Impact assessment of flood mitigation measures

~ some new developments ~

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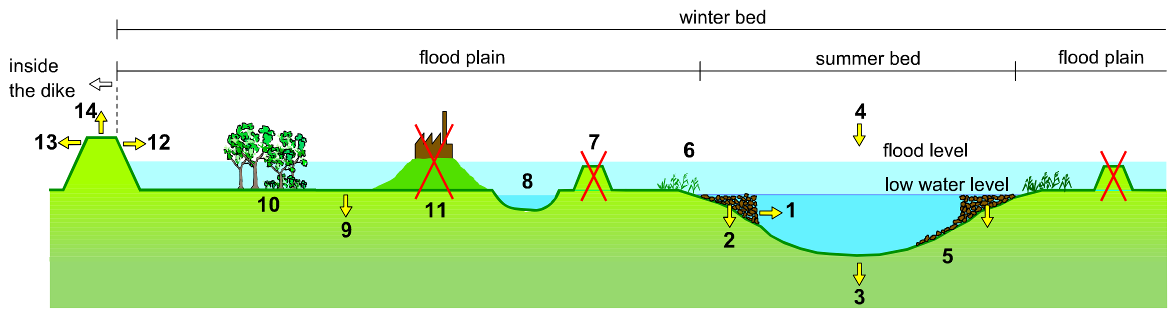
How to select measures?

Impacts:

- economic cost/benefit analysis
- nature
- landscape
- ………

Measures:



1	=	narrow the summerbed
2	=	lower groynes
3	=	dredge the summerbed
4	=	redump of sediment in the summerbed
5	=	add a permanent layer to the summerbed
6	=	add nature to the banks
7	=	remove summer embankment
8	=	build a secondary channel
9	=	lower the flood plain (excavate of clay/sand)
10	=	develop nature in the flood plain
11	=	remove high-water free areas
12	=	reinforce the dikes
13	=	reposition the dikes
14	=	raise the dikes

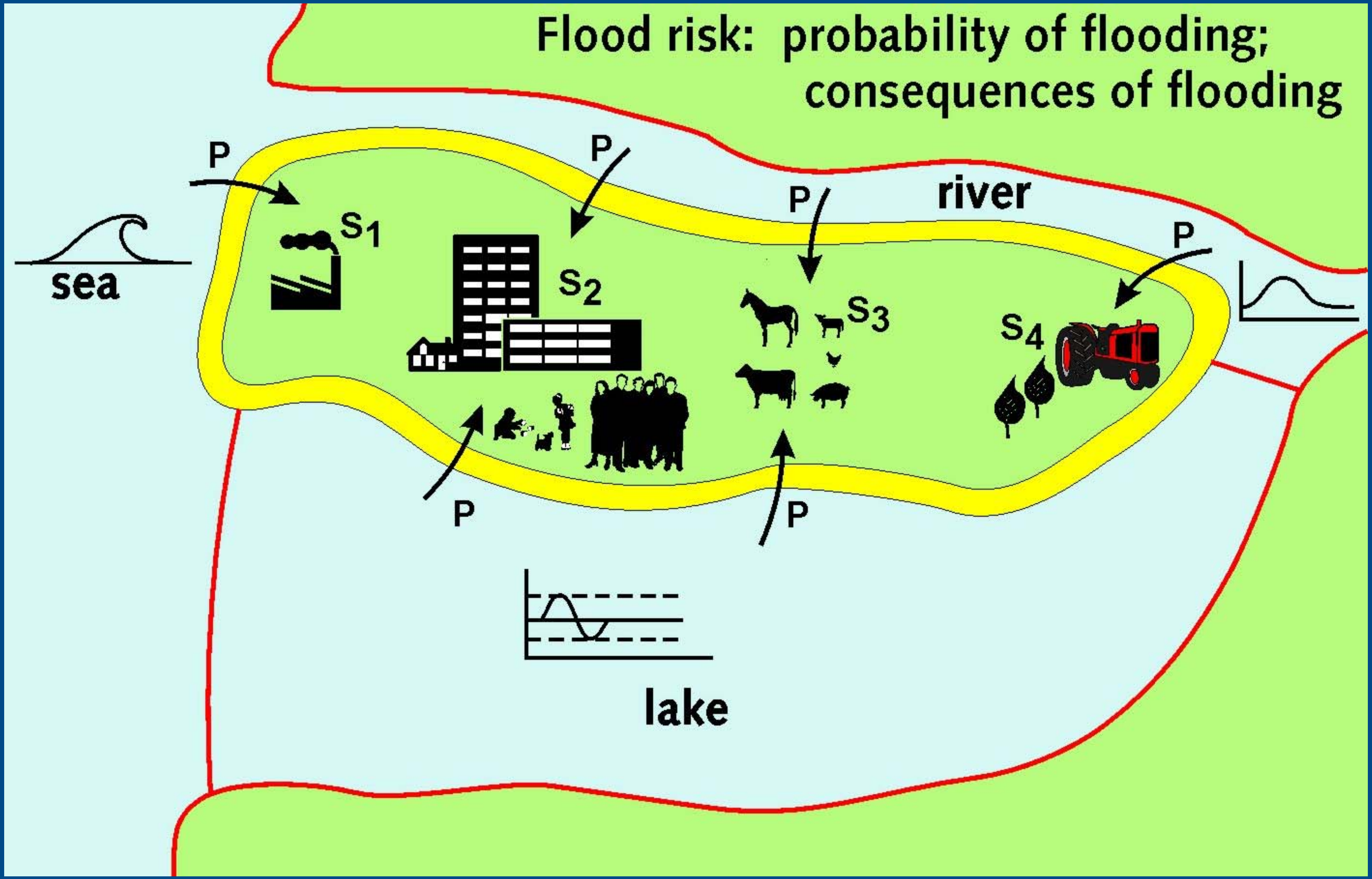
disaster management (evacuation, sand bags) and spatial planning

Flood risk evaluation

In the Netherlands the Technical Committee on Flood Defences (TAW) argues that flood defence should be based on:

- criteria on number of deaths (personal risk and societal risk)
- cost benefit analysis

But is not official policy (yet)



Flood risk: probability of flooding;
consequences of flooding
sea
river
lake
P
P
P
P
P
P
S_1
S_2
S_3
S_4

