Swiss Geoscience Meeting 2017 – Davos

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What are the effects of check dams?

Simulating the effect of check dams on landscape evolution at centennial time scales

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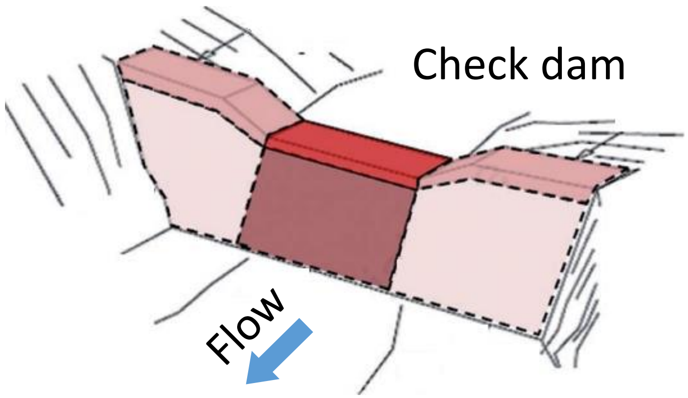
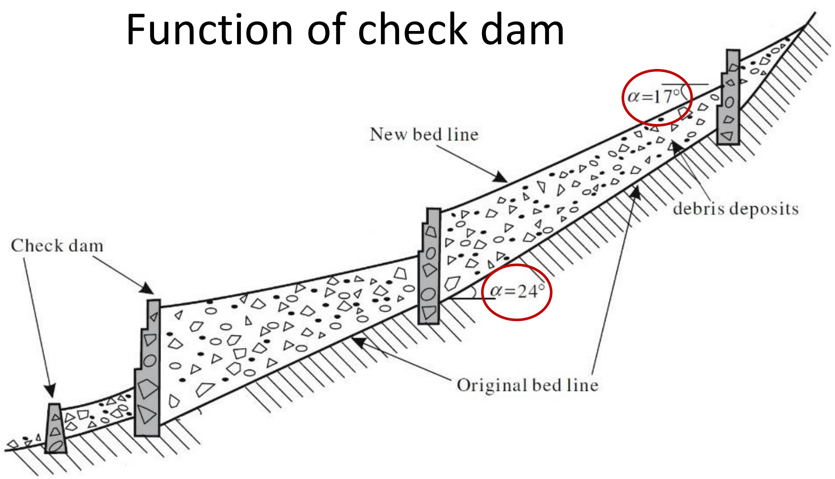
Functioning of check dam

Construction in torrent to control sediments



Function of check dam



Pros
Reduction of slope gradient
Lower water velocity → Sediment deposition
Control flow direction
Less channel erosion
Bank stability

Cons
Maintenance, renovation work
Efficiency loss
Ecological problems

Boix-Fayos (2008), Brown (2007), Dell'Agnese (2013), SUDAS (2013), Zeng (2009)

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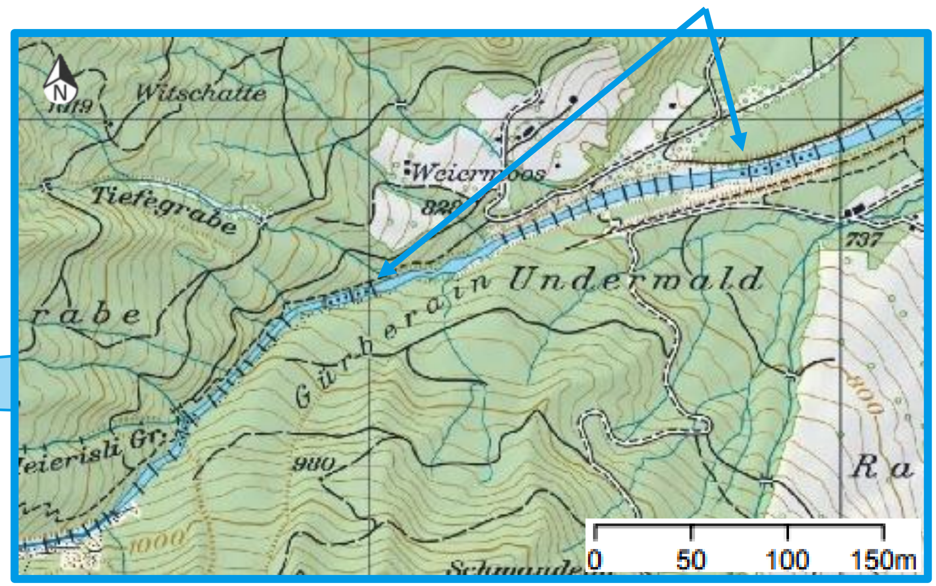
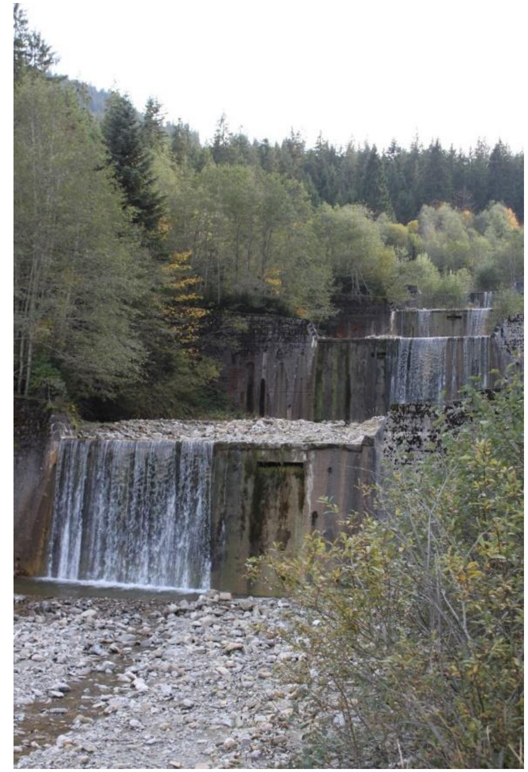
Study site: Gürbe river in Bernese Oberland



