Predicting Breach

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Practitioner Workshop on Asset Management
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Overview

1. **Why do we need to predict breach?** ***What does it affect?***
2. **Different breach processes -** ***the importance of different physical processes)***
3. **The broad range of methods that can be used to predict breach** ***- indicative pros/cons of each type of approach***
4. **Gaps in knowledge** ***- leading to the FRMRC2 work***
5. **The FRMRC WP4.4 research** ***- what it does and delivers***
6. **Access to the WP4.4 deliverable -** ***interim steps***

[1] Why do we need to predict breach?

Why do we need to predict breach?

The way and rate at which an embankment breaches can affect the timing of the breach, the rate and magnitude of the flood water released and the size of the breach itself.

Therefore, breach affects the analysis of flood risk (ie. FRAs) and can change the way in which flood events might be managed.

Understanding the degree of uncertainty within the process and any prediction is a very important aspect of using breach predictions

Why do we need to predict breach?

Consider that different aspects of breach prediction are important for different users:

Flood risk assessment

Planning

Scheme design

Emergency planning

Flood event management

Emergency repairs

Peak discharge? Flood volume? Rate of flooding?

Time to catastrophic failure? Size of breach?

[2] Different breach processes

The stages in breach development comprise:

- Initiation
  - Surface protection (grass) cover fails, soil starts to erode
- Formation
  - Significant erosion of material through embankment body and down to base
- Growth (widening)
  - Open breach; flow continues to widen the breach

Can be driven by wave overtopping, overflow or seepage

Different breach processes

Soil type and state affects the soil erodibility

Soil erodibility affects the overall physical process

...which (for external erosion) may be headcut erosion or surface erosion (or a combination / transition between the two).

Typically:

- Sandy, non cohesive soil = surface erosion
- Cohesive, clayey soil = headcut

[not forgetting that soil state significantly affects the process...]

Different breach processes

Different breach processes

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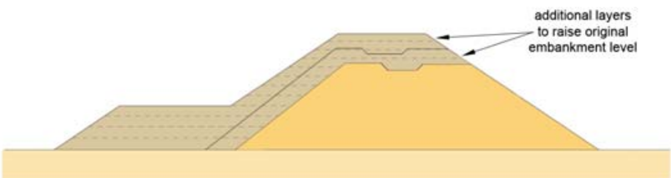
Different breach processes



[3] Range of methods to predict breach

Different methods include:

1. Judgement (guess work?)
2. Simple predictive equations
3. Simple predictive models
4. More complex predictive models

5. Integrated breach and flow models
6. Probabilistic breach models

Range of methods to predict breach

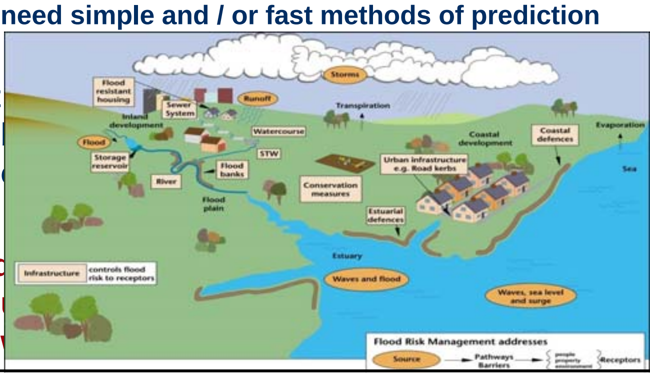
1. Judgement (guess work?)
   - Can vary from reasonable judgement to a blind guess hence can be highly inaccurate
   - Use historic records from same catchment / soil / structure type
2. Simple predictive equations
   - Typically developed for dams or non cohesive soils
   - Regression analysis on limited data (and hence specific conditions)
   - Can have large uncertainties
   - Typically give peak discharge, maybe breach width – not hydrograph

Range of methods to predict breach

3. **Simple predictive models**
   - Predefines and simplifies the breach process
     - Is the simplification acceptable?
4. **More complex predictive models**
   - Greater complexity – less uncertainty
   - typically a slower model
5. **Integrated breach and flow models**
   - Allows for drowning of breach – important but don't overlook what the model actually does
6. **Probabilistic breach models**
   - Gives more information regarding range of possible behaviour

[4] Gaps in knowledge

- **Industry often uses judgement or simple equations**
  - Confusion over choice of best (appropriate) method
  - Avoid cost – by avoiding time / complexity of analysis
  - System risk models run many thousands of simulations → need simple and / or fast methods of prediction



