COST Action
TU 1402

Quantifying the Value of Structural Health Monitoring

SHM for (earthen) flood defences

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Deltares
Enabling Delta Life

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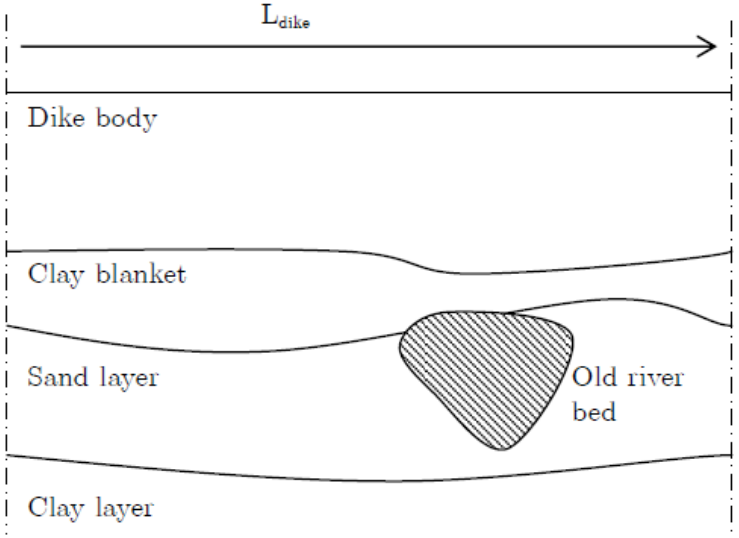
1. Background

- Netherlands: approximately 2/3rds is floodable area from the main water system.
- 4000 km of primary flood defences (with smaller ones: 18000 km)
- In 2017 new risk-based safety standards have been introduced, about 1500km of primary dikes has to be reinforced in the coming decades.

1. Background

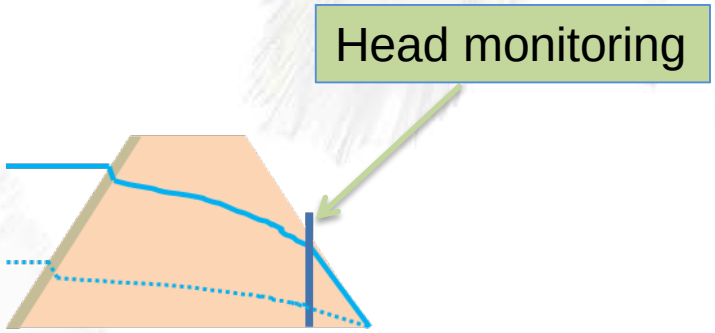
- Dikes are assessed every 12 years
- If disapproved they are added to the Flood Protection Program
- Aim is to be up to standard in 2050
- There are generally large challenges due to heterogeneity of dikes (in subsoil and dike body itself)
- That heterogeneity is one of the reasons why SHM is promising in many cases