- Gürbe river is located in the Bernese Prealps
- Torrent catchment area of 12 km^2
- River contains 70 check dams, first built in 1860
- Average river slope is 9°

https://map.geo.admin.ch

Check dams in the Gürbe



- Maintenance cost of check dams and protective system is 2 million USD/year
- In 1990, after a major flood event renovation costs were 40 million USD
- Most expensive river in Switzerland, but many other rivers are similar

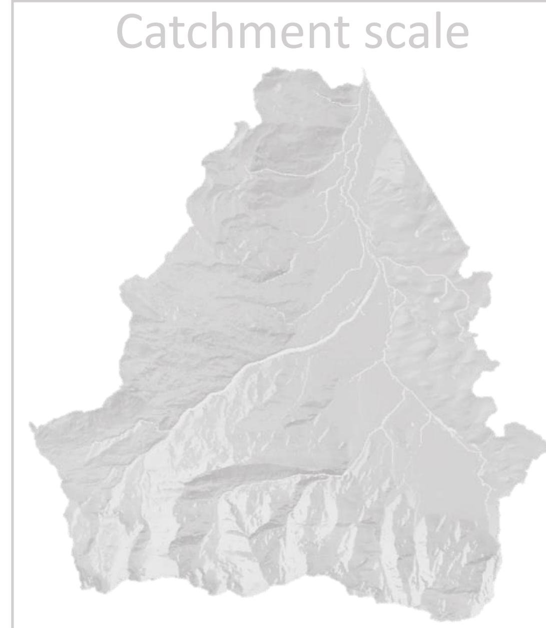
Bachmann (2009)

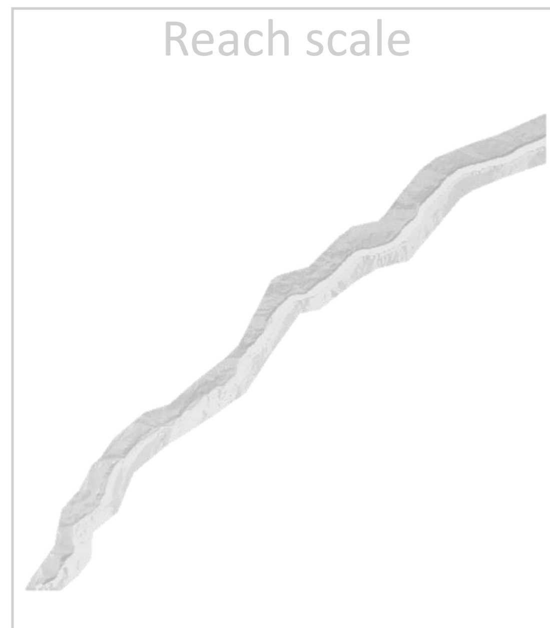
Research Question

What would happen **geo-morphologically** if check dams were **not maintained** and allowed to structurally deteriorate?

CAESAR-Lisflood

- **Numerical modelling** to understand complex physical processes which are difficult to simulate on a field or lab based approach
- Landscape evolution model

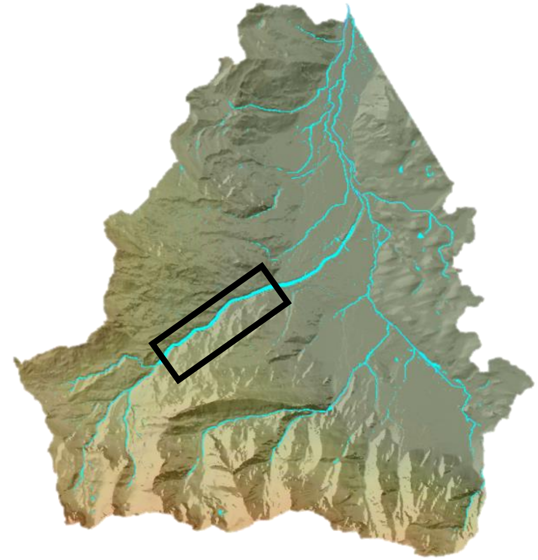




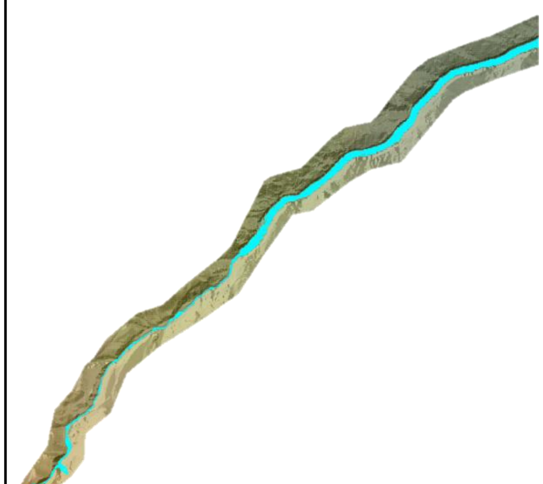
CAESAR-Lisflood

- **Numerical modelling** to understand complex physical processes which are difficult to simulate on a field or lab based approach
- Landscape evolution model
- Catchment or reach based cellular model