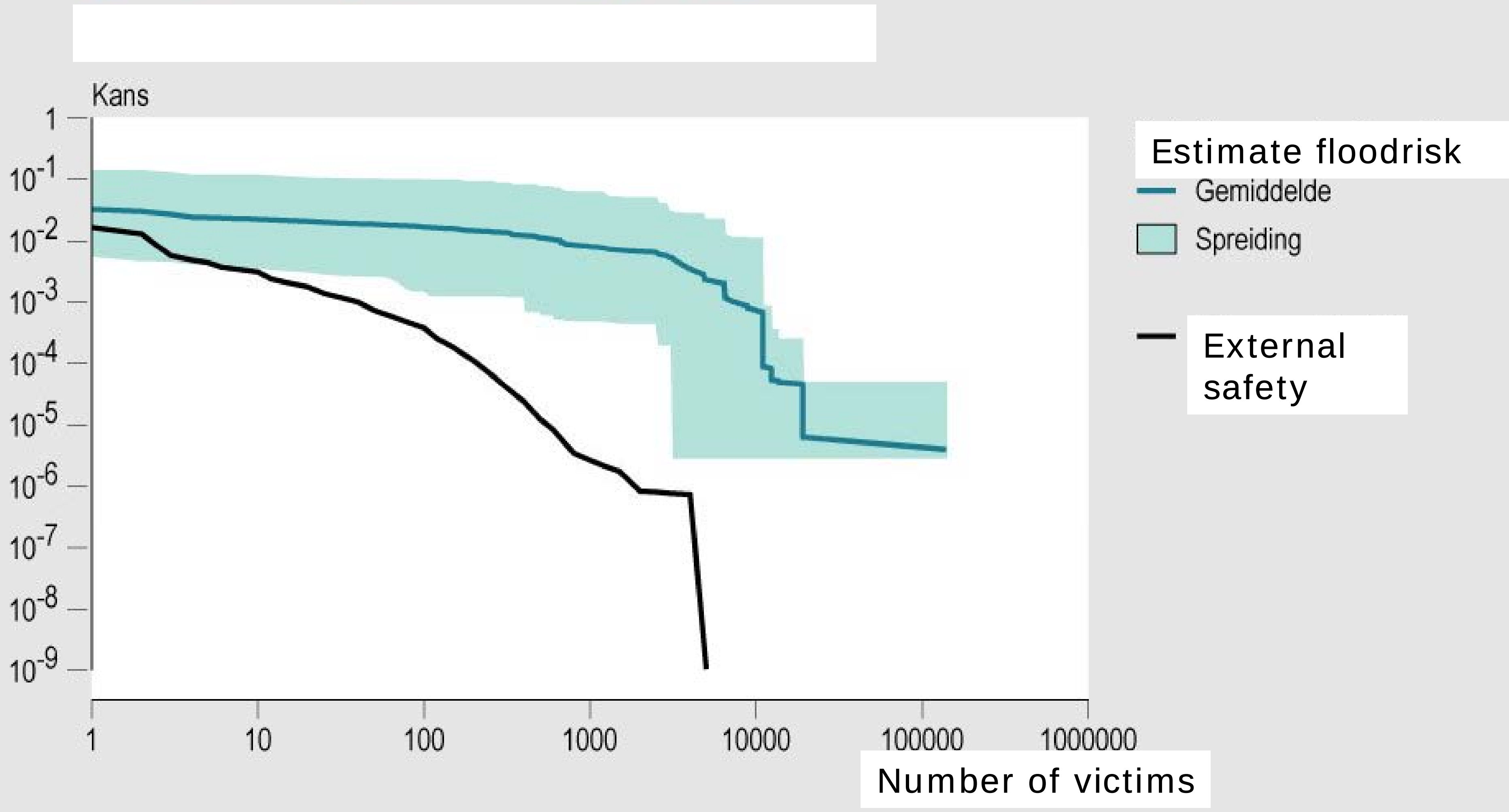
Is there a flood protection problem in the Netherlands?

- **No: ‘we have never been as safe as we are today’ (probability)**

- **Yes: ‘damage increase and safety standards are set up some 50 years ago, and population increases and economy growths’ (consequences)**

According to report of Ministry of Environment (RIVM) there is a serious problem (although the standards are relatively high!)

Flood risk in the Netherlands: social risk



New developments

Risk = flooding probability * consequences

(yearly insurance premium, expected number of deaths, ….)

- **often: flooding probability = exceedance probability of design water level (safety standard)**
- **often: no uncertainty in flood damage**
- **often: no assessment of economical safety standard**

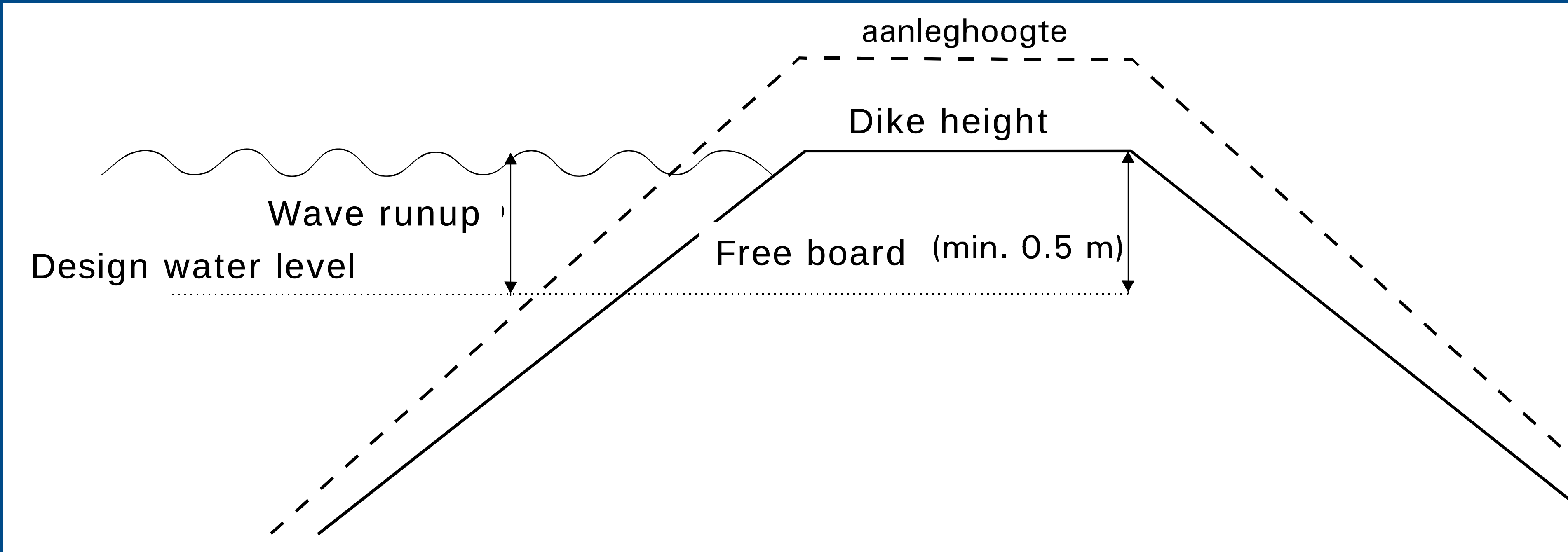
  (dynamic investment approach to assess risks)

