Animal burrows in your levees

What does it take to keep your levees safe from animals?

Vana Tsimopoulou & André Koelewijn

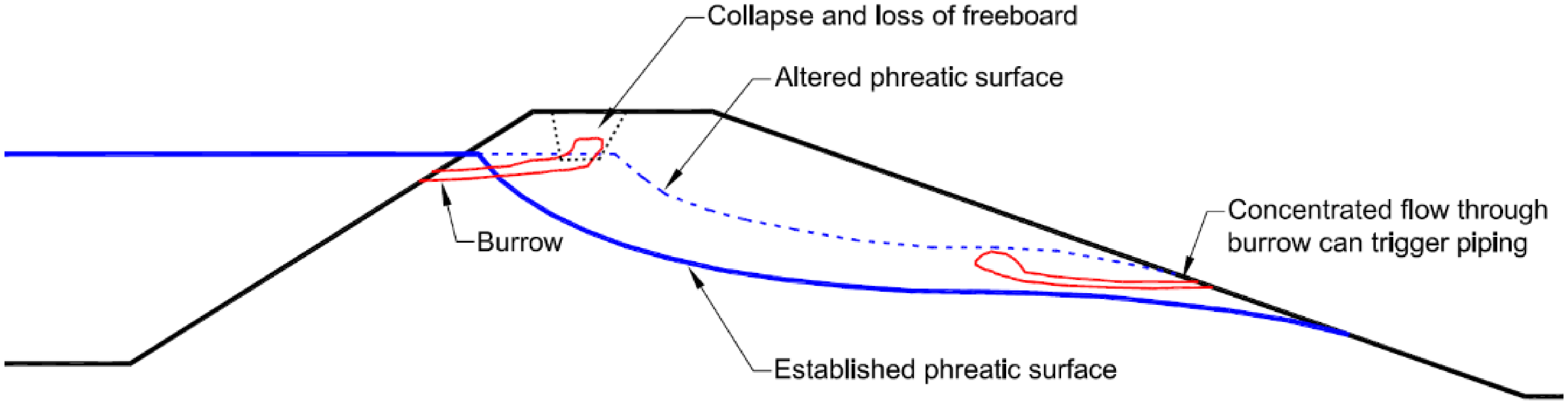
Polder2C's final conference, Antwerp 7-9 March 2023

This project has received funding from the Interreg 2 Seas programme 2014-2020 co-funded by the European Regional Development Fund under subsidy contract No [2S07-023]

The problem

Levee design and safety assessment

No explicit consideration of animal-induced **anomalies**



(Source: Cobos Roa, 2015)

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The problem

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Levee managers' perspective

- Levees attract burrowing animals
- Many of them are protected (e.g. beavers)
- **No straightforward approach** for dealing with them

Scientists' perspective

- Much tacit knowledge among levee guards (NL, B, UK, F)
- Limited reports with relevant information and studies
- **Formal knowledge** on the topic is **limited and fragmented**

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Animal burrows & Polder2C's

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Advance & share knowledge

Flood emergency response

Design & maintenance of levees

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Evidence of animal activity on the levee

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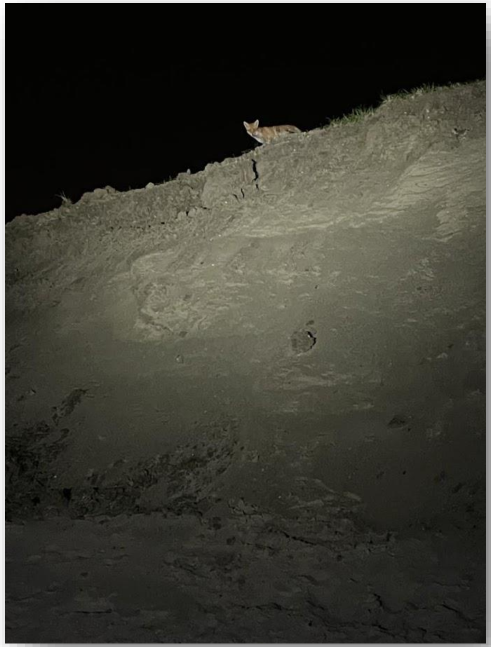

Fox during night inspection

Burrow on landward slope, diameter approx. 25cm

Sand deposit under foxhole

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Evidence of serious impact on the levee

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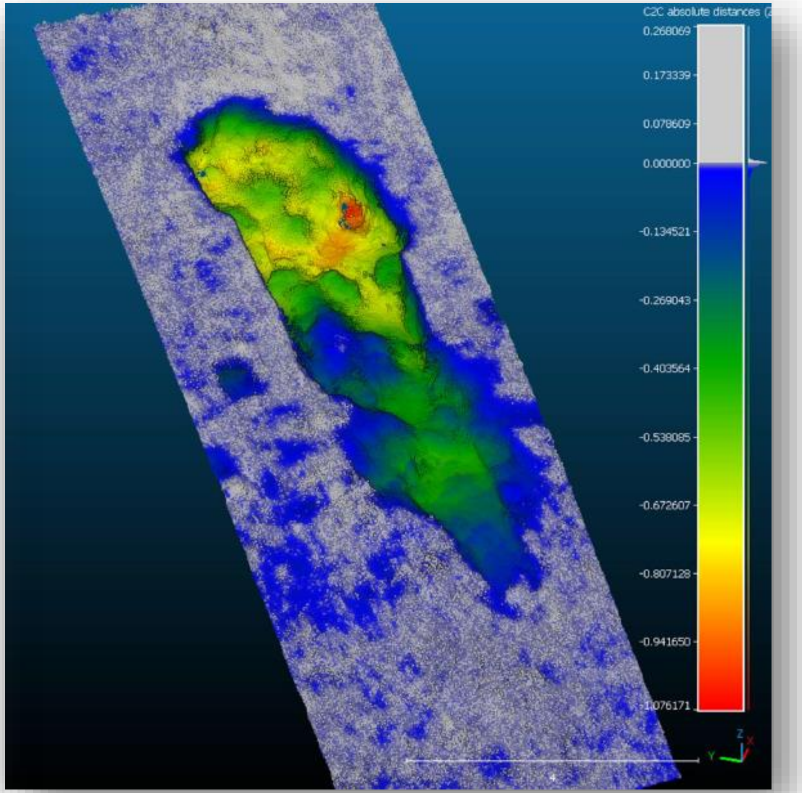

Overflow on section with a large burrow

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Defining topics of interest

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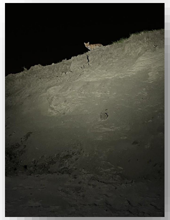
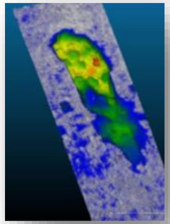


