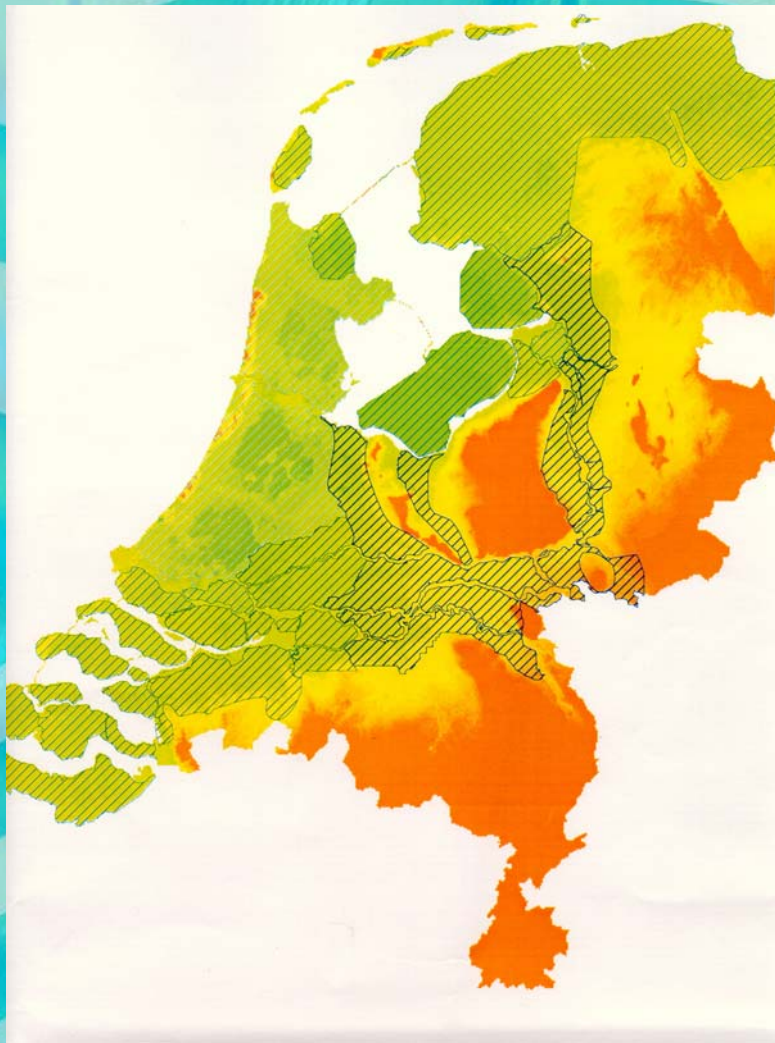
- 5 - locally setting back dikes
- 6 - setting back dikes on a large scale
- 7 - detention reservoir
- 8 - reduction lateral inflow