Picture from Kanning 2012

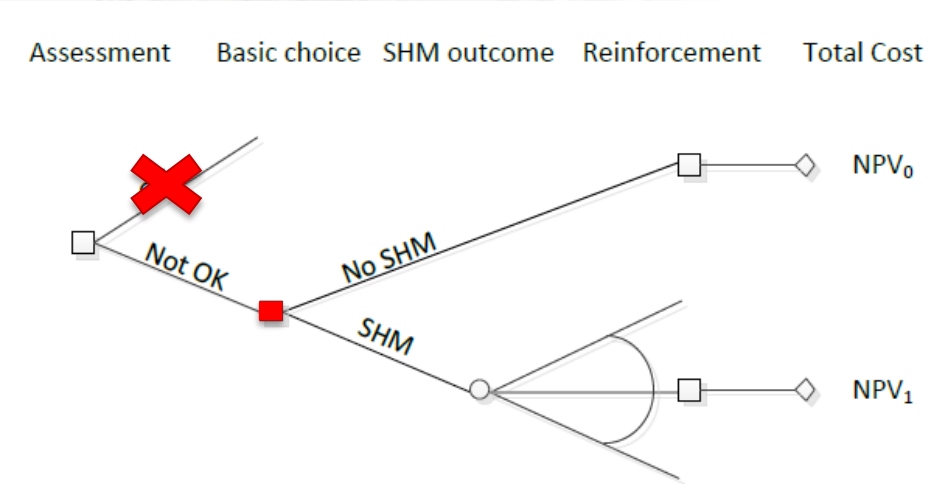
1. Background

- Sea dike in north of the Netherlands
- Disapproved in 2011 assessment
- Not believed by water authority
- FloodControl IJkdijk research program:
  - New methods for SHM of dikes
  - This became a (major) pilot
- Main part of SHM was monitoring of the hydraulic head inside the dike body.



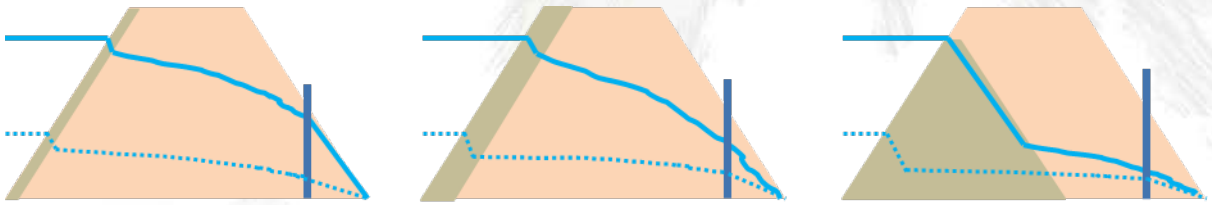
2. Decision scenario

- Disapproved, so normally: reinforcement
- But in this case alternative strategy:
  - Postpone reinforcement
  - do SHM (for 3 years)
  - then decide on reinforcement
- The decision scenario is recurring: every time an assessment is made (i.e. every 12 years)



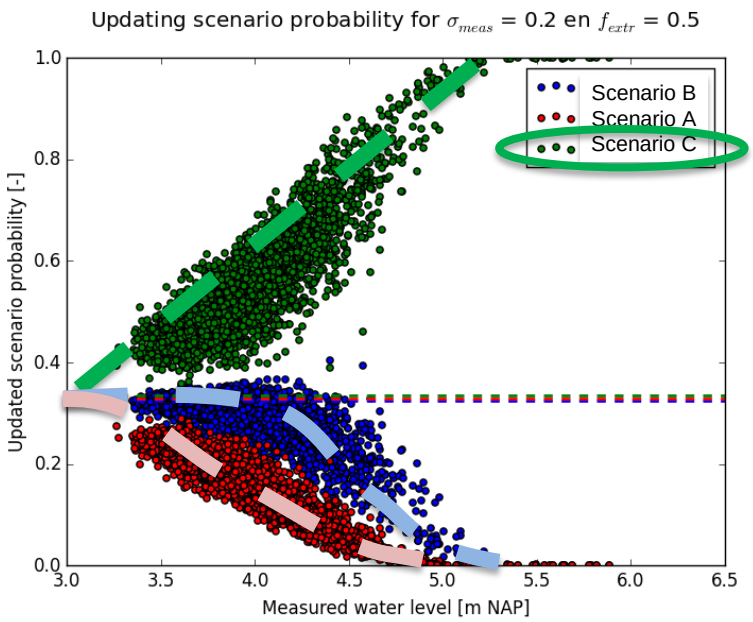
2. Decision scenario

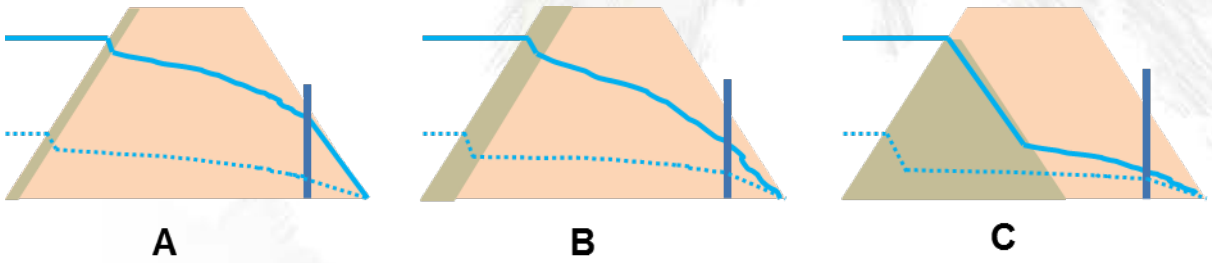
- During three years observations are made of the actual state
- There are three possible scenarios
  - Assessment (2011): scenario A
  - Water authority estimate (2011): scenario B
  - Eventually: scenario C
  - Prior probabilities: 20%, 60%, 20%