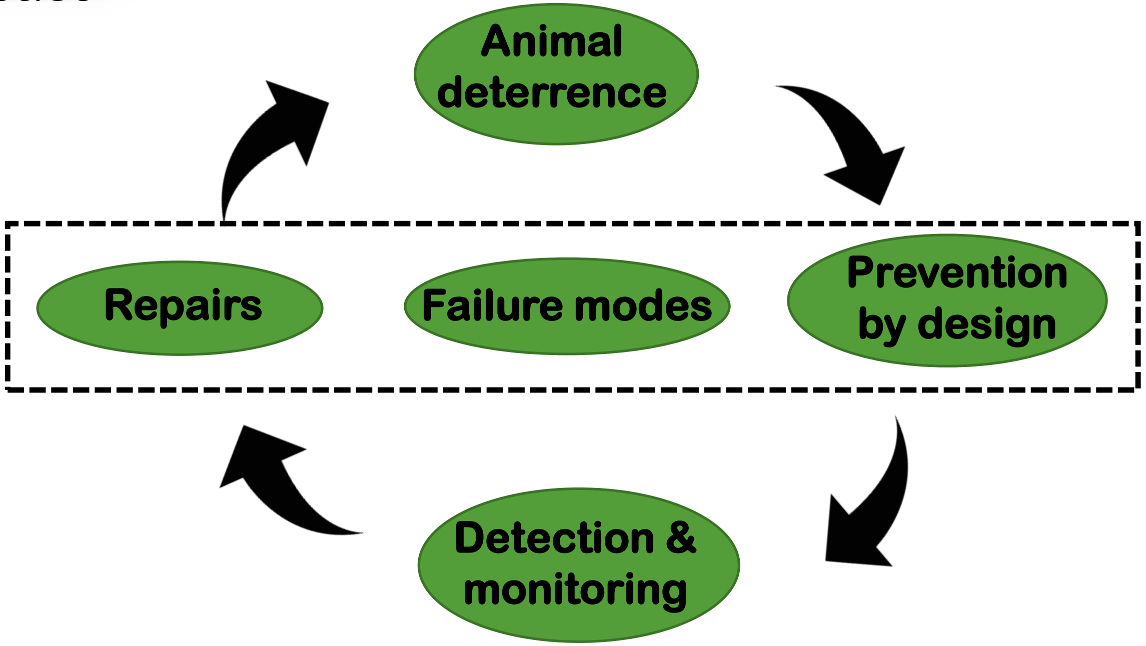
x



Likelihood Impact

Animal activity on levees cannot be ruled-out but can be managed like a risk

Compass
the safety chain concept



Key questions

- ✓ *Identify possible solutions*
- ✓ *Verify their technical feasibility*
- ✓ *Evaluate their effectiveness*

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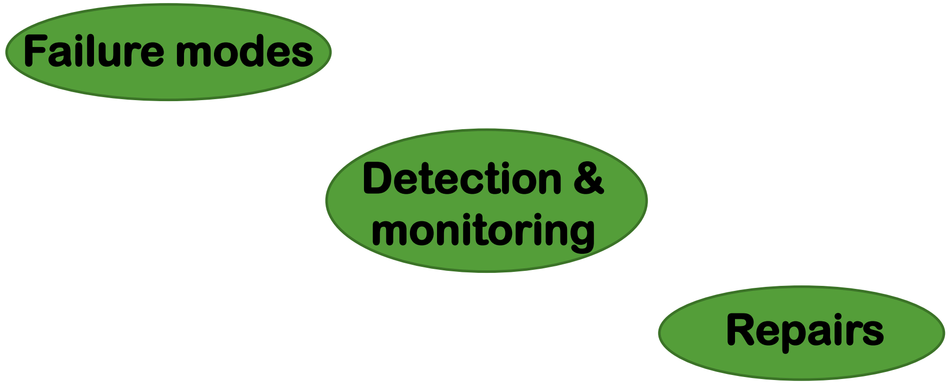
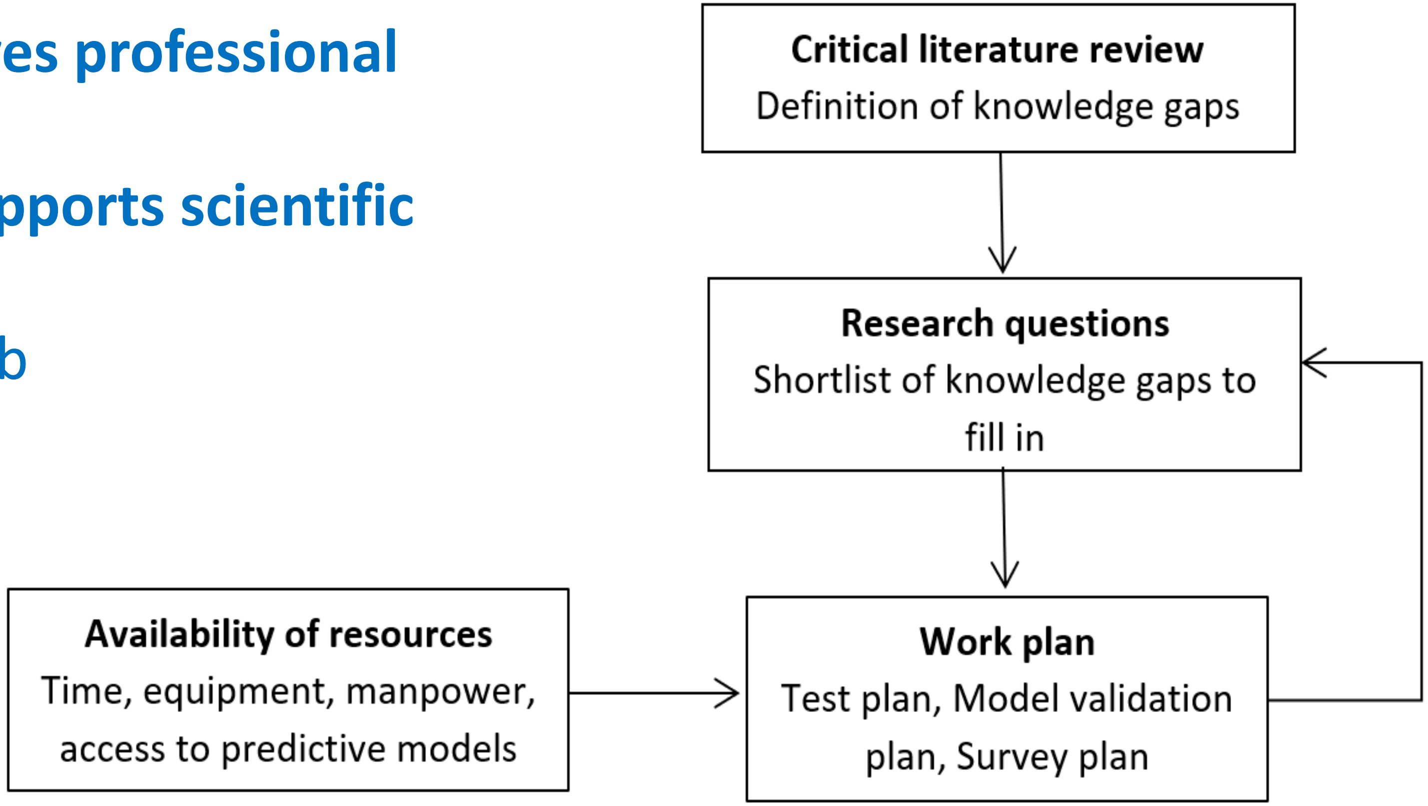
Defining study objectives

Boundary conditions

1. Develop knowledge that **improves professional practice**
2. Provide formal evidence that **supports scientific research**
3. **Fit in the context** of the living lab





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Failure modes

Which animal burrows are dangerous for your levee?