Catchment scale



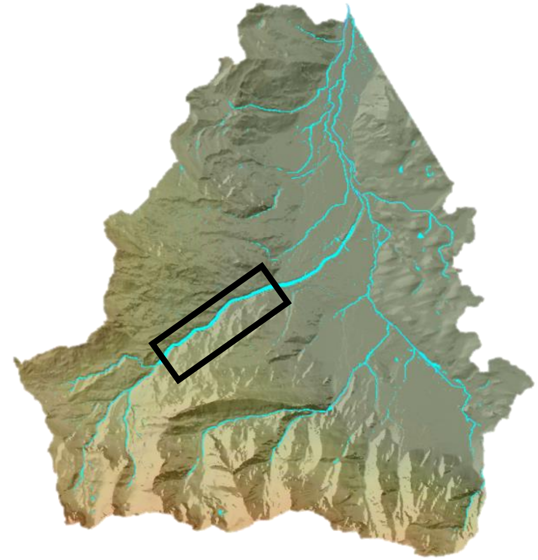
Reach scale



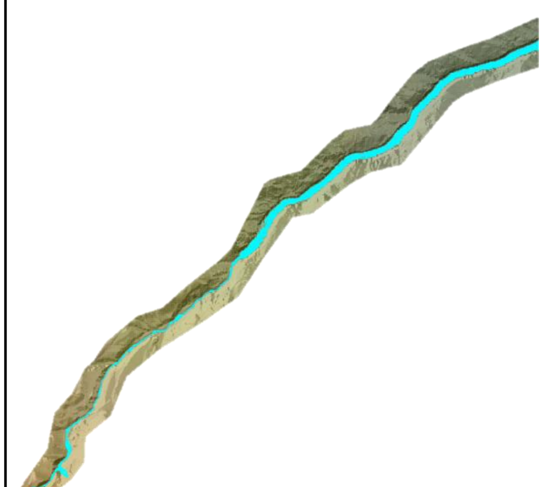
CAESAR-Lisflood

- **Numerical modelling** to understand complex physical processes which are difficult to simulate on a field or lab based approach
- Landscape evolution model
- Catchment or reach based cellular model
- Combination of
  - Hydrological model (TOPMODEL)
  - Hydraulic model (Lisflood-FP)
  - Geomorphic model (CAESAR)
- Sediment transport
  - Bedload, 9 fractions using Wilcock & Crowe equation
- Slope processes include landslides and soil creep

Catchment scale



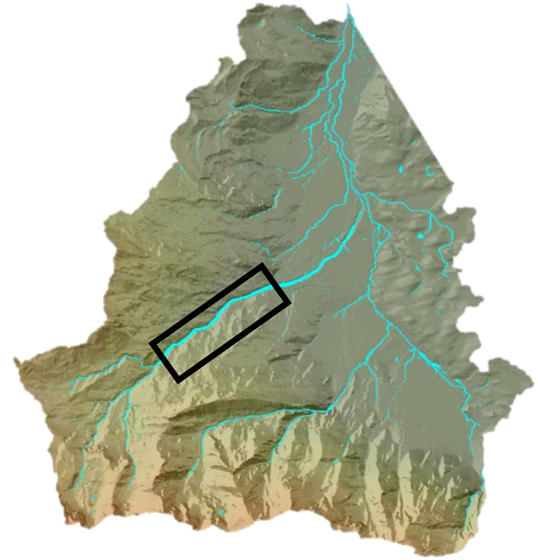
Reach scale



CAESAR-Lisflood

- Advantages of model
  - Computationally efficiency
  - Open source
  - 2D
  - Minimal parameterization
  - Large spatial scale and temporal extent without sacrificing fine-scale (<10m resolution)

Catchment scale



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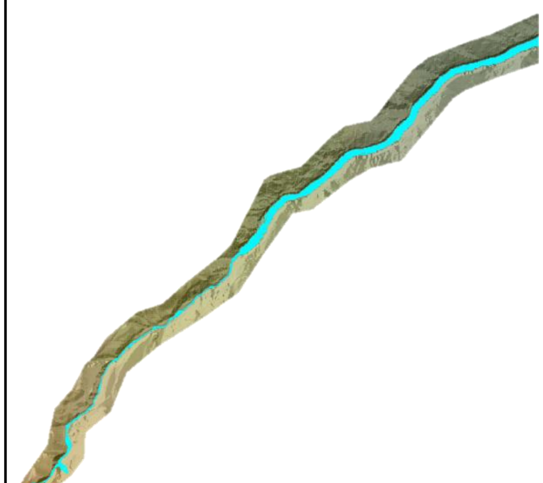