3. Methods applied

- We did two analysis:
  - Pre-posterior analysis
  - Posterior analysis
- As monitoring benefits for flood defences strongly depend on water levels we implemented an 'extrapolation uncertainty' (see figure)
- Consequence: benefits depend on observed water levels

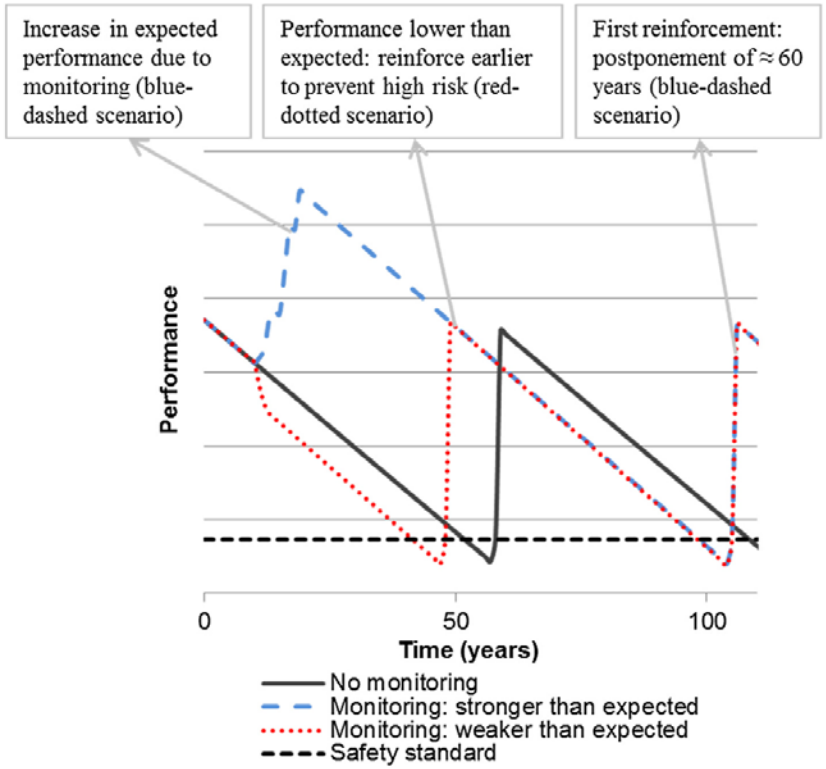




2. Methods applied

- In this case we consider a long term investment pattern:
  - Decision scenario is repeated

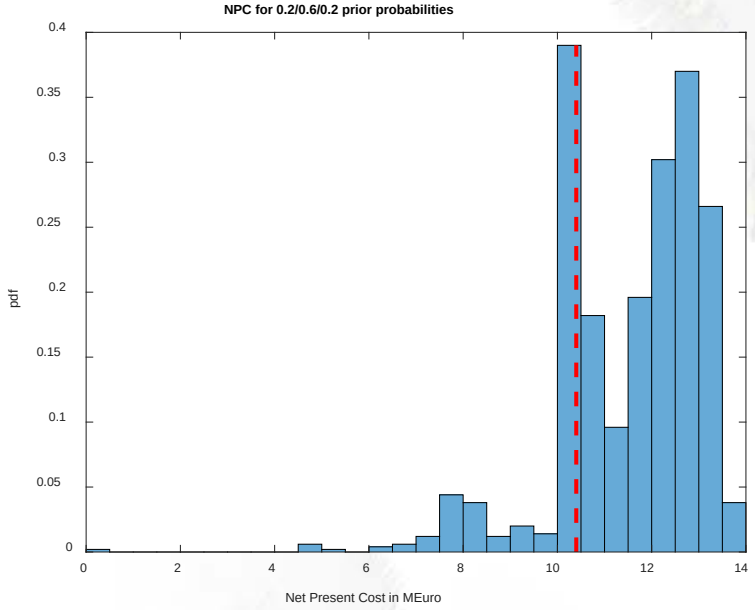
➢ So benefits of monitoring in the very long term are also accounted for