Flooding probability (1)

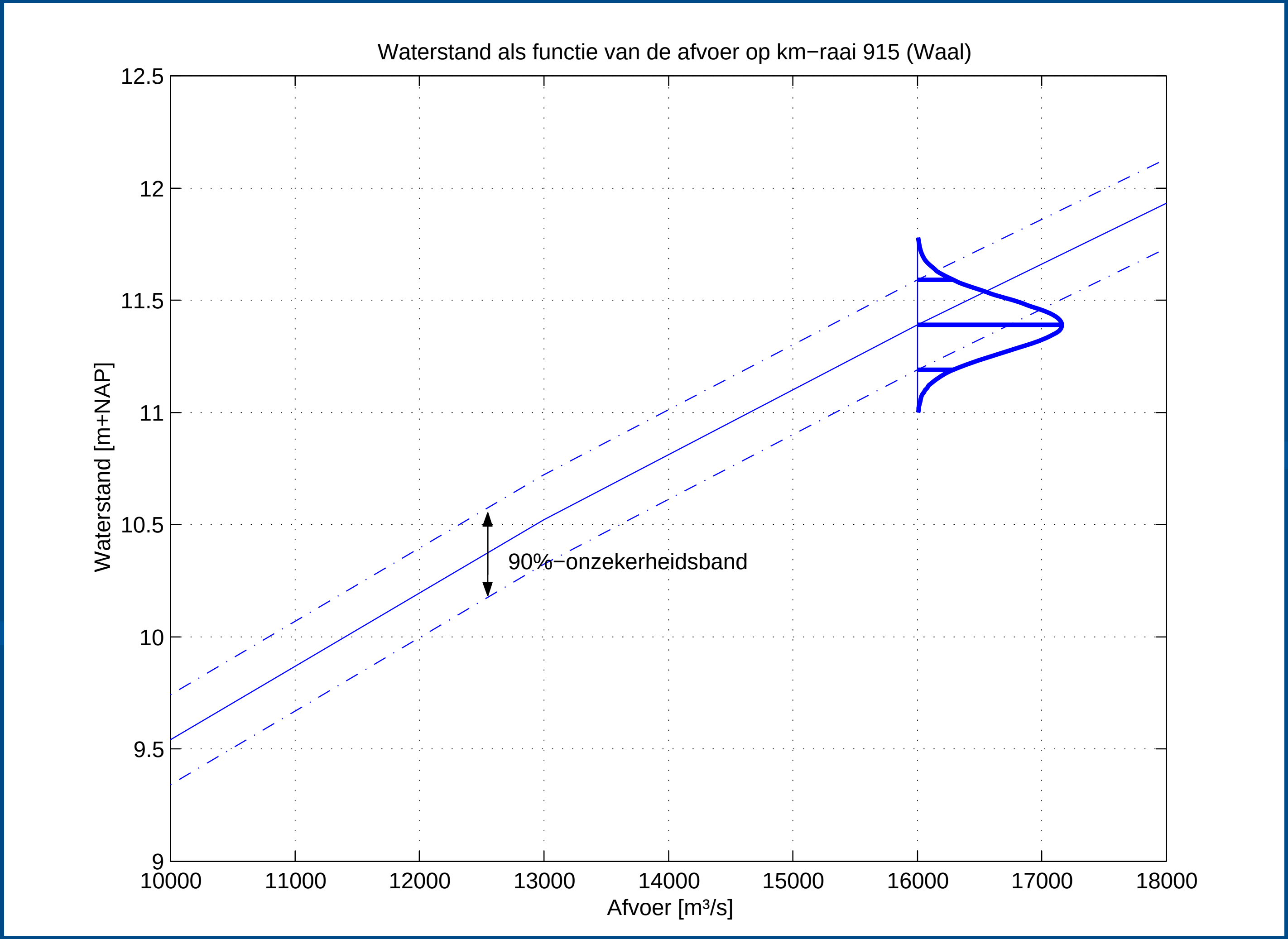
- Failure mechanism: overflow / wave overtopping the dike
- The Design water level is used to assess the flooding probability
- In design of dike we have a free board (of 0,5 - 1 meter) for (among others wave runup)

- There is a strong relation between the exceedance probability and the flooding probability. It depends among others on: probability distribution discharge, HQ relation, uncertainty in water levels given the discharge, wind speed and wind direction.

Flooding probability (2)



Flooding probability (3)



Flooding probability (4)

Example Tiel: Dike design based on Design water level (exceedance probability of **1/1250**) plus free board of 0,5 m

Stochastic variable	
Discharge + wave runup according guidelines	1/1800
Discharge + wave runup all wind directions	1/2200
Discharge + waver runup all wind speeds	1/2500
Discharge + uncertainty water levels	1/1700
Discharge + wind direction + wind speed + uncertainty water levels	1/2600
Discharge + wind direction + wind speed + uncertainty water levels + shape discharge	1/1700

Results for other locations: range 1/1000 -- 1/8000.

Uncertainty flood damage (1)

- **Based on results of R. Egorova (Delft University of Technology and HKV Consultants)**
- **The general formula:**

$$S = \sum_{i=1}^{m} S_i \sum_{j=1}^{n} \alpha_{ij} n_{ij}$$

where:

α_{ij} **-- damage factor for category i in cell j,**

$0 \le \alpha_i \le 1$ **(damage function)**

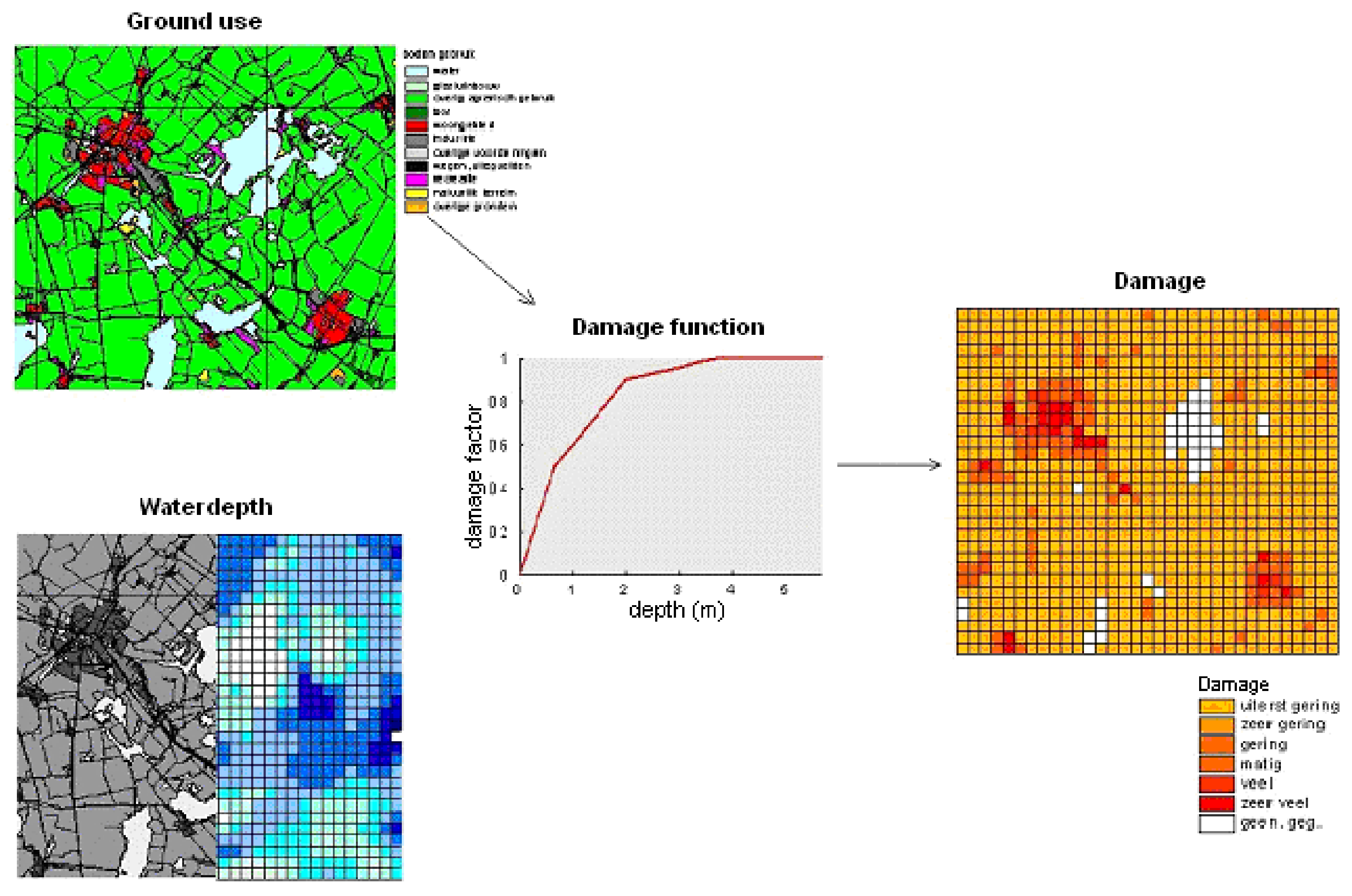
n_{ij} **-- number of flooded units in category i in cell j**

S_i **-- maximum damage per unit in category i (Netherlands Economic Institute)**

n – number of grid cells

m – number of damage categories (equal to 51)

"Standard" method for Assessing Damage and Casualties as result of flooding (HIS-SSM software)



Uncertainty flood damage (2)

Main Terms to calculate damage:

- **Flood scenario**
- **Damage category**
- **Damage: direct, indirect, business interruption**
- **Maximum damage**
- **Damage factor (damage function)**

Sources of uncertainty:

- **<u>damage factor</u>**
- **number of flooded units**
- **<u>maximum damage per unit</u>**
- **<u>flood depth</u>**
- **flow velocities**
- **rate of water rising**

Dependence modeling

- **Spatial dependence**

  HIS-SSM cells structure

$$S = \sum_{j=1}^{m} \sum_{i=1}^{n} \alpha_{ij} n_{ij} S_i = \sum_{i=1}^{n} S_i \sum_{j=1}^{m} \alpha_{ij} n_{ij}$$

- **Complete dependence**
- **Independence**
- **Stratified water depths (complete dependence within class, independence between classes)**