Room for  
the Rhine branches



E000323c

# Meuse Works – mainly improvement of the 40 new dikes and lowering of the flow channel

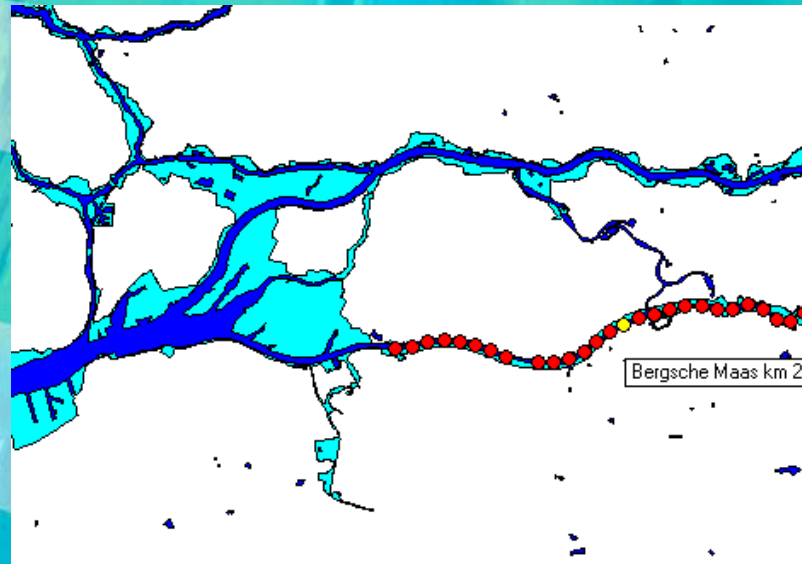




# Climate change, the influence on dike heights

- 1) Extra storm surge and sea level rise:  
an effect of 60-70% in the lower Rhine and Meuse reaches

The influence on design water levels of a 60 cm sea level rise	
location	meters
Bergse Maas km 231	0,10
Bergse Maas km 235	0,12
Bergse Maas km 240	0,16
Bergse Maas km 245	0,23
Bergse Maas km 246	0,25
Bergsche Maas 247	0,37
Bergsche Maas 251	0,50
Hollandsch Diep km 980	0,40

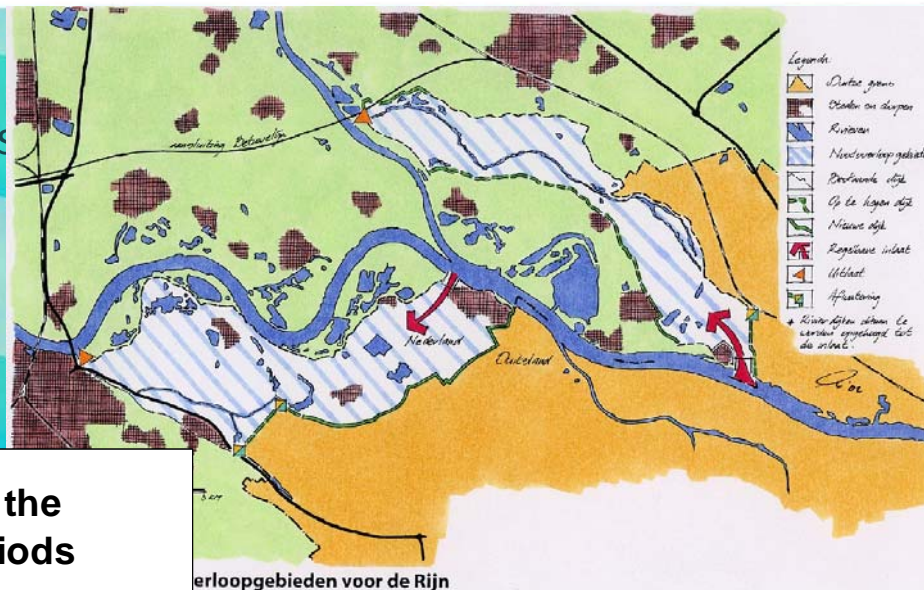


- 2) Higher design discharges, main branches and tributaries  
a 0,60 to 0,80 m increase from the main branches