- **Past** … **ding to** … **more**
- **Need** … **t can be** … **for use**

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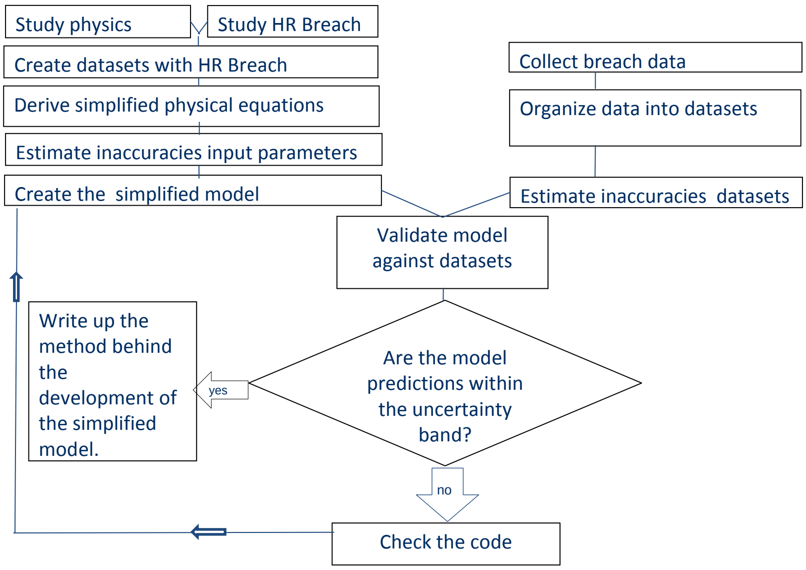
[5] The FRMRC WP4.4 research

Goal of the research

WP4.4 (University of Oxford and HR Wallingford): Rapid breach assessment - will develop simplified equations for the rapid prediction of breach size for a limited range of embankment structures. The methods will be directly applicable to practicing engineers and will replace the default and very approximate breach modelling methods currently included within the RASP family of tools.

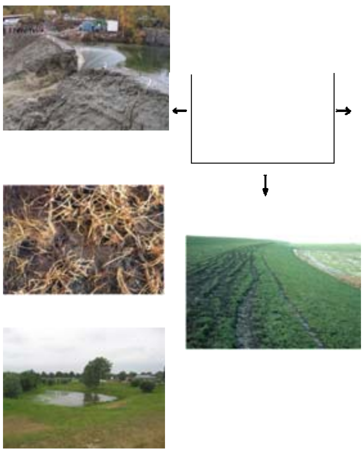
Creation of the simplified breach model



Underlying assumptions (1)

General assumptions

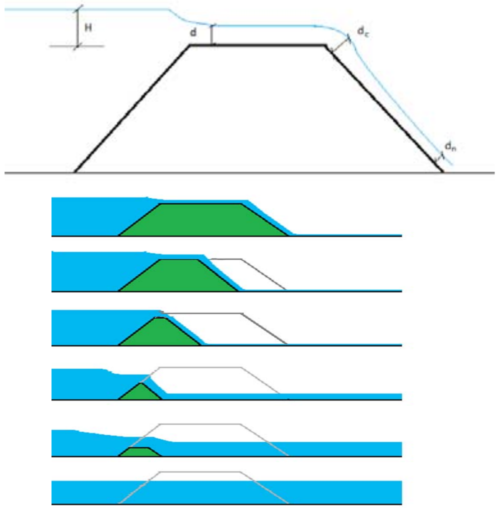
- 1D flow behaviour
- Rectangular spatially constant cross section breach
- No equilibrium transport conditions
- Constant soil erodibility
- Instantaneous failure grass cover
- No erosion below the foundation level of the embankment
- Widening rate is proportional to the downward erosion rate



Underlying assumptions (2)

Assumptions surface erosion

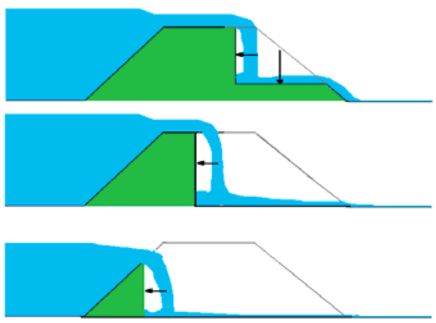
- Landside slope remains equal to the initial slope gradient
- Depth along landside slope approaches the normal depth starting from the critical depth
- Landside slope retreats at a spatially averaged erosion rate
- Crest erodes downward while landside slope retreats



Underlying assumptions (3)

Assumptions headcut erosion

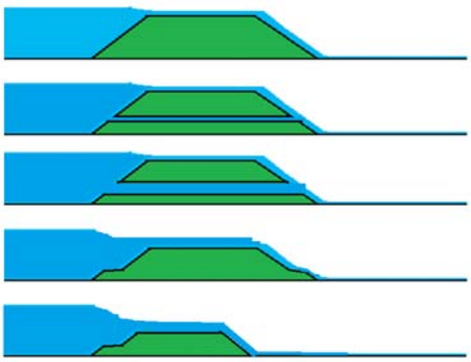
- No downward erosion due to flow over the crest
- Headcut starts at the top of landside slope