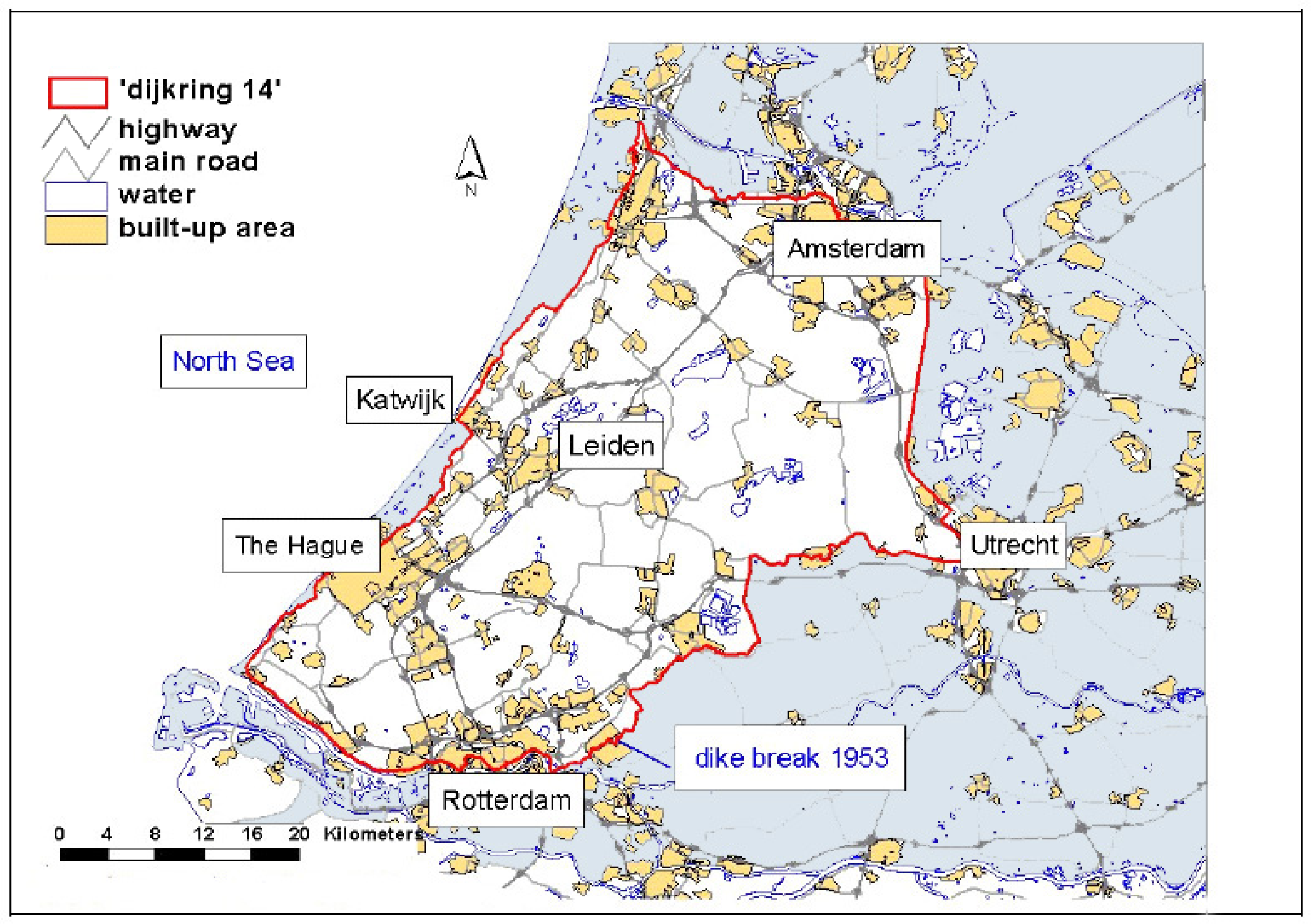
Uncertainty maximum damage

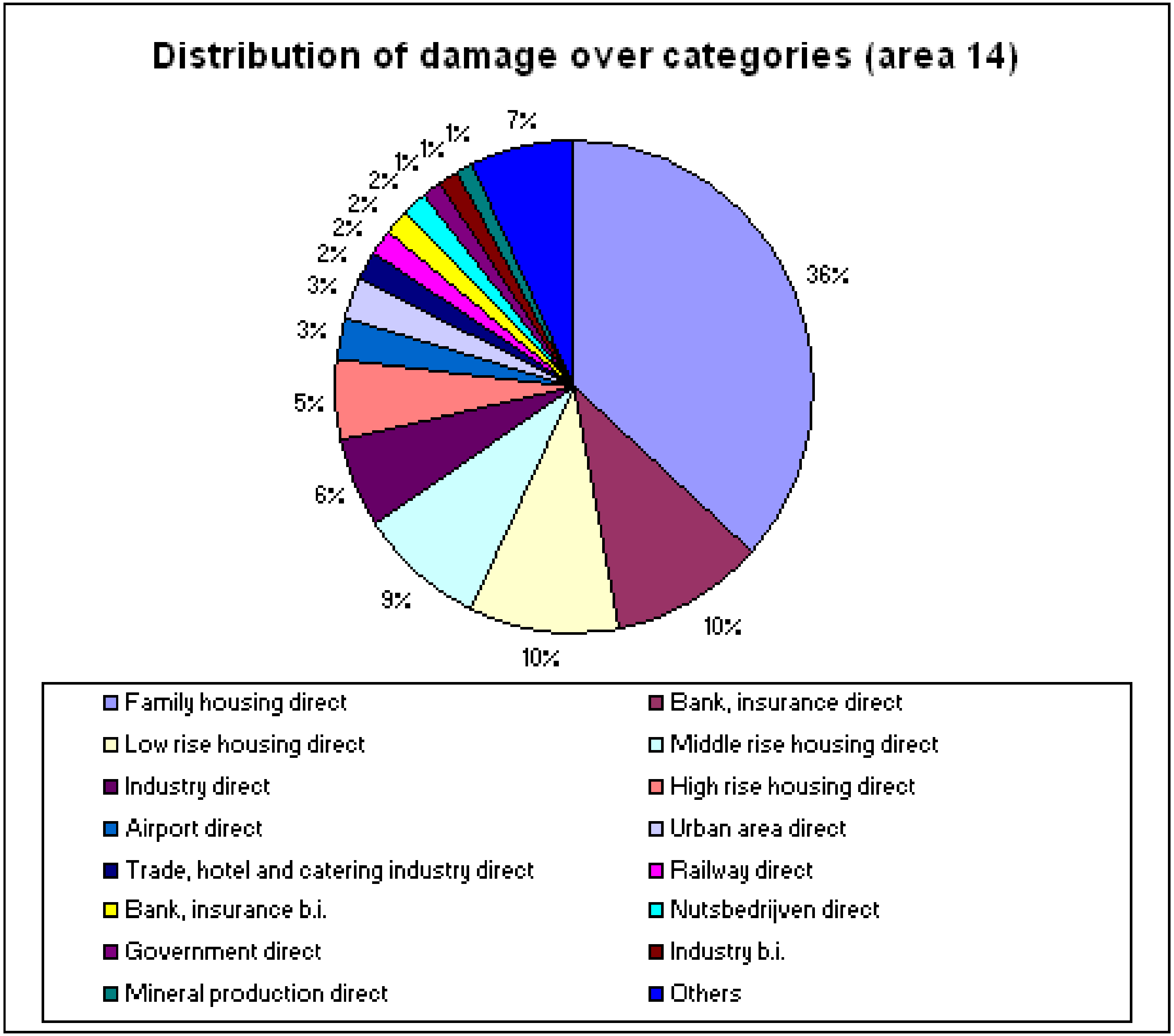
Maximum damage per unit object

Damage categories	*Unit*	*Maximum damage amount (€)*	*Damage Function*	*Database*	*90% confidence bounds*
Agriculture direct	m^2	1.50	1	CBS	0.7 - 7.1
Urban area	m^2	48.6	1	CBS	32 - 63

- **Mean**
- **5th percentile** $\Rightarrow$ **probability**
- **95th percentile** **distribution**

Case study:
dike-ring area 14 (Central-Holland)





Distribution of damage over categories (area 14)
36%
10%
10%
9%
6%
5%
3%
3%
2%
2%
2%
2%
1%
1%
1%
7%
Family housing direct
Bank, insurance direct
Low rise housing direct
Middle rise housing direct
Industry direct
High rise housing direct
Airport direct
Urban area direct
Trade, hotel and catering industry direct
Railway direct
Bank, insurance b.i.
Nutsbedrijven direct
Government direct
Industry b.i.
Mineral production direct
Others

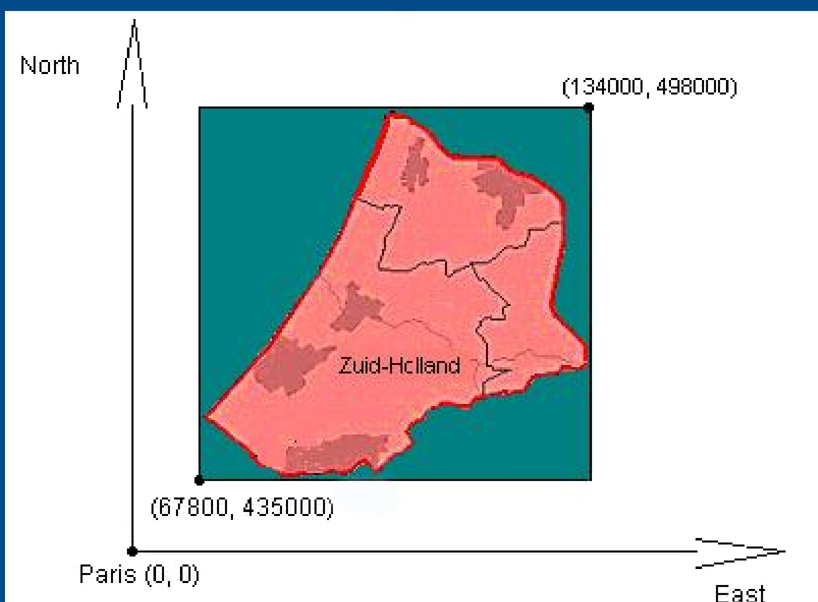
Simulation (MATLAB)