Jonkman, S.N., Voortman, H.G., Klerk, W.J., van Vuren, S., 2018. Developments in the management of flood defences and hydraulic infrastructure in the Netherlands. Struct. Infrastruct. Eng. 1–16. doi:10.1080/15732479.2018.1441317

3. Results obtained (pre-posterior)

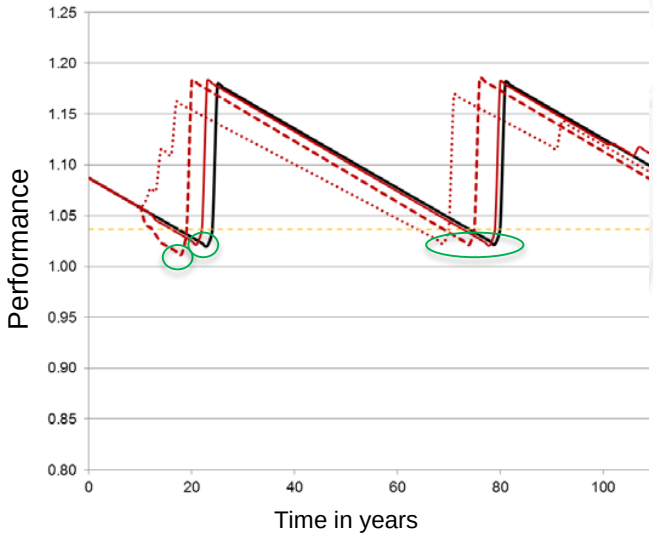
- Not attractive:
  - Due to increased risk cost from postponing reinforcement
  - Due to limited expected value of 3 years of monitoring
  - In all cases some reinforcement is needed
- So intermediate conclusion:
  - SHM benefits depend on: efficiency of monitoring, duration, risk level & cost difference for different scenarios

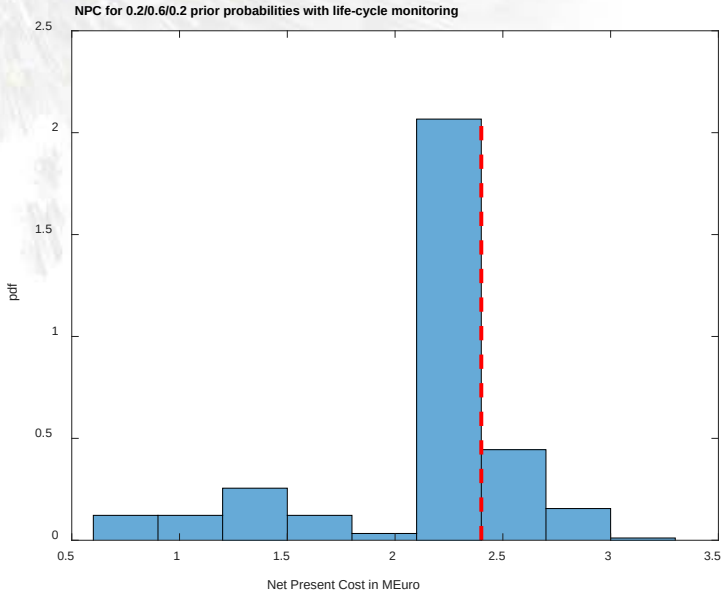


Net Present Risk Cost (in M€)	5%	median	95%
No SHM	0.1	7.0	23.6
SHM	0.2	11.4	37.7