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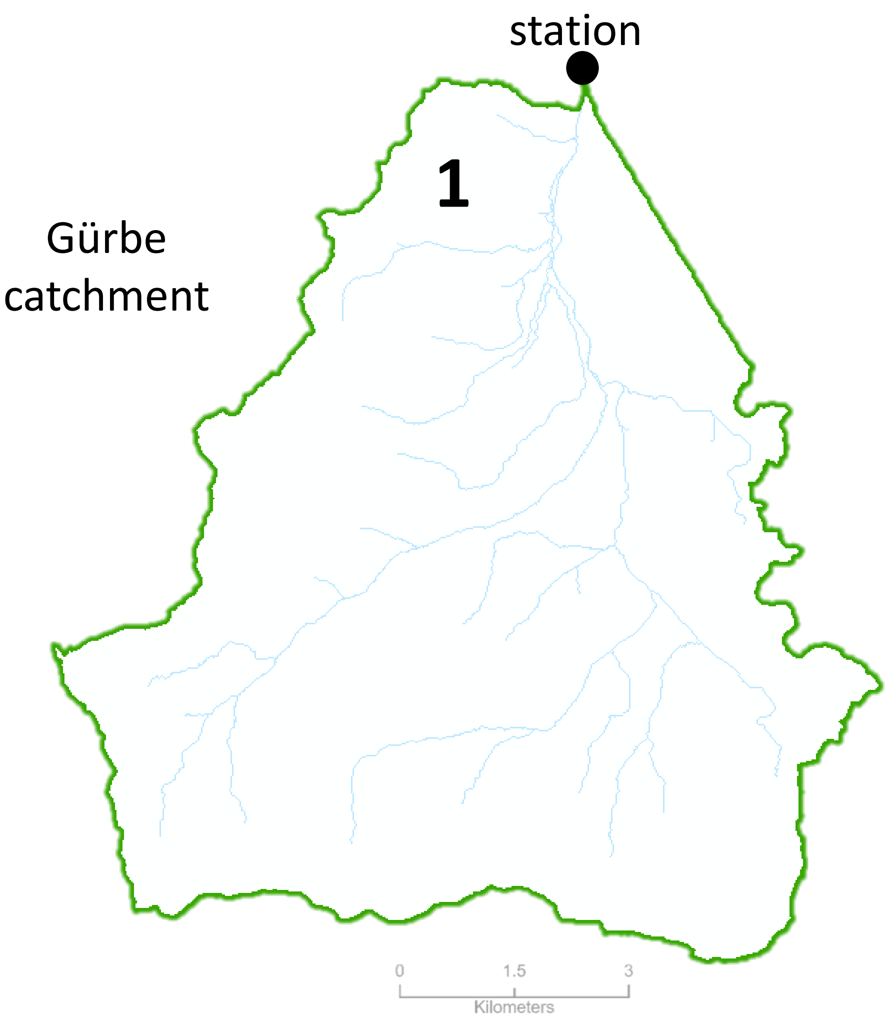
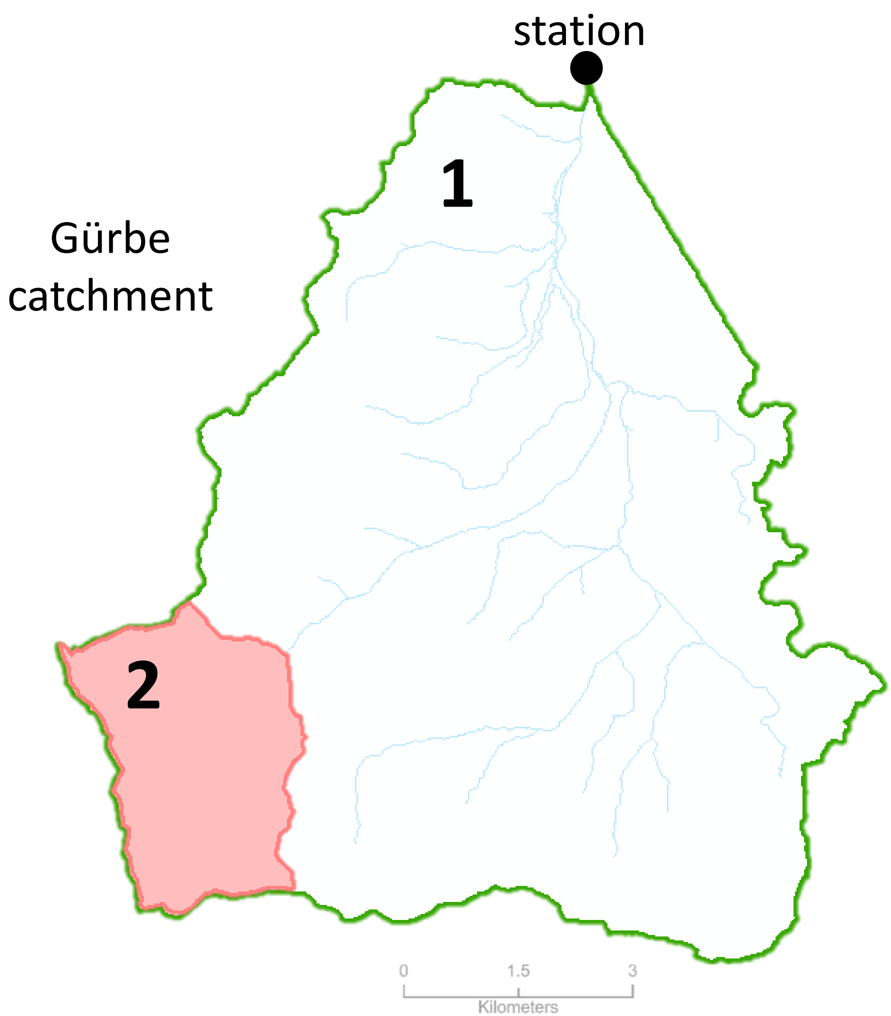
Model setup