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Overflow test on a fox/rabbit hole (1 h 13 min)

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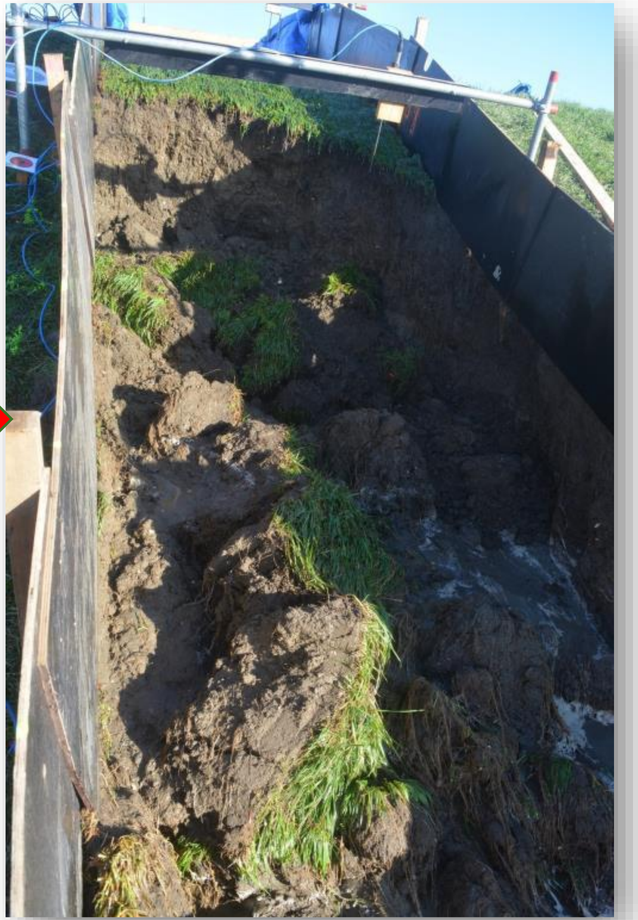

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Overflow test with mole burrows (1 h 7 min)

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Influence of mole burrows

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- Another test with a tree failed by mole burrows after 13 hours of flow
- Tests where no failure occurred, had no mole burrows
- Elsewhere, wave overtopping tests showed a remarkable influence of the presence/absence of mole burrows (MSc thesis Peter van Dijk, TU Delft, 31 August 2021)
- Yet, how to quantify this influence, in general or in specific cases…?

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Beavers in embankments

- A beaver hole through a regional dike (Zijkade near Vianen, Netherlands)

Did this dike fail or not?

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A spin-off of Polder2C's: a Table of Influence

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Animal species – location in dike	Landward stability	Uplift of cover layer	Erosion of cover	Piping through hole in cover	Backward erosion piping
Beaver					
- landside slope	0.01 – 1	0.000 1 – 1	*	1 – 100 000	1 – 10 000
- waterside slope	1 – 1000	1 – 1000	1 – 100	1 – 100	1 – 100 000
- both slopes	0.1 – 100	0.001 – 100	1 – 1000	10 – 1 000 000	1 – 10 000 000
Badger					
- landside slope	0.01 – 1	0.001 – 1	3 – 1000	1 – 100 000	*
- waterside slope	1 – 10 000	1 – 10 000	3 – 1000	1 – 1000	*
- both slopes	0.1 – 1000	0.001 – 10 000	3 – 10 000	3 – 10 000 000	*
Mole					
- landside slope	0.1 – 1	0.01 – 1	1 – 100	1 – 1000	*
- waterside slope	1 – 30	1 – 10	1 – 100	1 – 100	*
- both slopes	1 – 10	0.01 – 10	1 – 1000	1 – 10 000	*
Fox and rabbit					
- near creast	0.1 – 3	0.3 – 10	3 – 1000	1 – 100	*
- low, landside	0.01 – 1	0.001 – 1	3 – 1000	1 – 1000	*
- low, waterside	*	*	*	*	*
Vole and mouse					
- landside slope	0.1 – 1	0.1 – 1	1 – 3	1 – 10	*
- waterside slope	1 – 3	1 – 3	1 – 3	1 – 3	*
- both slopes	0.1 – 3	0.1 – 3	1 – 3	1 – 30	*

Remarks on the table

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- Values indicate the increase of the probability of failure (>1 = more risk)
- All values are part of a range – the extreme values will rarely be reached
- The values are derived for the primary flood defences of the Netherlands, for other dikes and levees, the size and other characteristics should be taken into account
- Probabilities of failure tend to be in orders of magnitude, so a factor of 10 or 100 may be reached easily
- Most of the more extreme numbers have been derived by a combination of field observations and numerical analyses
- Many entries are still based on proportionality and reasoning

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Derivation of entries

- Observations and calculations
- Observations and reasoning
- Calculations only
- Reasoning only
- Proportionality with other species

Animal species – location in dike	Landward stability	Uplift of cover layer	Erosion of cover	Piping through hole in cover	Backward erosion piping
Beaver					
- landside slope	0.01 – 1	0.000 1 – 1	*	1 – 100 000	1 – 10 000
- waterside slope	1 – 1000	1 – 1000	1 – 100	1 – 100	1 – 100 000
- both slopes	0.1 – 100	0.001 – 100	1 – 1000	10 – 1 000 000	1 – 10 000 000
Badger					
- landside slope	0.01 – 1	0.001 – 1	3 – 1000	1 – 100 000	*
- waterside slope	1 – 10 000	1 – 10 000	3 – 1000	1 – 1000	*
- both slopes	0.1 – 1000	0.001 – 10 000	3 – 10 000	3 – 10 000 000	*
Mole					
- landside slope	0.1 – 1	0.01 – 1	1 – 100	1 – 1000	*
- waterside slope	1 – 30	1 – 10	1 – 100	1 – 100	*
- both slopes	1 – 10	0.01 – 10	1 – 1000	1 – 10 000	*
Fox and rabbit					
- near creast	0.1 – 3	0.3 – 10	3 – 1000	1 – 100	*
- low, landside	0.01 – 1	0.001 – 1	3 – 1000	1 – 1000	*
- low, waterside	*	*	*	*	*
Vole and mouse					
- landside slope	0.1 – 1	0.1 – 1	1 – 3	1 – 10	*
- waterside slope	1 – 3	1 – 3	1 – 3	1 – 3	*
- both slopes	0.1 – 3	0.1 – 3	1 – 3	1 – 30	*