3. Results obtained (pre-posterior)

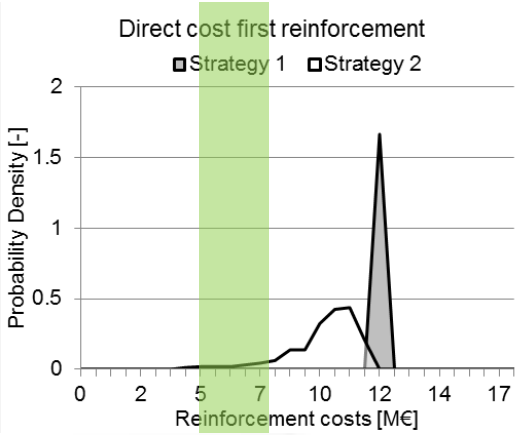
- So proposal to not monitor if reinforcement is needed already
  - Life-cycle monitoring instead of ‘project monitoring’
- Assume a flood defence that is not disapproved yet
- More time available -> more valuable information
- Lower risk costs due to not postponing needed reinforcement

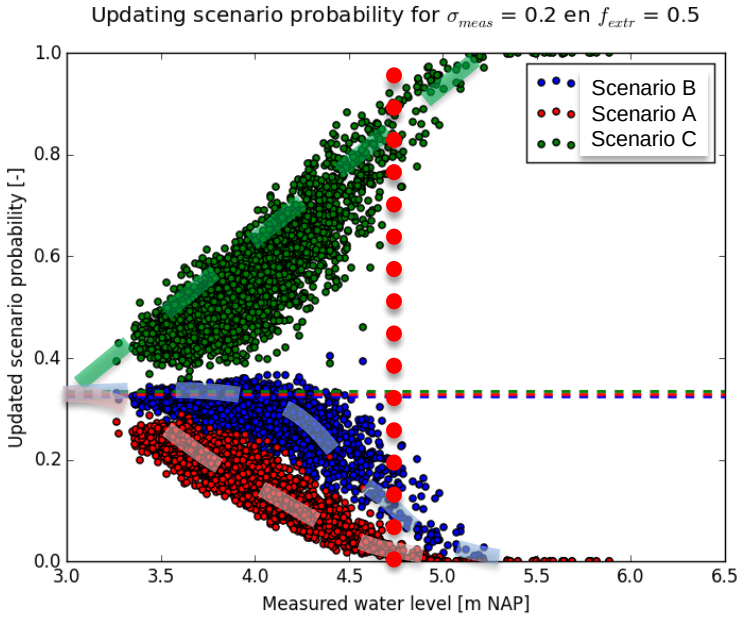




3. Results obtained (posterior)

- Posterior: state of nature = most favourable scenario
- Great benefits (green area in figure) ≈35% saving in reinforcement.
- About 20% including risk costs.
- But 'a bit' lucky, 1/80 yr^{-1} storm in 3 years of monitoring
- And no flood occurred: so no 'risk costs'





4. Value of the SHM information for the owner/concessionaire

Case specific:

- The actual case (posterior) was very insightful and ‘no regret’
- This also follows from additional benefits (that were not taken into account) such as:
  - Improved insight in behaviour during high water
  - General experiences obtained with SHM
  - No flood occurred during the monitoring campaign…
  - During campaign: thorough ‘fact-finding’ effort to understand flood defence behaviour -> real understanding of behaviour (cultural improvement)

4. Value of the SHM information for the owner/concessionaire

General conclusion:

- A decision on SHM for a flood defence should always be a consideration between:
  - Risk level
  - Whether a large (risk-reducing) intervention has to be postponed
  - Expected benefits in different scenarios, e.g. :
    - Distinctive features of scenarios
    - Probability of measuring meaningful behaviour

5. Open question addressed to decision makers

- How would you value the risk costs and maintenance/reinforcement costs relatively (e.g. equal, or risk-averse/seeking)?
- What would you perceive as your most important benefit: insight in extreme situations? Reduced costs for interventions? Something else?
- Does your organizational structure (e.g. performance indicators) support activities such as life-cycle monitoring? (i.e. pre-investing with uncertain benefits)

Thank you for your attention

http://www.cost-tu1402.eu/
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