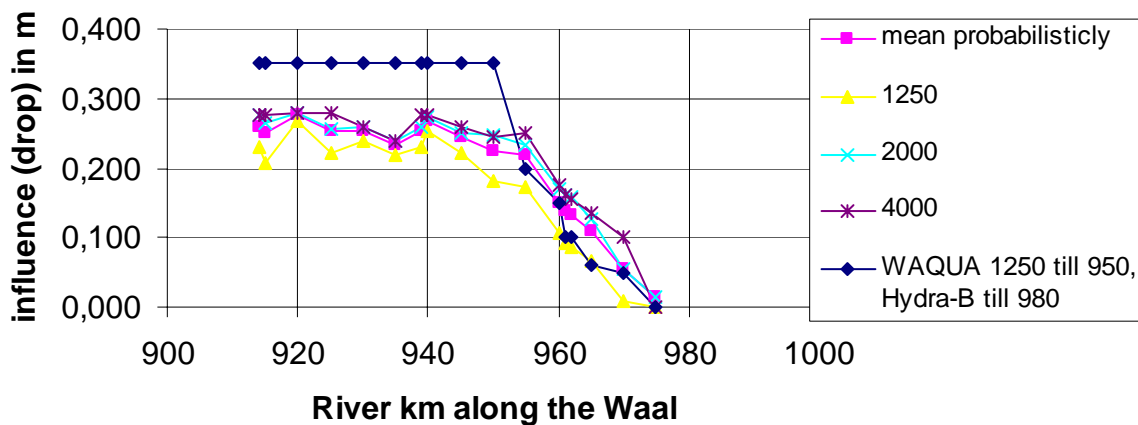
- 3) 10% higher wind speeds and more westerly winds  
10% increase?

# Flood retention on the Rhine

1000 m<sup>3</sup>/s flood retention is a drop of 30 -35 cm on the Waal in design water levels  
Probabilisticly this is only 20 – 25 cm