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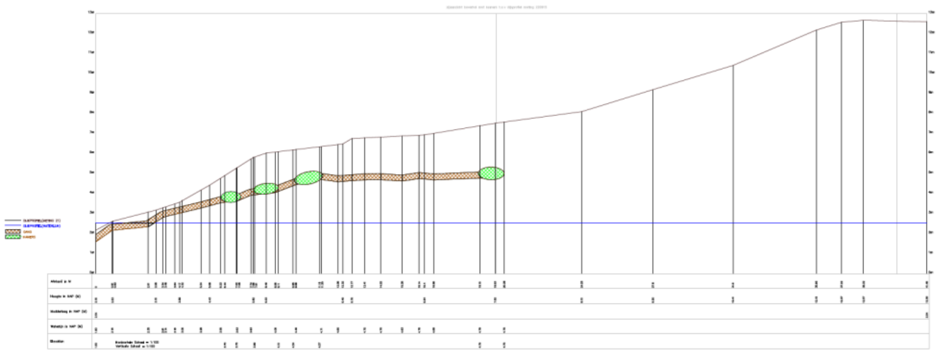
Case: beaver causing piping through a hole in the cover

Beaver burrow system at Wamel (NL), Summer 2022

Scenario at highwater conditions:

1. Burrows attract more water than drainage system *0.5-0.8*
2. Fluidisation of lower landside toe *probability of 0.1-0.5*
3. Instability of entire slope – *probability of failure 1.48x10^{-4} per year with burrows + step 1,2 | 3.55x10^{-9} per year for completely intact situation*
4. Further failure of remaining profile *prob. 0.5-0.9*
5. Emergency measures fail *probability of 0.1-0.9*

Altogether 100 – 14 000 higher failure prob.



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Case: beaver causing backward erosion piping

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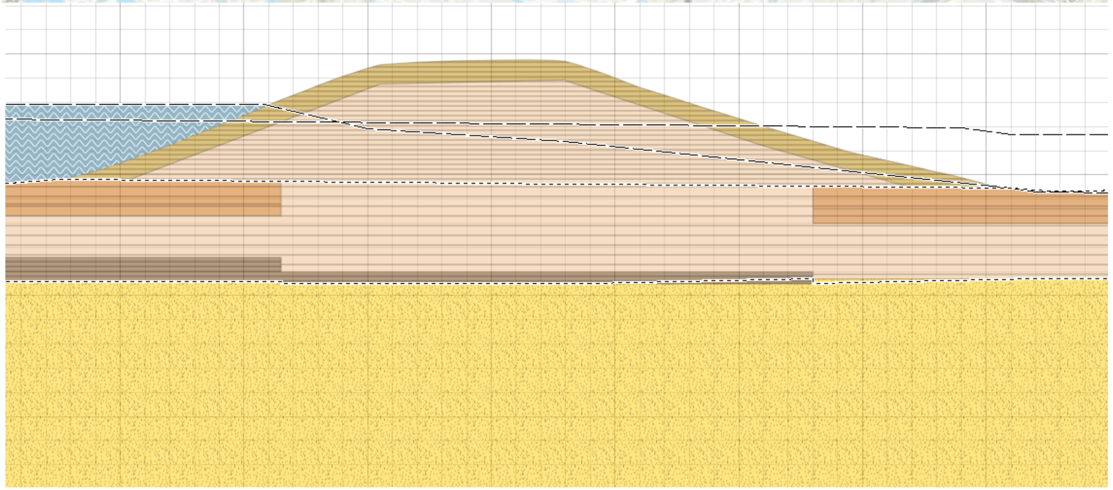
- Area to the West of Arnhem
- Currently, seepage length is around 180 m, several beaver families residing on both sides of the river (Nederrijn)
- In case of a beaver connecting to the sand layer close to the levee, e.g. during a (very) dry period, seepage length reduces to 85 m
- Probability of failure changes from 1:22 000 000 per year to 1:264 per year – nearly 100 000 times higher



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Detection & Monitoring

Q1: How can we spot burrows during visual inspections?

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Mapping burrows with visual inspections

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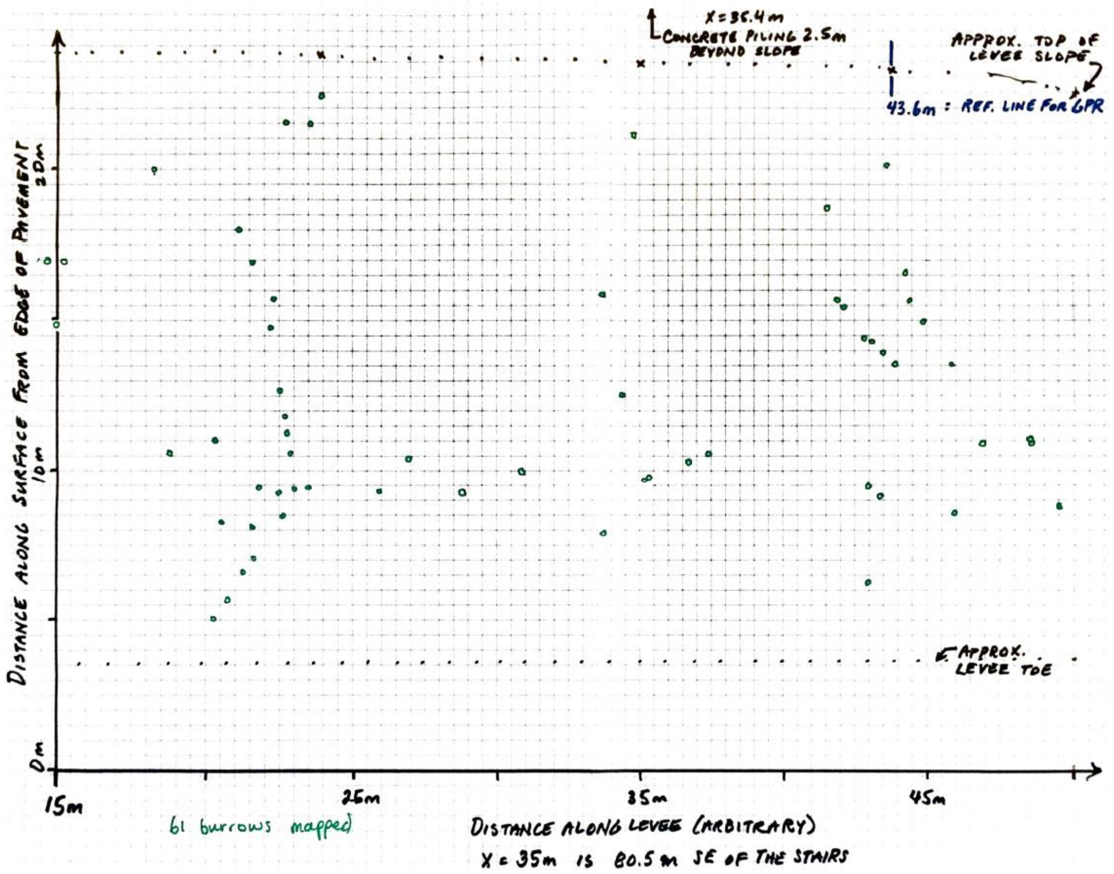
Mapping burrows with visual inspections