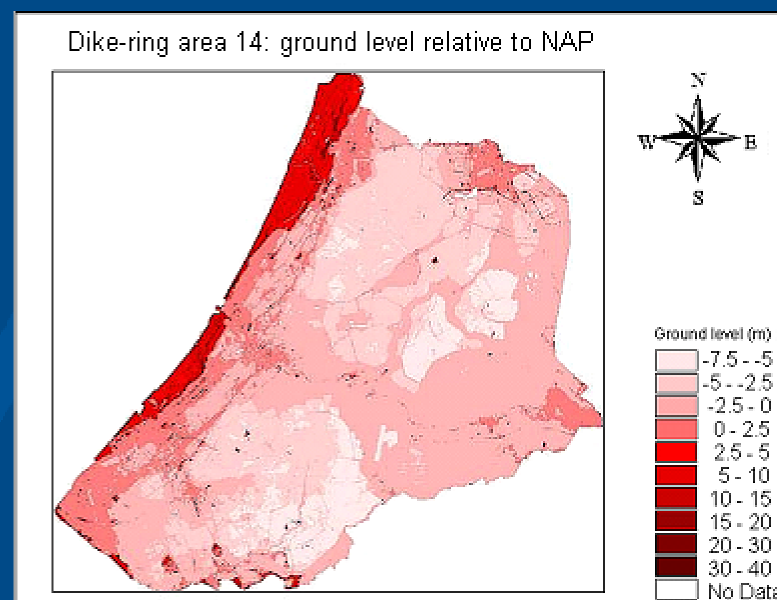
objects per cell →

water depth → damage function → Beta samples

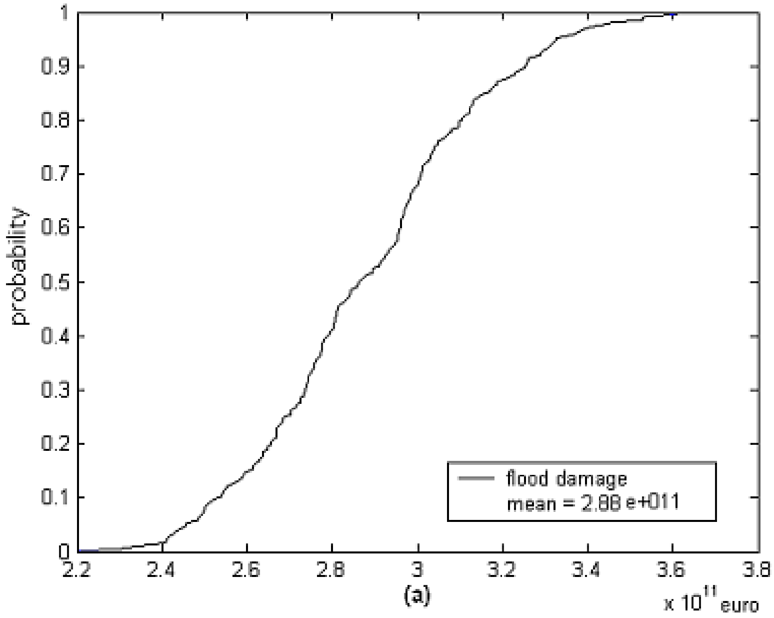
maximum damage → Triangular samples

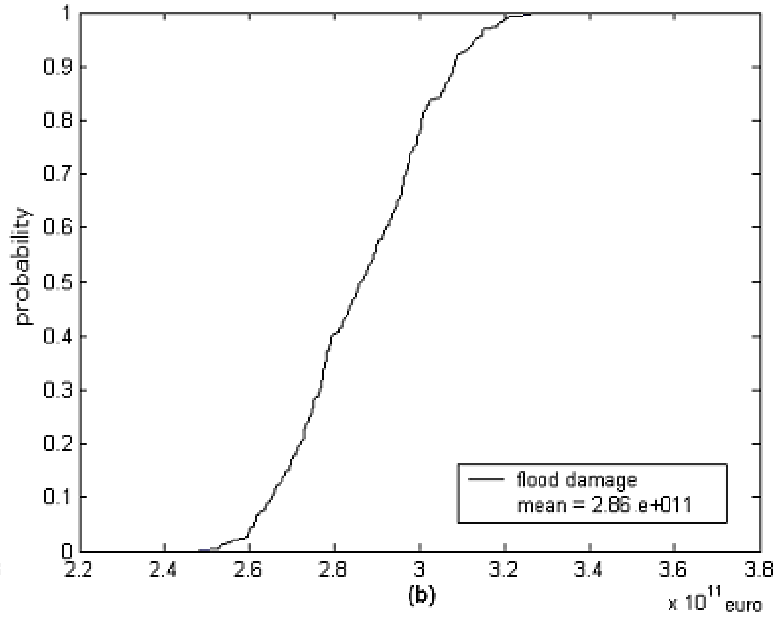
→ inner sum samples → Flood damage samples