3 step process

1. Calibration on **large catchment** using observed discharge and simulated rainfall

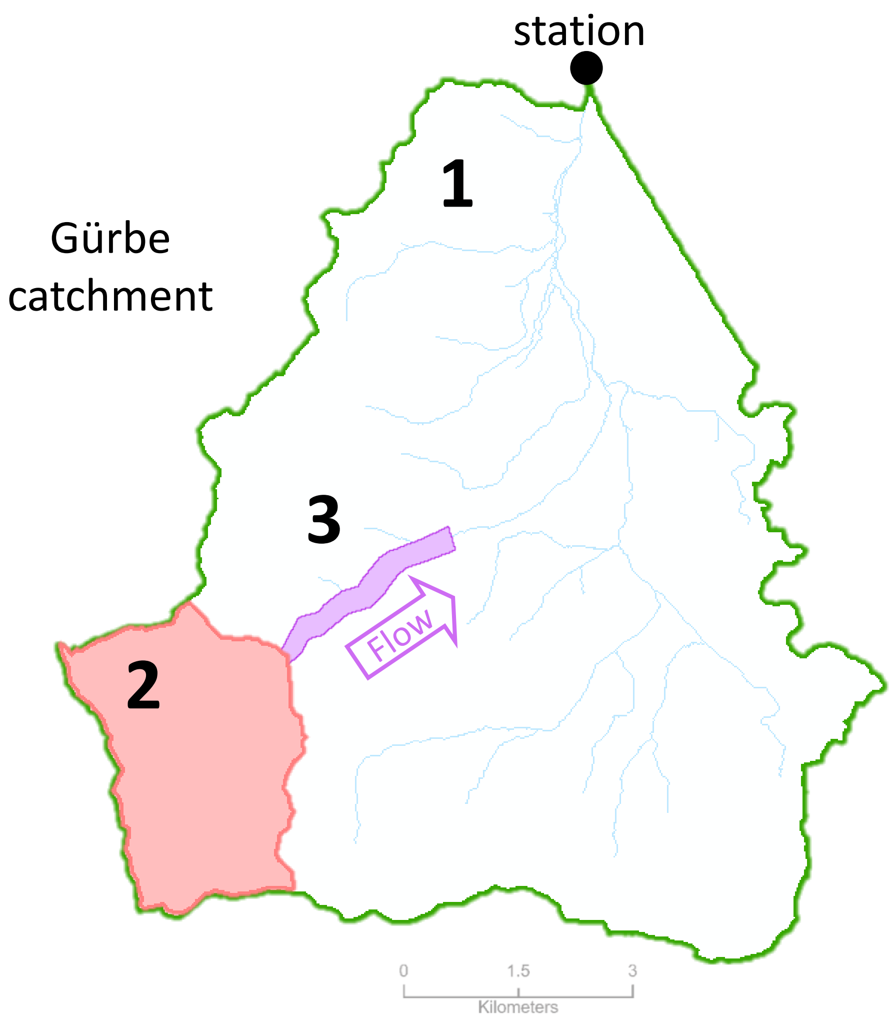
Model setup



3 step process

1. Calibration on **large catchment** using observed discharge and simulated rainfall
2. Generate discharge and sediment output from **sub-catchment**