Hedwigepolder, September 2021



- Burrows of small rodents
- 100 m of levee surveyed
- 90 burrows detected
- Depths < 25 cm
- Diameters: 1 - 12 cm

Mapping burrows with visual inspections

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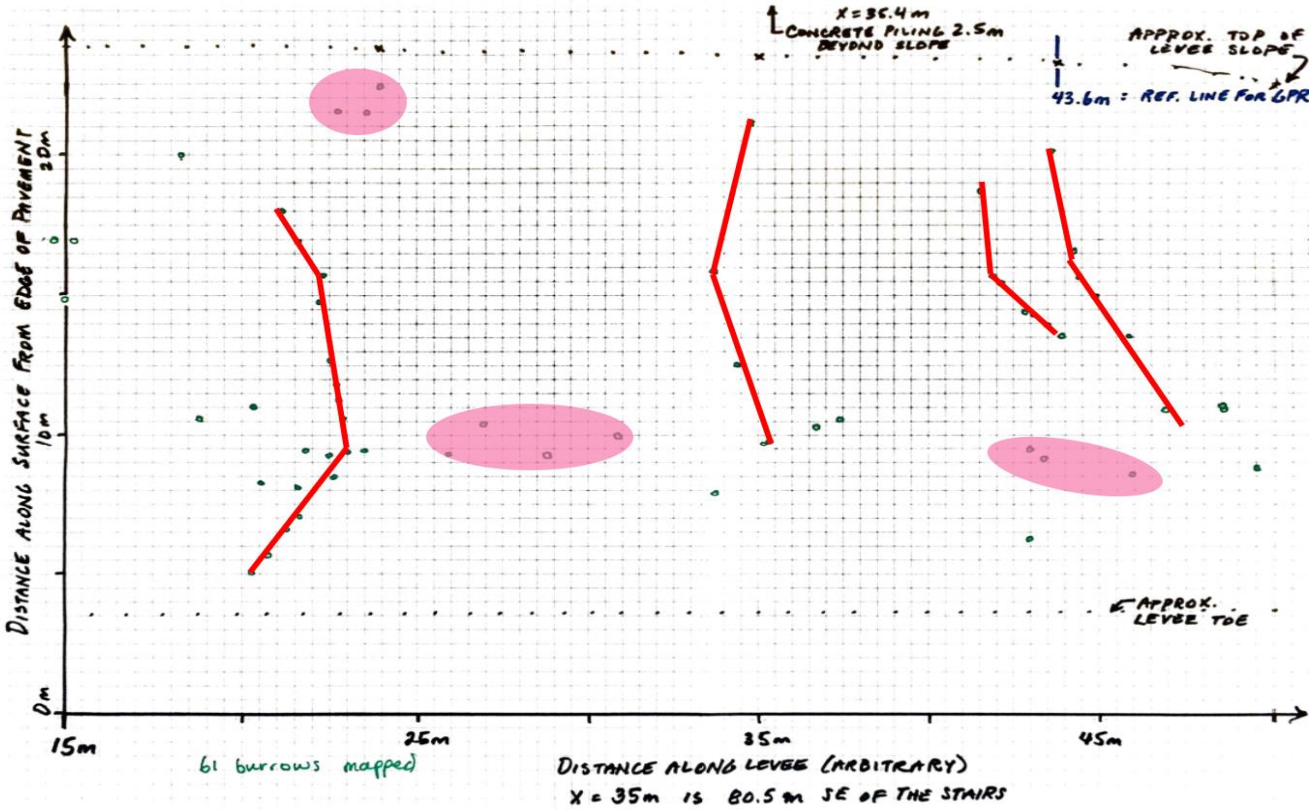
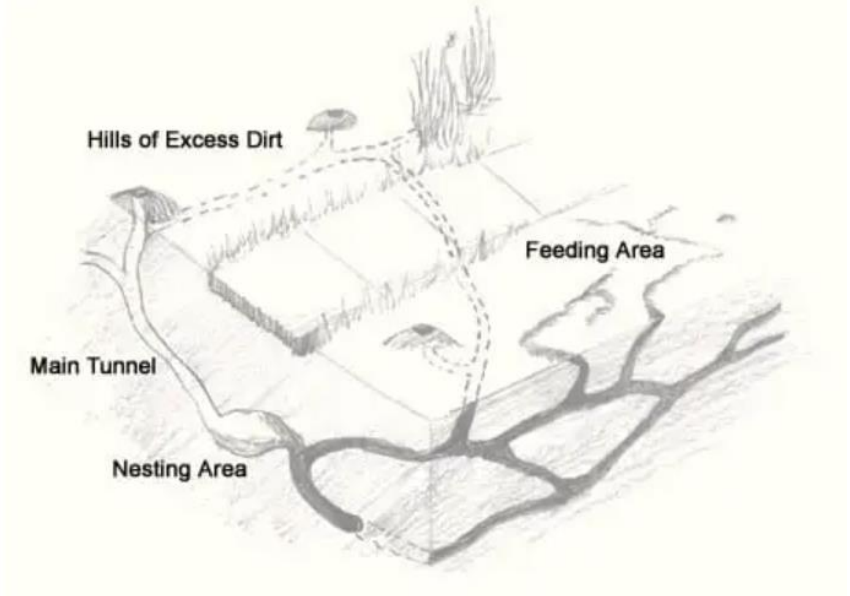
Spatial distribution patterns

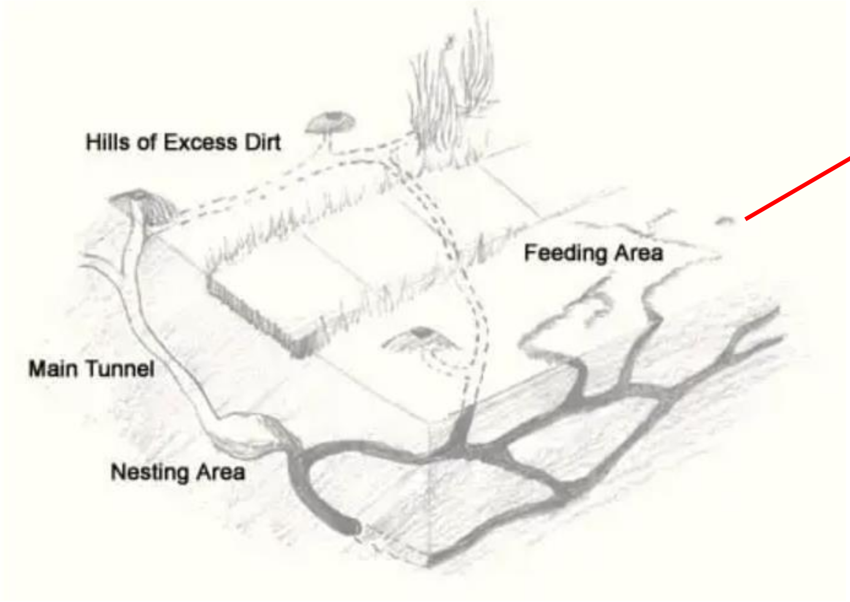


- Clusters (mice & moles)
- Lines (moles)



Mapping burrows with visual inspections

Other visual clues



- Clay mounds (moles)
- Patches of sand (larger animals)

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Detection & Monitoring

Q2: How can we detect the extent of burrows?

