Flood risk management in the Netherlands

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Outline

• Introduction

• Quantifying the risk of flooding

• Evaluating risk acceptability

• Conclusions
A history marked by floods
Major Flood of 1953

> 1800 fatalities
> 1800 km² flooded
Major Flood of 1953

> 1800 fatalities
> 1800 km² flooded
>50 major levee systems
>3600 km of flood defenses
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Recent innovations

Building with Nature:
Sand engine

Hidden structures
Current standards

Defined in terms of design loads

1 Standard for each major levee system

Based on cost-benefit analyses from the 1950s and 1990s
VNK2-project objectives

Provide detailed flood risk estimates...

- Economic risk
- Fatality risk

...for all 53 major levee systems

- 3600km of levees
- 60% of Dutch territory
Participating organisations

**Government bodies**
- Rijkswaterstaat
- More than 20 water boards
- 12 Provinces

**Research institutes/networks**
- TNO
- Deltares
- Delft University of Technology
- Expertise Network for Flood Protection (ENW)

**Engineering consultancies**
- Arcadis
- DHV
- Fugro
- Greenrivers
- Grontmij
- HKV Consultants
- Hydraulologic
- Infram
- IV-Infra
- JongejanRMC
- Lievense
- Oranjewoud
- Royal Haskoning
- RPS
- Tauw
- Witteveen+Bos
Risk analysis procedure

1. Decompose levee system into smaller sections
2. Calculate failure probabilities per section
3. Define flood scenarios and compute their probabilities
4. Estimate consequences per flood scenario
5. Combine scenario probabilities and consequences
1. Decompose levee system
2. Calculate failure probabilities

Failure mechanisms

**levees**
- Overtopping
- Slope instability
- Piping
- Revetment failure

**Hydraulic structures**
- Overtopping
- Non-closure
- Piping
- Structural failure
2. Calculate failure probabilities

<table>
<thead>
<tr>
<th></th>
<th>Section 1</th>
<th>Section 2</th>
<th>Section j</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism 1</td>
<td>$P_{11}$</td>
<td>$P_{12}$</td>
<td>$P_{1j}$</td>
<td>$P_{1,ring}$</td>
</tr>
<tr>
<td>Mechanism 2</td>
<td>$P_{21}$</td>
<td>$P_{22}$</td>
<td>$P_{2j}$</td>
<td>$P_{2,ring}$</td>
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<tr>
<td>Mechanism i</td>
<td>$P_{i1}$</td>
<td>$P_{i2}$</td>
<td>$P_{ij}$</td>
<td>$P_{i,ring}$</td>
</tr>
<tr>
<td>Combined</td>
<td>$P_{\text{mech},1}$</td>
<td>$P_{\text{mech},2}$</td>
<td>$P_{\text{mech},j}$</td>
<td>$P_{\text{flood}}$</td>
</tr>
</tbody>
</table>

Correlations are taken into account
3. Define flood scenarios and calculate probabilities

Flood scenario = Sequence of events, initiated by one or more section failures

These 4 sections fail and no other section fails
4. Estimate consequences per scenario
4. Estimate consequences per scenario

- Flood simulation
- Inundation depth
- Land use
- Evacuation effectiveness
- Damage function
- Damage
5. Combine probabilities and consequences

<table>
<thead>
<tr>
<th>Expected value of economic damage [euro yr(^{-1})ha(^{-1})]</th>
<th>FN-curve</th>
</tr>
</thead>
</table>

- **Expected value of economic damage [euro yr\(^{-1}\)ha\(^{-1}\)]**
  - < 10
  - 10 - 100
  - 100 - 1000
  - 1000 - 5000
  - > 5000

- **FN-curve**
  - FN-curve dike ring 5 Texel
  - FN-curve dike ring 14 South Holland

<table>
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<th>Individual risk excl. the effect of evacuation [yr(^{-1})]</th>
<th>Individual risk incl. the effect of evacuation [yr(^{-1})]</th>
</tr>
</thead>
</table>

- **Individual risk excl. the effect of evacuation [yr\(^{-1}\)]**
  - Presented with a gradient of risk levels.

- **Individual risk incl. the effect of evacuation [yr\(^{-1}\)]**
  - Presented with a gradient of risk levels, indicating potential evacuation impact.
Analyzing the effect of flood risk management actions

10 measures
Evaluating current practice

The same standards for the north and the south?
Results of VNK2

• Insight
  – into the risk of flooding
  – into the inefficiencies of the “old” standards/practices
  – into key risk factors

• Confidence in the feasibility of a probabilistic approach

• Greater familiarity with basic concepts in risk analysis
Strategic choices - the Delta Program

1. Crisis management
   e.g. www.overstroomik.nl

2. Spatial planning

3. Prevention
New standards of protection (2017)

Based on:
- Individual risk $< 10^{-5}$ per year
- Societal risk
- Cost-benefit analysis
Individual risk $< 10^{-5}$ per year

Source: VNK2, 2014
Societal risk

Source: VNK2, 2014
Cost-benefit analysis

- System reliability
- Investment cost
- Risk

![Graph showing cost-benefit analysis with axes for $, Risk, and System reliability](image-url)
Cost-benefit analysis

- Investment cost
- Risk
- System reliability

$
Cost-benefit analysis

- System reliability
- Investment cost
- Risk

$ \quad \text{Risk} \quad \text{System reliability}$

Investment cost + Risk

Investment cost
Cost-benefit analysis

$\quad$ Investment cost + Risk

$\quad$ Investment cost

$\quad$ Risk

$\quad$ System reliability

Cost - benefit analysis
New flood protection standards (2017)

- 1/100 – 1/100,000 per year
- Variations within major levee systems
Closing remarks

• Dutch flood risk management practices are strongly risk-informed

• The focus lies heavily on prevention, with an eye for crisis management and spatial planning

• New flood protection standards (2017) based on:
  – individual risk < 10^{-5} per year
  – societal risk evaluation
  – cost-benefit analysis
Questions?

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Organization of flood protection

National government
- legislation (protection standards)
- financial assistance
- management of coastline, rivers and several large dams/barriers

12 Provinces
- supervision
- spatial planning

25 Water boards (levee owners)
- periodic safety assessments
- maintenance, restoration projects
A short history of the Dutch protection standards

1953 Major Flood

1953-1960 Delta Committee
Design standards based on cost-benefit analysis

1995 Flood Protection Law (later: Water Law)
Standards codified, also for river areas
A short history of the Dutch protection standards

2007-2008 2nd Delta Committee
Policy review

2010 Delta Programme starts
Regional studies, discussions

2014 Proposal

2015 Draft update of Water Law
Strategic

Important aspects:
• Climate change
• Economic growth
• Population growth
• Changing preferences

Operational

Important aspects:
• Budget constraints
• Scientific progress

Evaluate risk acceptability

25-50 years

Evaluate alternatives

Choose approach Set standards

Minitor

Maintenance

12 years

Assessment

Design

Programming
2. Calculate failure probabilities
Individual risk

Probability of dying at a particular location:

$$\text{IR}(x, y) = \sum_{i} (1 - P_{\text{evacuation}}) P_{f,i} P_{d|f,i}(x, y)$$

- Probability of succesful evacuation
- Probability of flood scenario i
- Probability of dying at location $(x, y)$ given scenario $i$