Model setup

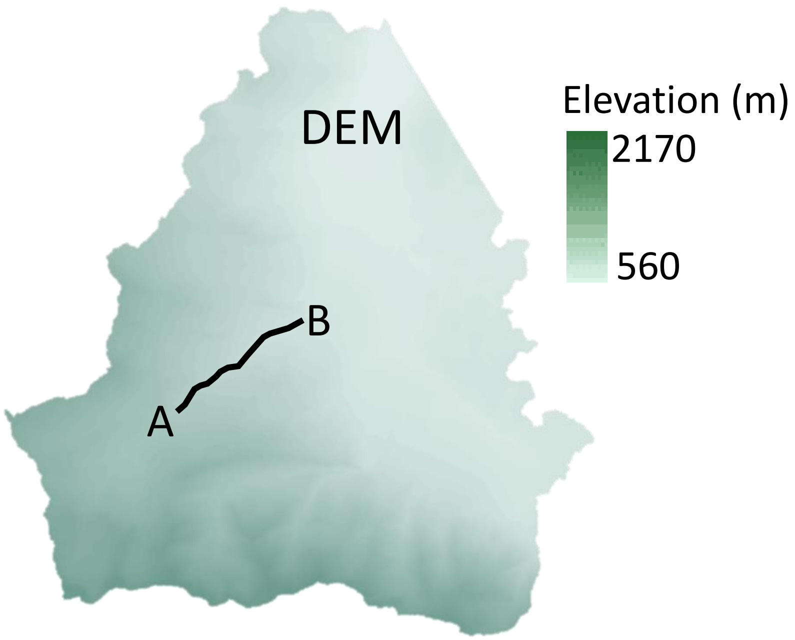


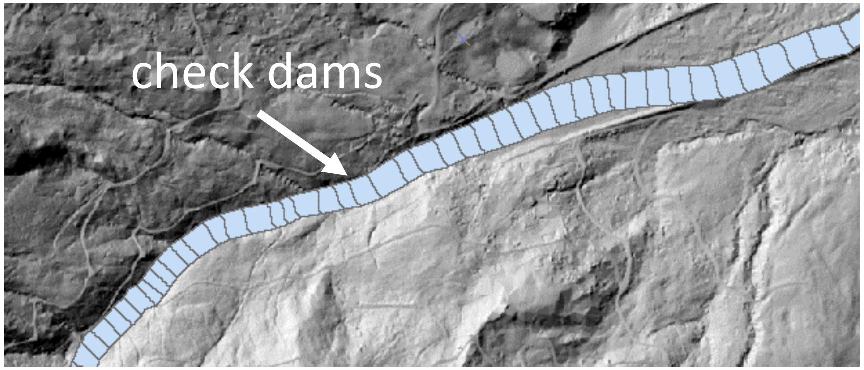
3 step process

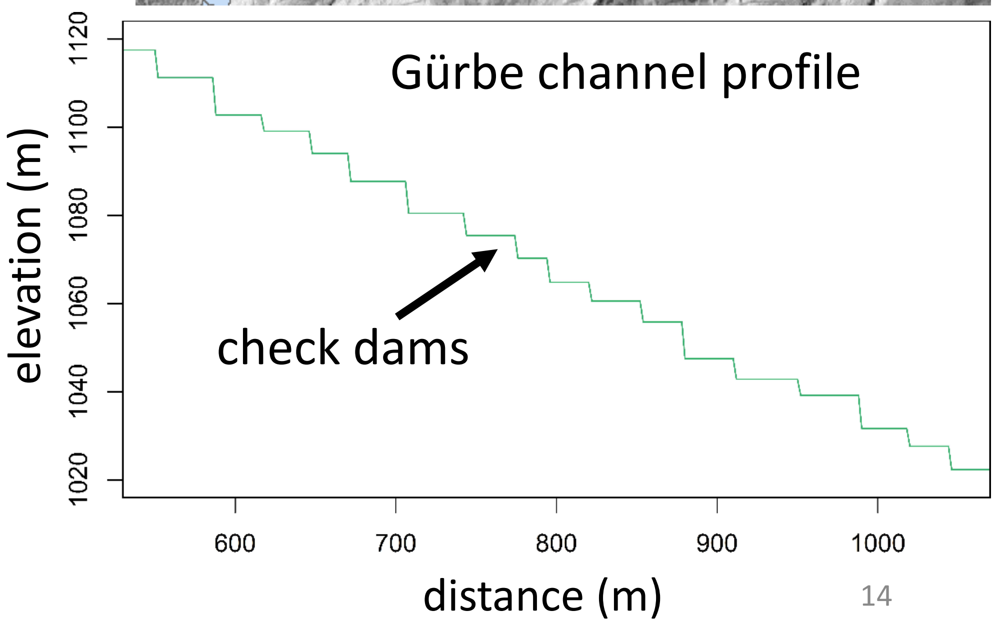
1. Calibration on **large catchment** using observed discharge and simulated rainfall
2. Generate discharge and sediment output from **sub-catchment**
3. Water and sediment outputs from sub-catchment is the input to the **reach scale** model with check dams

Topography

- Digitize location of check dams in DEM (2m)
- Check dams are reinforced into coarser DEM (15m) to ensure topographic representation