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1. The smoke test

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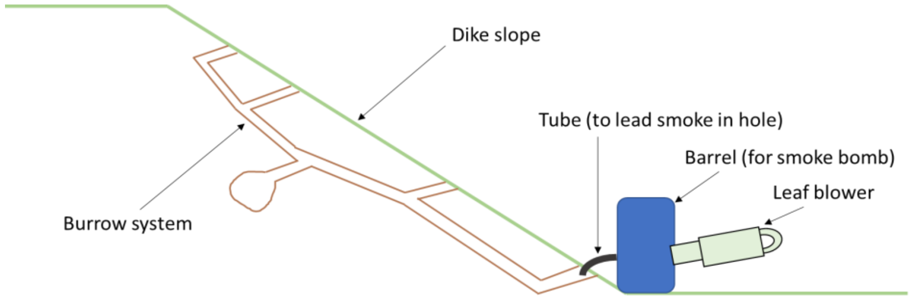
Tested and improved in LLHPP



Version 1: Hedwigepolder (09-21)

Version 2: Prosperpolder (10-21)

Version 3 Hedwigepolder (12-21)

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1. The smoke test

Evaluation

Feasibility

(+) Easy to apply

(+) Complementary to visual inspections

(-) Effect on health and safety of animals unknown

Effectiveness

(+) Immediate results

(+) Effective in most trials

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2. Ground penetrating radar

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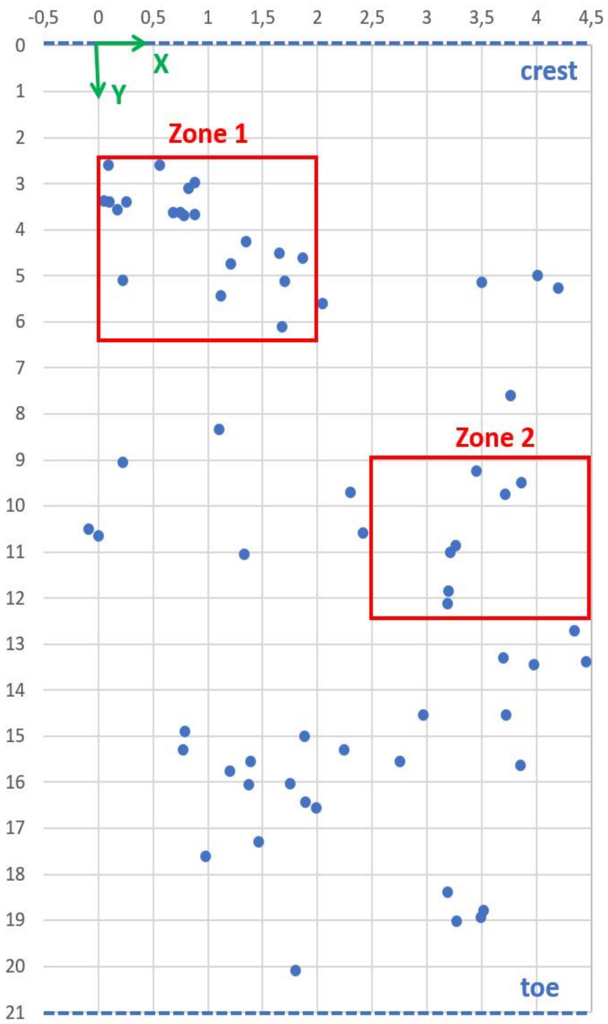
Non-destructive technique



2. Ground penetrating radar

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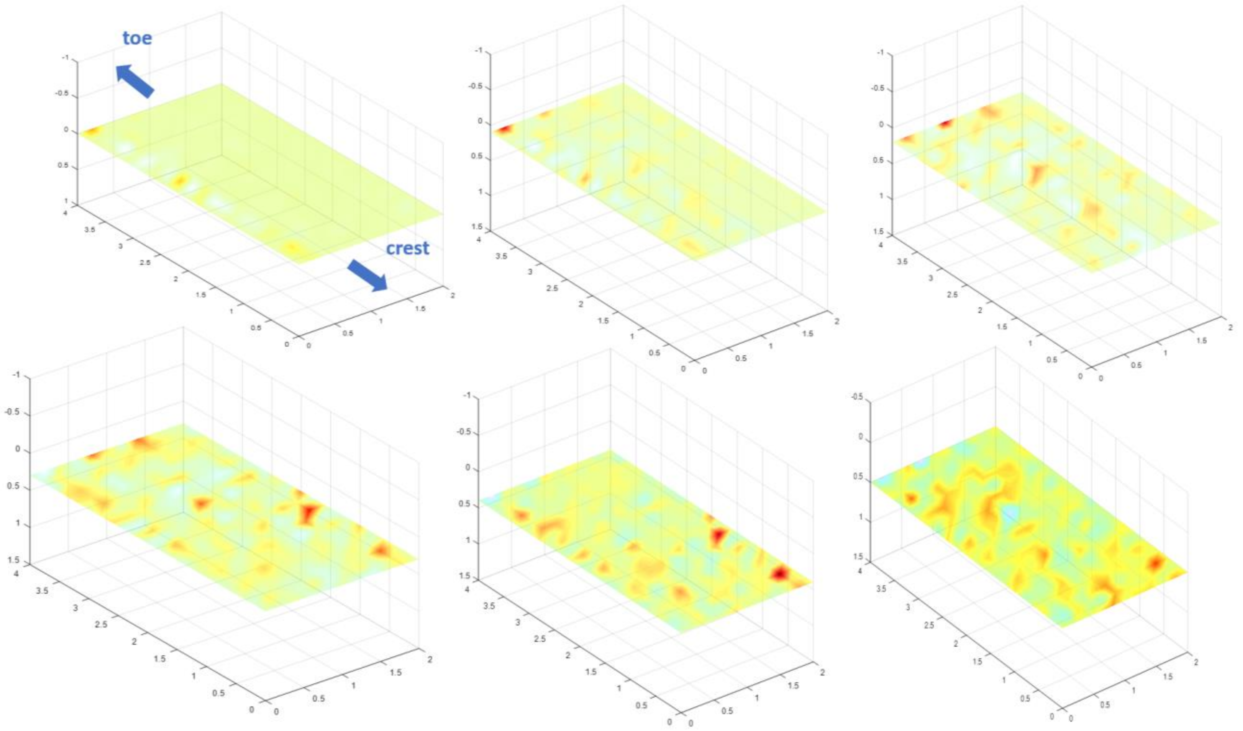
Sample of results & preliminary findings



Feasibility

(+) Possible on a slope!