Underlying assumptions (4)

Assumptions piping

- An initial pipe diameter widens in an equal rate due to the flow through the pipe
- After slumping of the soil above the pipe, potential further failure of the embankment is described by the surface erosion failure process
- The grass cover is assumed to have failed with failure of the pipe



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Performance and validation

- **AREBA - A Rapid Embankment Breach Assessment**
- **AREBA gives promising results when being bench marked against HR BREACH**
- **Validating AREBA against the IMPACT experiments showed that the model prediction lie within the bounds of uncertainty following from the uncertainty in the input parameters**
- **Run speed AREBA is approximately 0.2s per run.**

Data Requirements / Applicability

- AREBA predicts breach through simple, homogeneous embankments
  - Does not simulate composite or complex structures
  - But speed of simulation does allow the user to 'play'
- AREBA requires definition of:
  - Upstream load (time varying water level)
  - Embankment geometry
  - Embankment soil erodibility
  - Assumed failure mode (surface, headcut, internal erosion)
  - Downstream volume / stage (time varying water level)

Soil Erodibility

- AREBA predicts the breach process using an erosion equation that requires a value for soil erodibility (Kd)
- Kd depends upon the soil type and state
  - For example, a highly compacted soil is less likely to erode than a poorly compacted soil
- For an accurate measure of Kd, soil testing is required (Jet test in field or lab)
- However, in many situations this will not be practicable – hence use of indicative values and sensitivity testing might be an appropriate approach
- Indicative guidance on Kd values is given...

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Conclusions

WP4.4 Research

- **A fast running, simplified breach model has been developed suitable for the use within system risk models (or 'stand alone') that deals with grass protection failure, surface erosion failure, head cut failure, and piping.**
- **The model is able to predict a flood hydrograph that falls within the bounds of uncertainty given by input parameters for a number of case studies.**
- **A comparison between the outcomes for system risk analysis using the current method applied in RASP versus this new approach is currently underway.**

Report detailing the analysis leading to the development of simple equations for the prediction of breach through flood embankments.

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[6] Access to the WP4.4 research outputs

WP4.4 Deliverable

Report detailing the analysis leading to the development of simple equations for the prediction of breach through flood embankments

As with all other FRMRC developments, the model (ie. working material rather than formal deliverable) is available to any of the funders under the terms of the FRMRC funding arrangement (...developers retain IPR, sublicence to funders with a royalty free license etc.).

If the model is intended for wider release by funders, then some testing & development is required to ensure that it is appropriate for industry use (i.e. Usability / interface / code type / stand alone – integrated etc)

More information on breach?

General background papers

Froehlich, D.C. (2008) 'Embankment dam breach parameters and their uncertainties', *Journal of Hydraulic Engineering, ASCE,* Vol. 134 (No. 12), pp. pp. 1708-1721.

Morris, M.W. (2011) *Breaching of earth embankments and dams,* The Open University, England. PhD.

D.M. Temple, G.J. Hanson, M.L. Nielsen, and K.R. Cook, "Simplified Breach Analysis Model for Homogeneous Embankments: Part 1, Background and model components," in Technologies to Enhance Dam Safety and the Environment, 25th Annual USSD Conference, 2005, pp. 151-161.

Wahl, T.L. (2004) 'Uncertainty of prediction of embankment dam breach parameters', *Journal of Hydraulic Engineering,* Vol. 130 (No. 5), pp. pp. 389-397.

Wahl, T.L. (2009) 'Evaluation of new models for simulating embankment dam breach', *ASDSO Dam Safety 2009,* Hollywood, Florida. US., 27 Sept - 1 Oct, 2009.

Wahl, T.L., Hanson, G.J., Courivaud, J.-R., Morris, M.W., Kahawita, R., McClenathan, J.T. and Gee, D.M. (2008) 'Development of next generation embankment dam breach models', *US Society of Dams Annual Meeting and Conference 2008,* Portland, Oregon. US.2008.

More information on breach?

Website information

The EU FP6 Integrated Project – FLOODsite:

See Tasks 4 & 6 in particular:

www.floodsite.net/html/work_programme2.asp?taskID=4
www.floodsite.net/html/work_programme2.asp?taskID=6

The CEATI Dam Safety Interest Group breach modelling project

See

www.ceati.com/collaborative-programs/generation/dam-safety

The FRMRC II project website

www.floodrisk.org.uk

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More information?

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Questions?