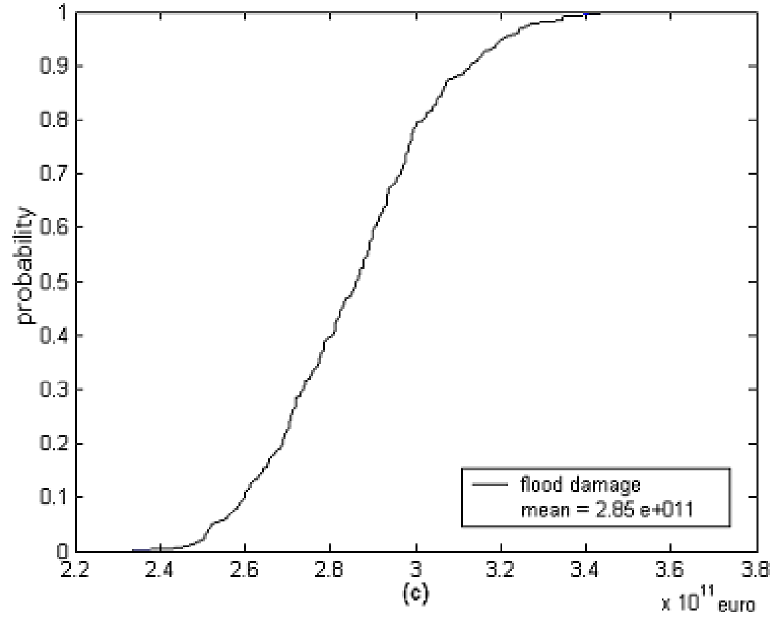




Results: 2m (NAP) water level







(a) - complete dependence

(b) - independence

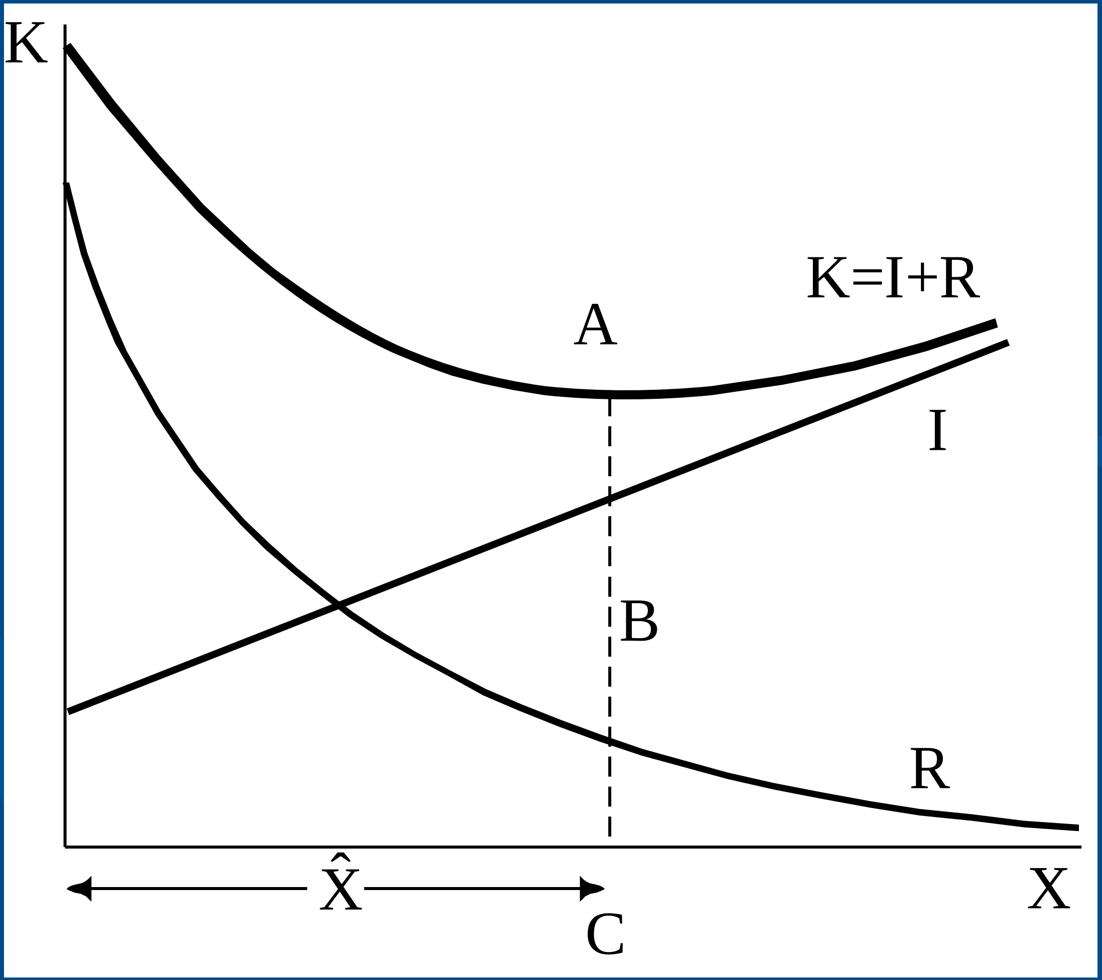
(c) - stratified dependence

Uncertainty flood damage: results

depth	HIS(bln.)	model	mean	5%	95%	st.dev(bln.)	coef.var.
2m (NAP)	282.7	DEP	288.0	245.1	332.7	26.6	0.092
		IND	286.5	260.7	313.2	16.3	0.057
		STR	285.6	251.7	320.5	20.1	0.070
-2m (NAP)	56.9	DEP	60.8	45.7	78.3	9.9	0.163
		IND	60.6	55.4	66.0	3.3	0.055
		STR	60.8	51.9	71.3	5.9	0.097

Economic safety standard (1)

Minimising sum of Loss (R) and Investment (I)



Economic safety standard (2)

- Deterioration of watersystem (settlement, climate change)

  => Increase of flooding probability

- Economic growth and increase population

  => Increase of potential damage

- In combination: Expected loss increases
  - ➢ Change of conditions implies more than one decision on height of dikes

Economic safety standard (3)