(-) Weather conditions influence accuracy

(-) Results not readily available in the field

Effectiveness

(-) Scans with 2GHz provide a satisfactory picture of the first 50cm, less suitable for large burrows

(+) More accurate than inspection with a probe (depth and geometry)

3. Grouting and excavation

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Destructive monitoring technique

Linear mole system

Cluster of mice burrows

3. Grouting and excavation

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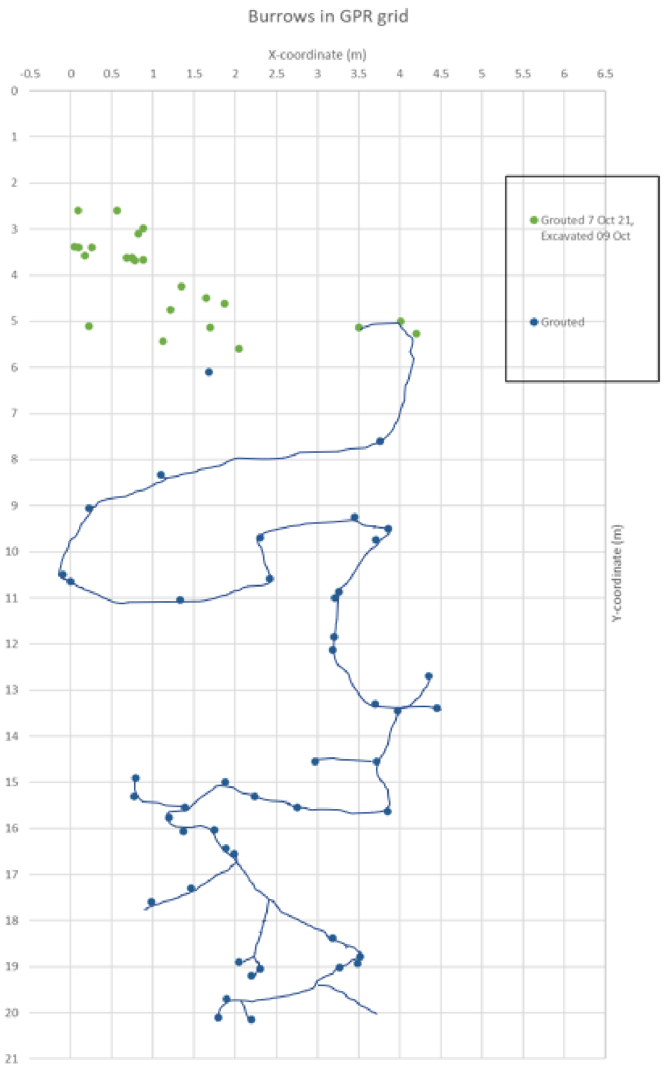
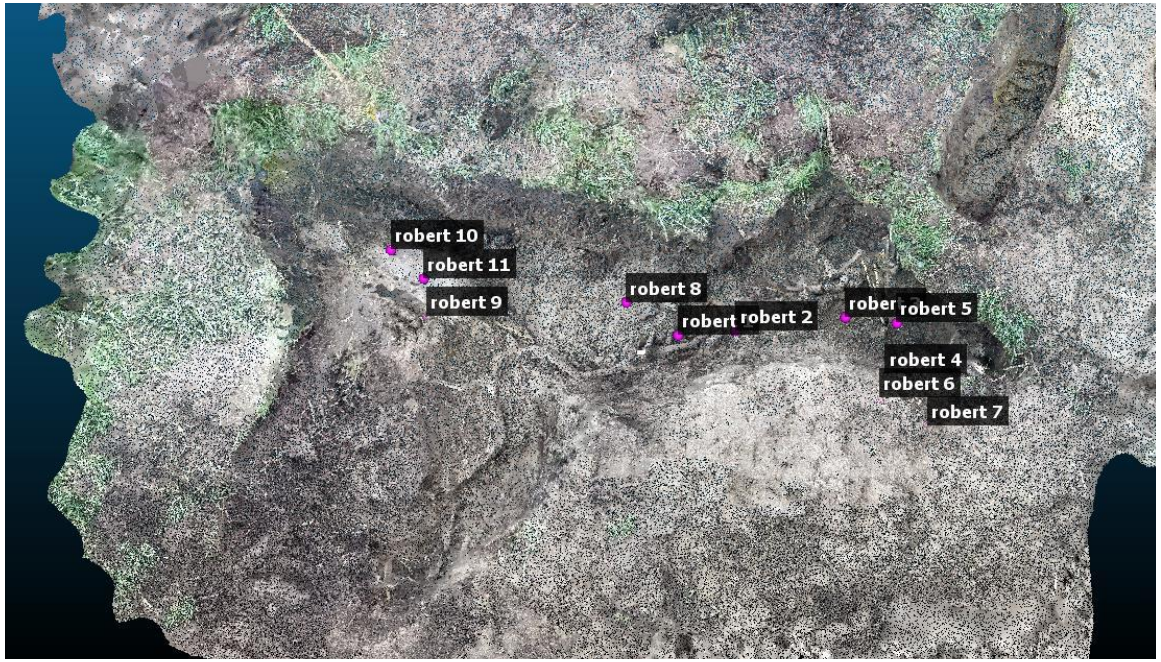
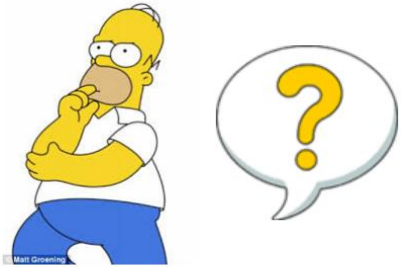


…. Burrows by small rodents seem to go much deeper in the levee than we thought before…





Detection & Monitoring

Failure modes

Q3: Can we monitor what happens to animal burrows when there is overflow?