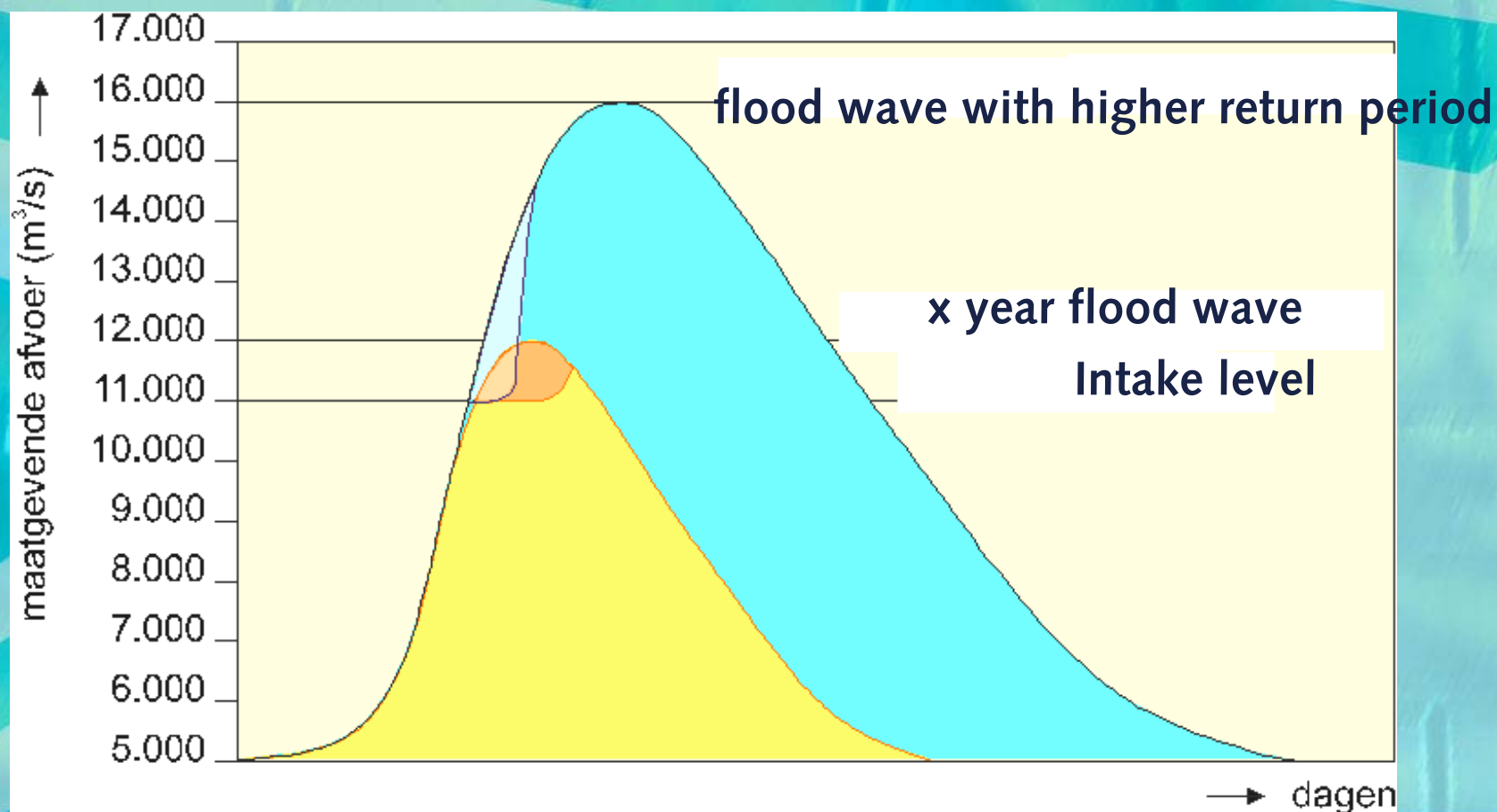


**Influence of a retention area 1000 m<sup>3</sup>/s on the design water levels, for different return periods**





# Flood retention only takes a bite out of the flood wave



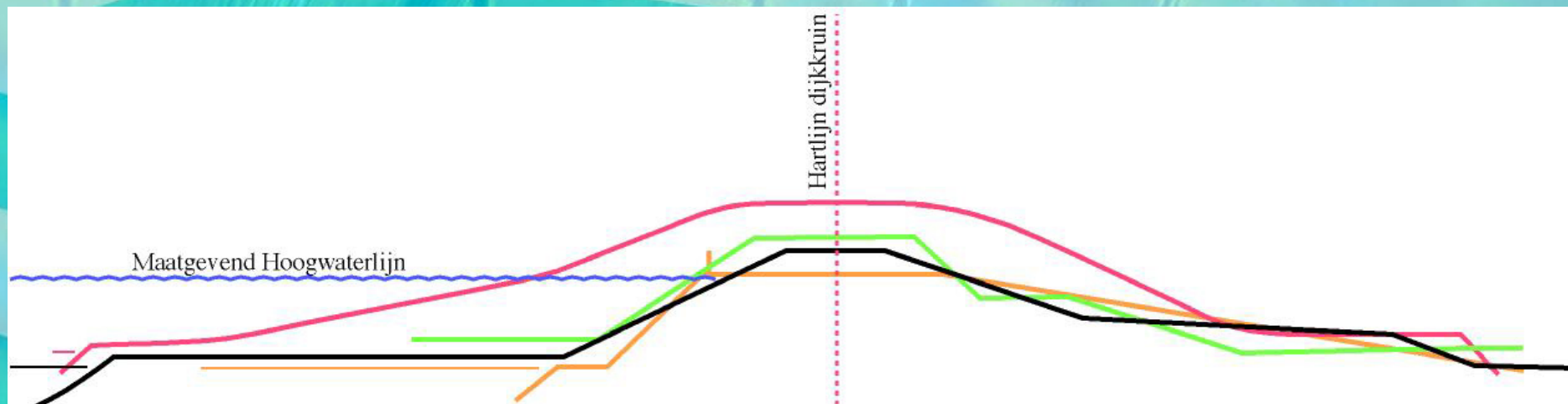
# Flood retention on the Rhine

Effect on dike heights

The background of the slide features a series of overlapping, wavy bands in shades of teal and light blue, creating a sense of movement and depth. The bands are layered, with some appearing more prominent than others, and they curve across the frame from the bottom left towards the top right.