- **Interest rate (r > 0) :**

  postpone costs as much as possible, do not more than strictly necessary at once

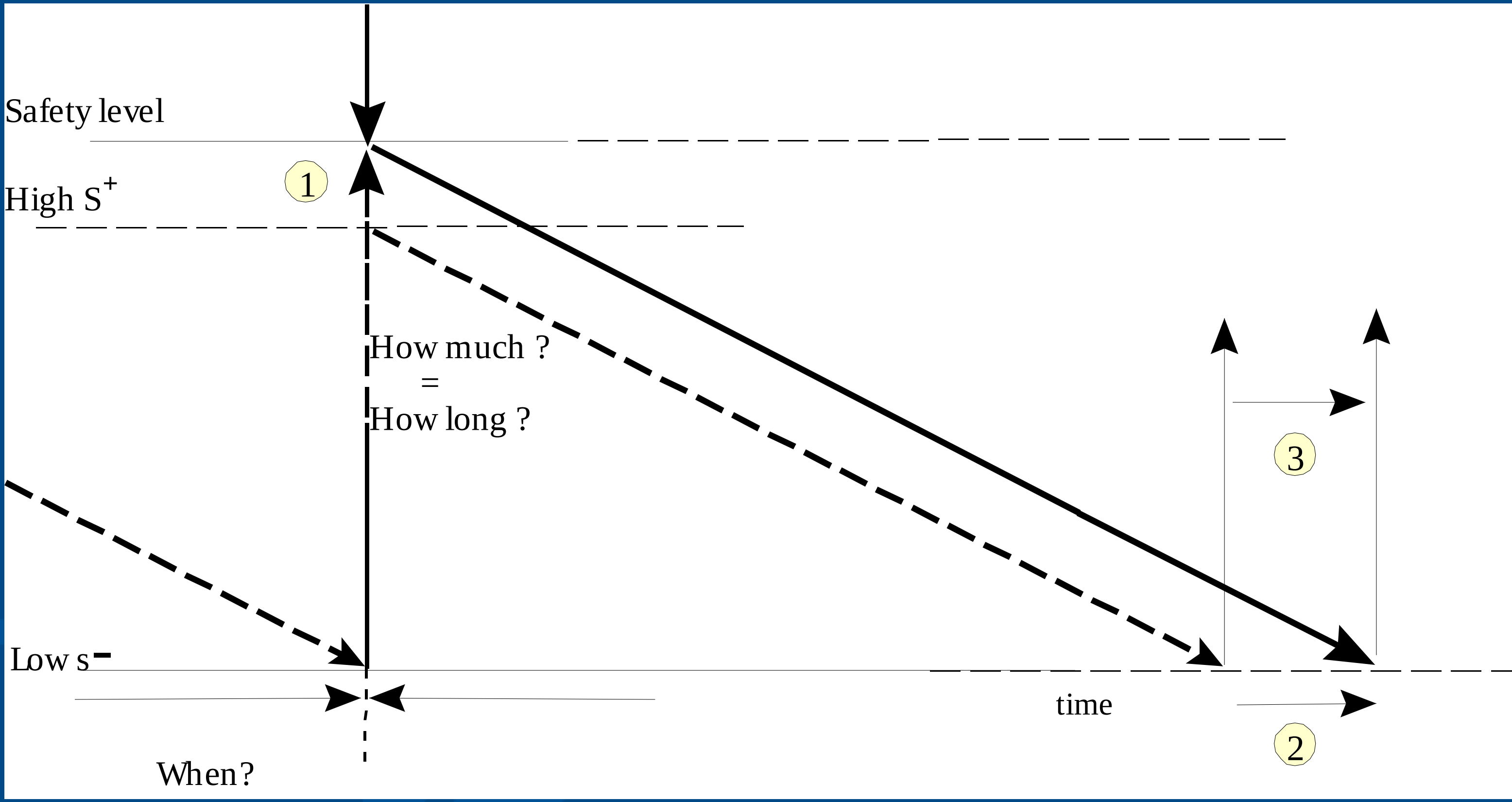
- **Fixed investment costs**

  investment in safety in ‘jumps’

Result: Safety level is not constant

- **High, directly after investment**
- **Gradually decreasing afterwards untill just before new investment**

New strategy: periodic investments



Proposed by Central Planning Office (CPB)
(mr. C. Eijgenraam)

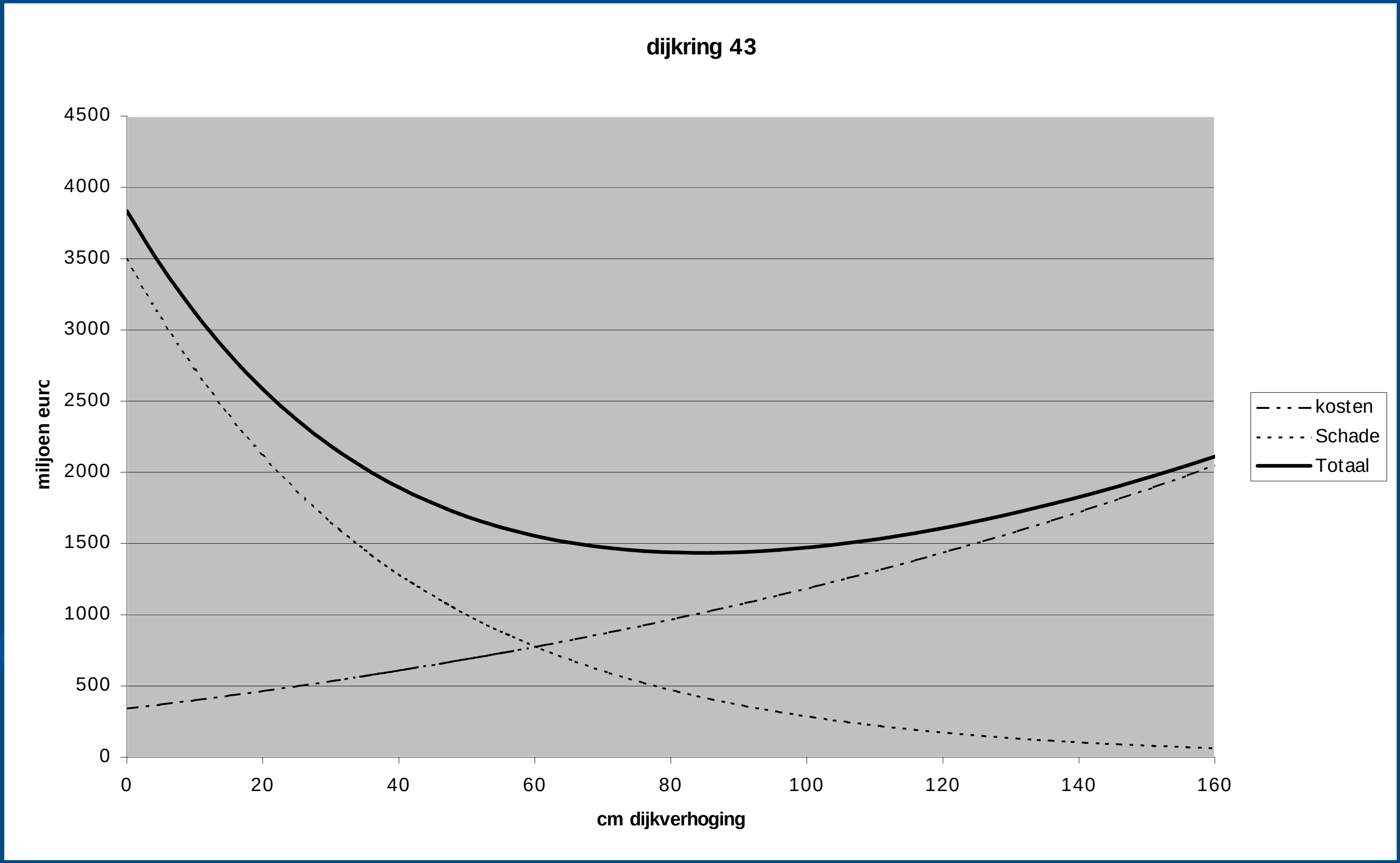
Economic safety standard (4)

Conclusions of Central planning Office:

- **Constant exceedance probabilities are misleading as good safety standards**
- **Expected loss is correct criterion for safety standards**
- **Actual calculation is needed**

In future shift needed towards: control of expected loss by flooding

Economic safety standard (5)



Total costs: very flat

Optimum safety level: 1/4800 (now: 1/1250)