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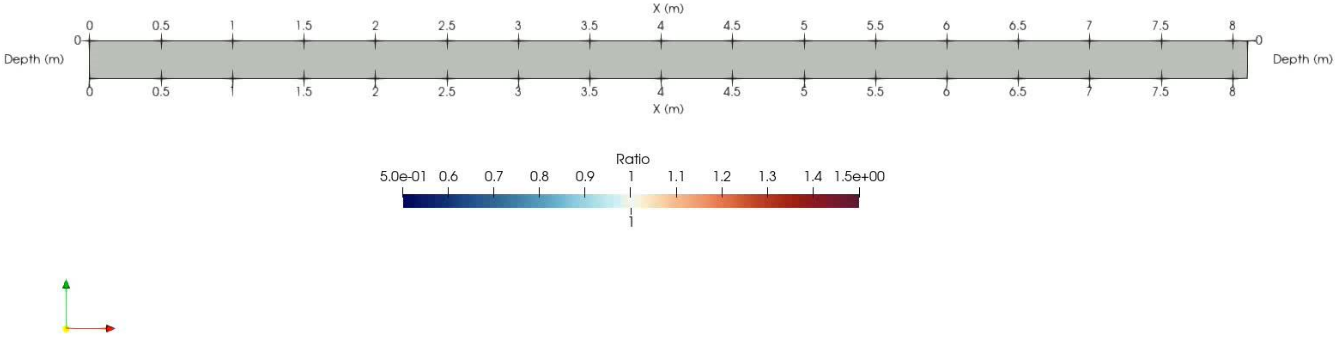
Electric Resistivity Tomography monitoring

Timeseries of electric resistivity in the subsoil during an overflow test



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Electric Resistivity Tomography monitoring

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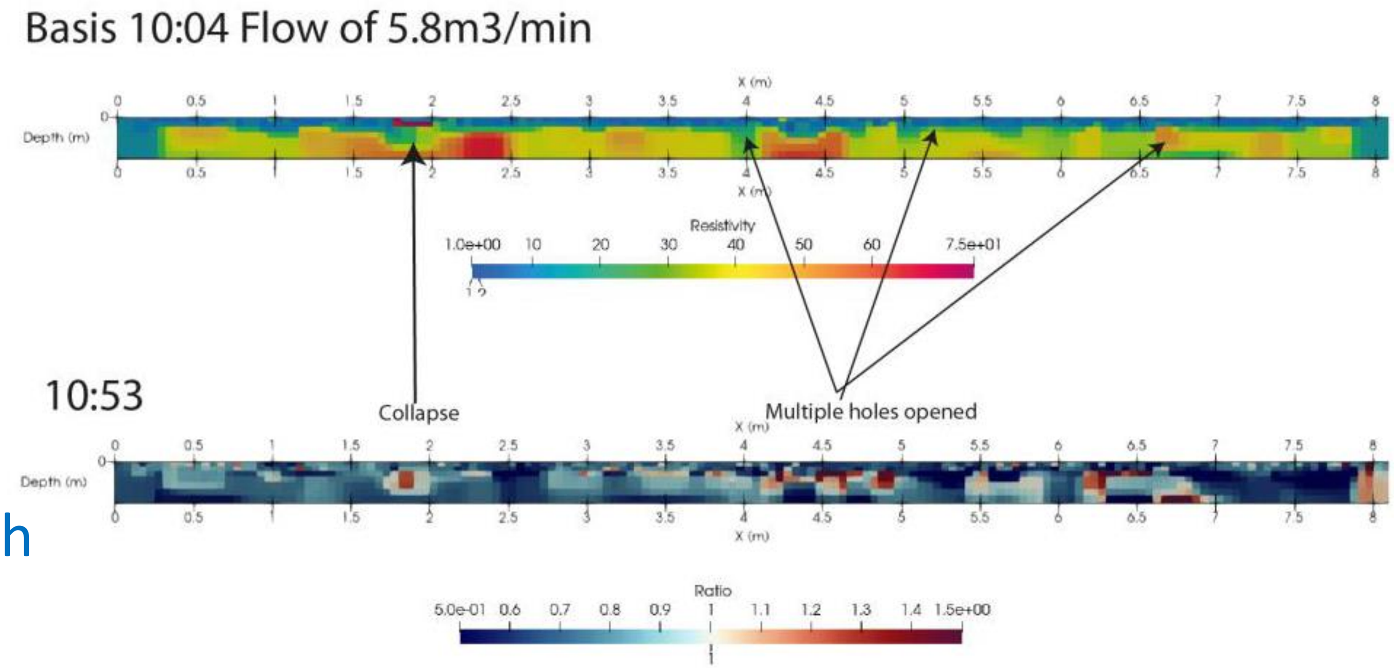

Recorded phenomena

1. Cavities being filled with water
2. Creation of new cavities (filled with air or water)
3. Collapsing of existing cavities
4. Cavities staring to connect with each other

➢ Promising results for ***modelling of internal erosion*** processes.

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Repairs

Failure modes

Can we protect a section with burrows with road plates when we expect high water?

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Low-cost repair with road plates

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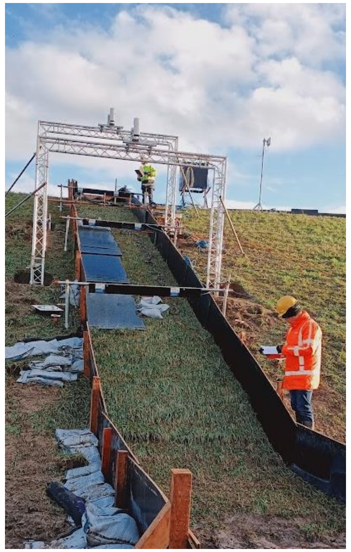
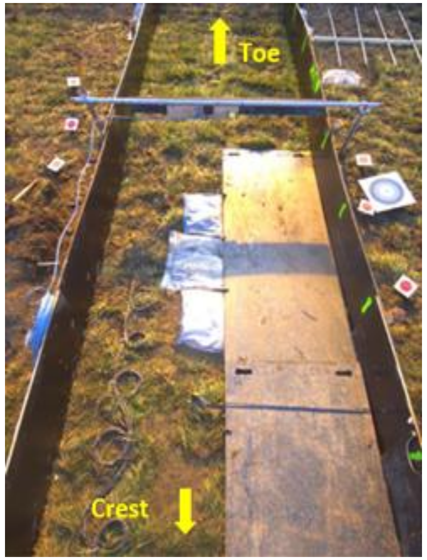
Overflow experiment, November 2021




Feasibility

(+) Very easy installation

(+) Low-cost

(-) Configuration is site-specific

Effectiveness

(+) Solution remained intact after 10hrs & 18min of testing

(+) Similar approaches worked in other LLHPP activities

(0) Sandbags did not play a role

➢ ***Further testing is needed*** *for benchmarking*

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Summary

1. *Topics of interest* were defined following a **risk-based approach**
2. *Study priorities* were set based on **knowledge gaps** in current practices, but they were conditioned by **pragmatic limitations**.
3. *Focus topics*: failure modes, detection and monitoring and repairs techniques.
4. Serious failures can occur in sections with large burrows (e.g. fox and beaver holes), but also in sections with mole burrows. ***Research in progress***
5. Detection and monitoring techniques were developed and tested in the living lab, but results are site-specific. Further testing is needed for benchmarking.
6. A low-cost repair technique was developed and evaluated.

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Proposition 1

Beavers and badgers should be kept away from your levee at all costs

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Proposition 2

Burrows of small rodents that penetrate to the sand core are dangerous for your levee

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Proposition 3

Clusters of small burrows constitute weak spots on your levee

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