# Dikes have been built in all sizes, forms and heights



**Rhine Branches 600 km dike, 6000 cross sections**

**Meuse 200 km dike, 2000 cross sections**

**All dikes are modeled as:**

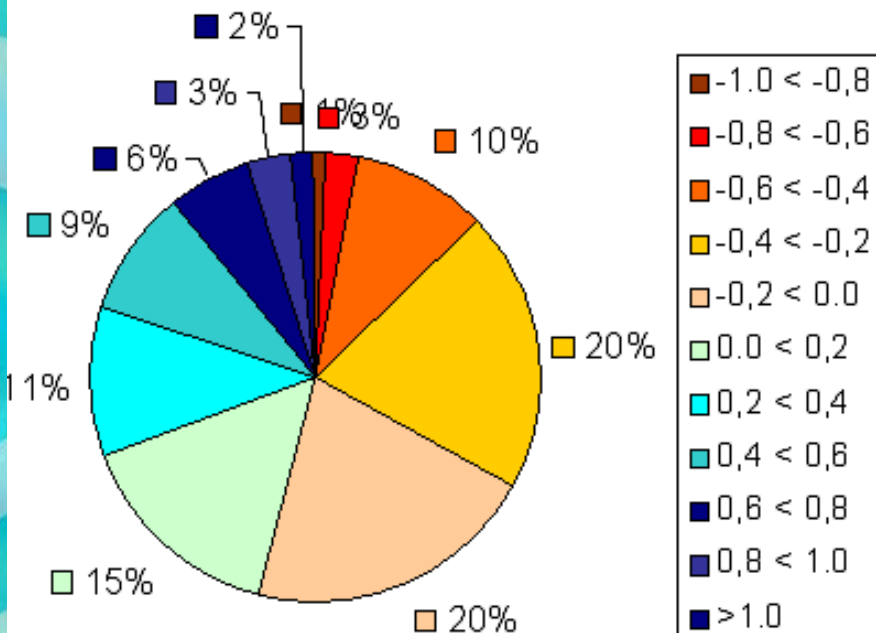
a 1 in 3 outer slope

the actual outer crest level

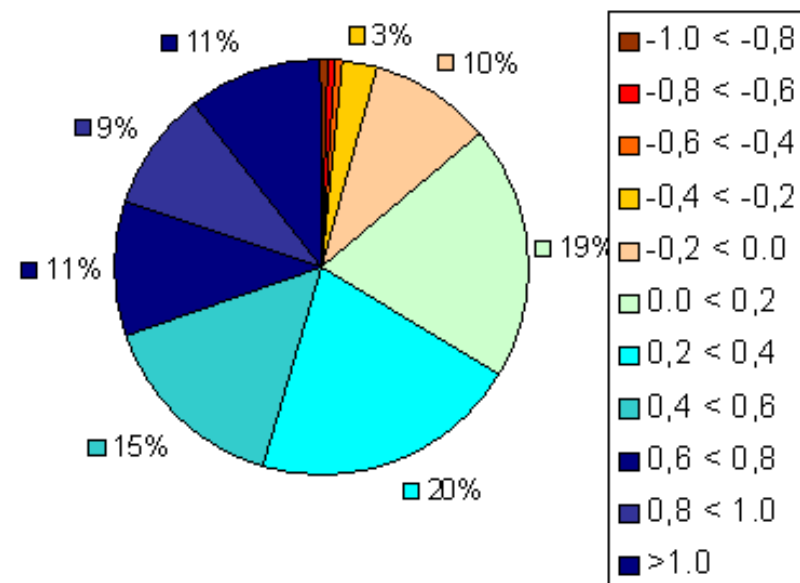
the dike perpendicular line from GIS, filtered for 100 m sections

# Surplus dike heights before and after Room for the River

Surplus dike levels Rhine Branches in 2001, using 0,1 l/s per m as critical overtopping limit