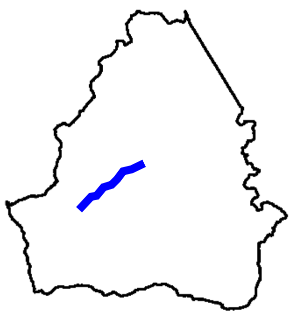




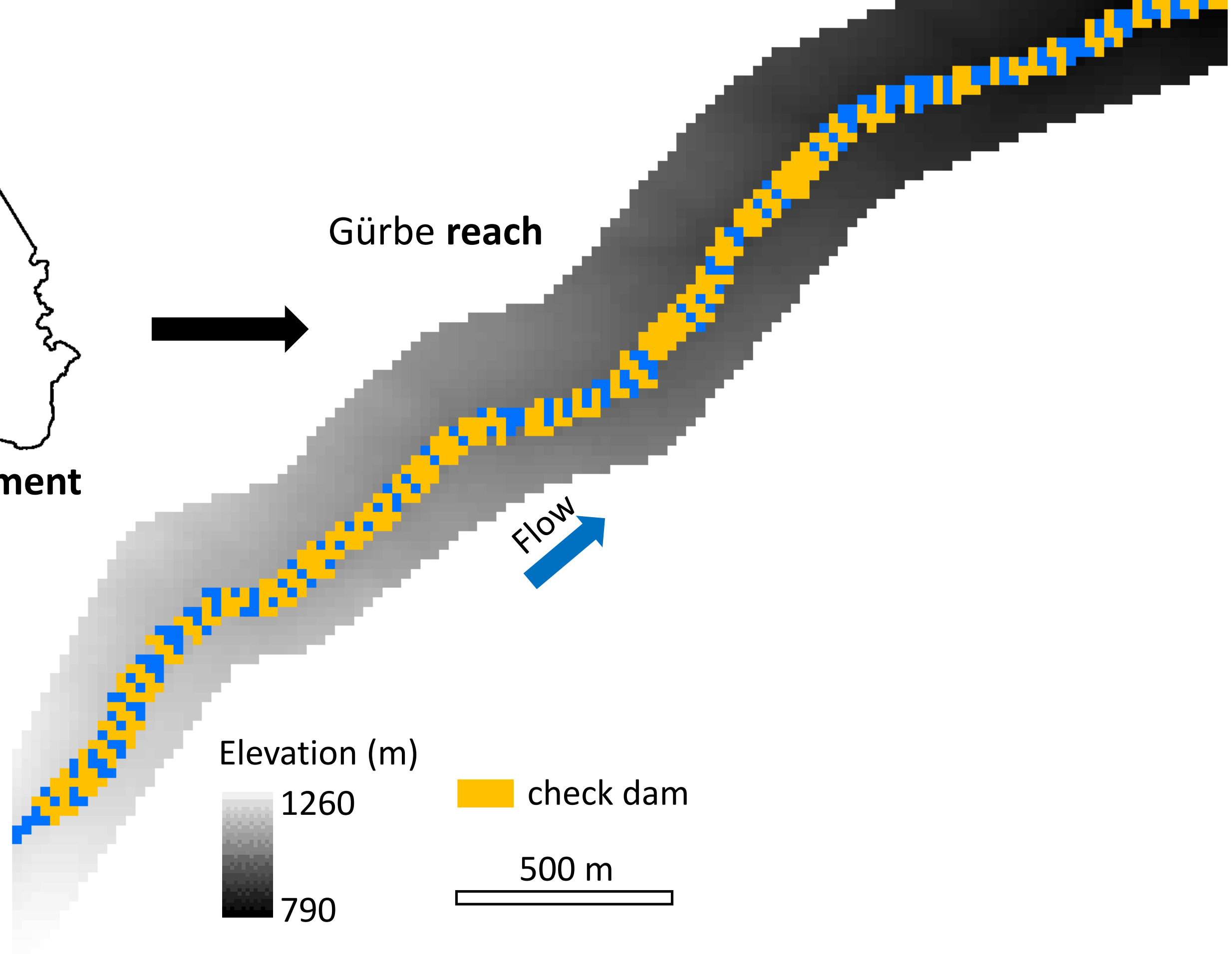
Proof of concept: reach scale

Does a reach scale model respond to check dam failure?

- DEM (15m) with check dams “reinforced”
- 70 check dams



Gürbe **catchment**



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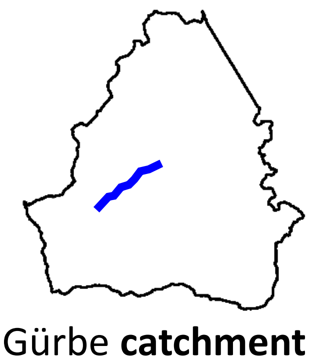
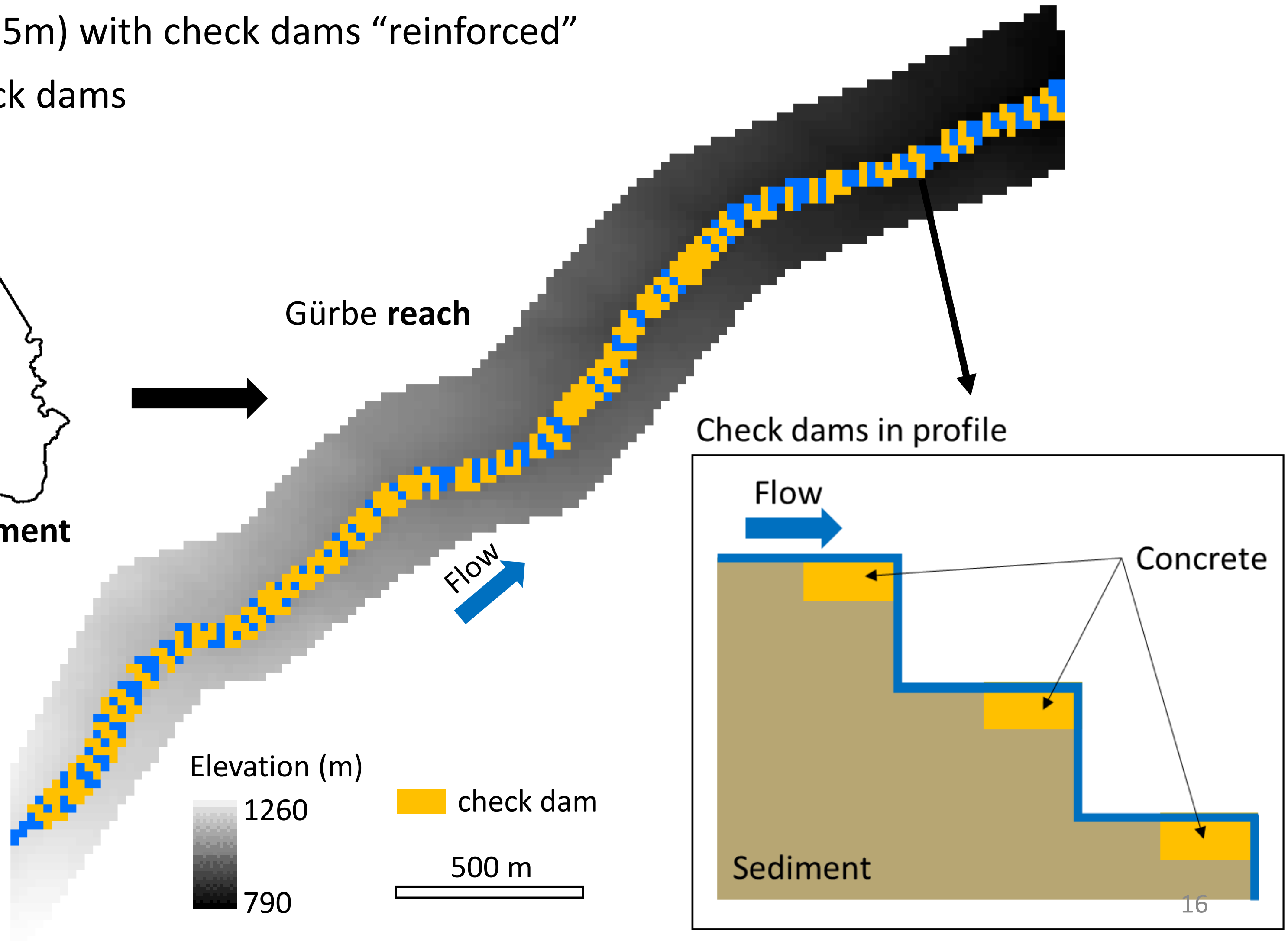
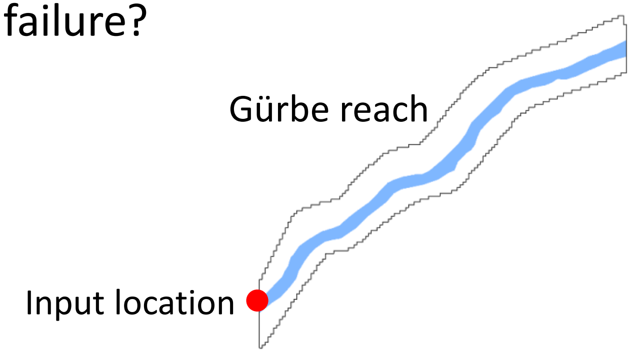