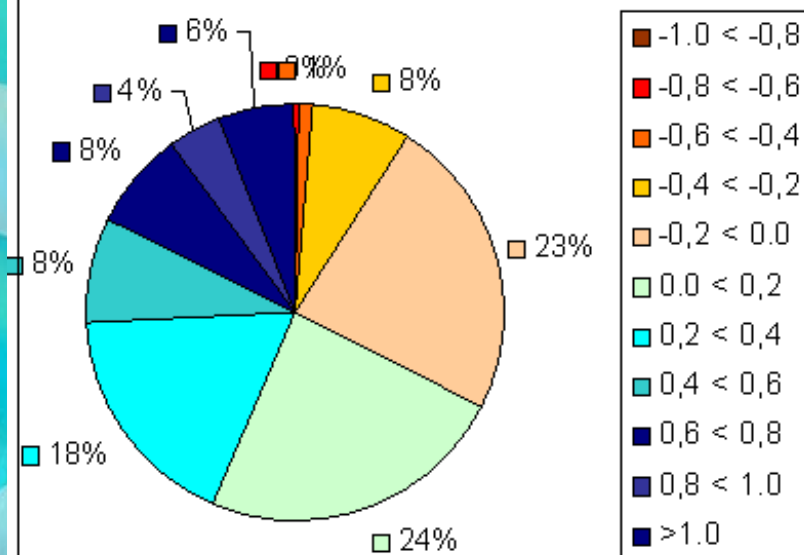
Surplus dike levels Rhine Branches in 2015, using 0,1 l/s per m as critical overtopping limit



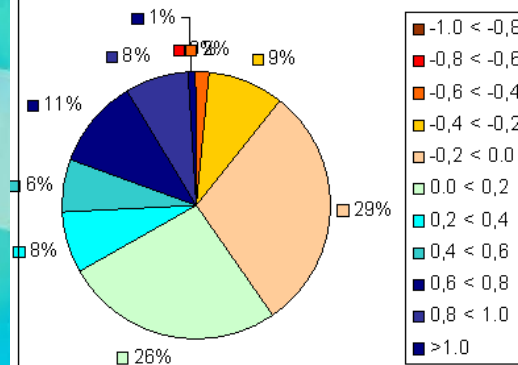


# Surplus dike heights before and after Meuse Works

Surplus dike levels Meuse in 2001,  
using 0,1 l/s per m as critical overtopping limit



Surplus dike levels Meuse in 2015,  
using 0,1 l/s per m as critical overtopping limit  
flooding behind dikes in Limburg not optimal

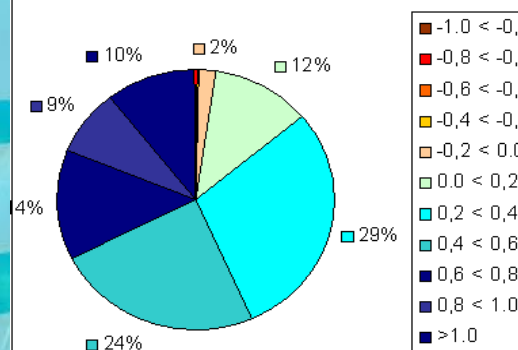


1

Negligible flooding  
of upper reaches  
Km 3 to 150/170

?

Surplus dike levels Meuse in 2015,  
using 0,1 l/s per m as critical overtopping limit  
flooding behind dikes in Limburg optimal



2

Perfect flooding  
of upper reaches  
Km 3 to 150/170

# Probability of dike failure dike ring 43

probability of dike failure, dike ring 43				
scenario	dike heights	critical overtopping limit	max discharge Rhine	probability
Actual 2001	current design practice	1 l/s per m	18 000 m <sup>3</sup>	1/600
Actual 2001	actual dikes	1 l/s per m	18 000 m <sup>3</sup>	1/200
After RvdR 2015	current design practice	1 l/s per m	18 000 m <sup>3</sup>	1/1100
After RvdR 2015	actual dikes	1 l/s per m	18 000 m <sup>3</sup>	1/1200
After RvdR 2015	actual dikes	50 l/s per m	18 000 m <sup>3</sup>	1/5000
After RvdR 2015	actual dikes	1 l/s per m	16000 m <sup>3</sup>	1/1400