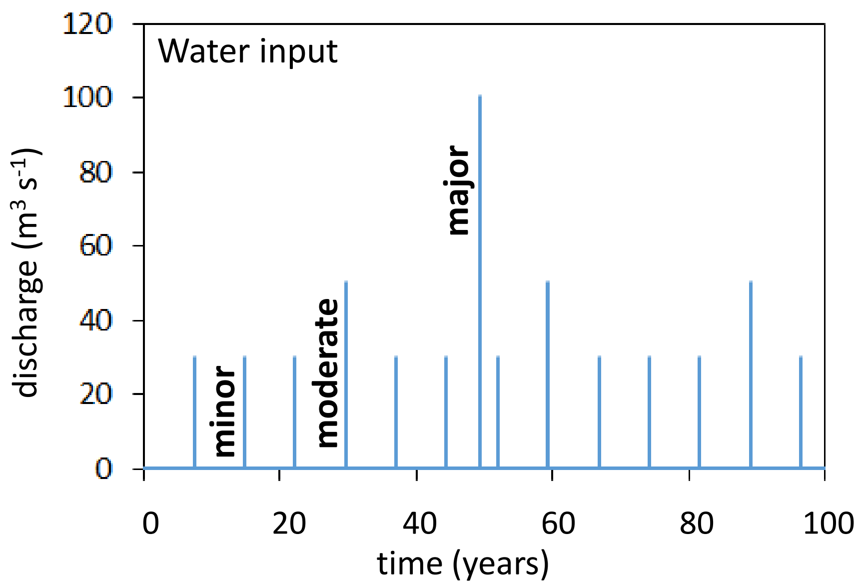


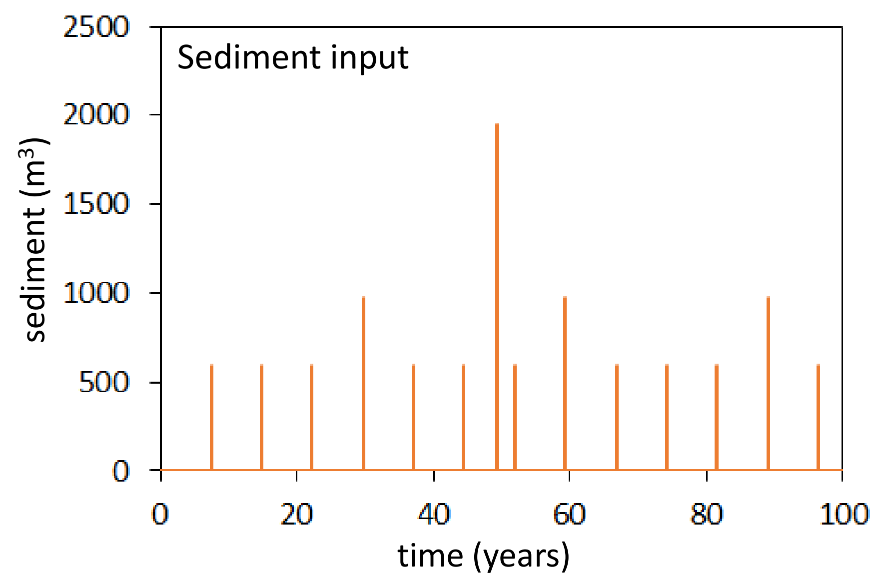
Proof of concept: reach scale

Does a reach scale model respond to check dam failure?

- DEM (15m) with check dams “reinforced”
- 70 check dams
- Synthetic discharge and sediment input

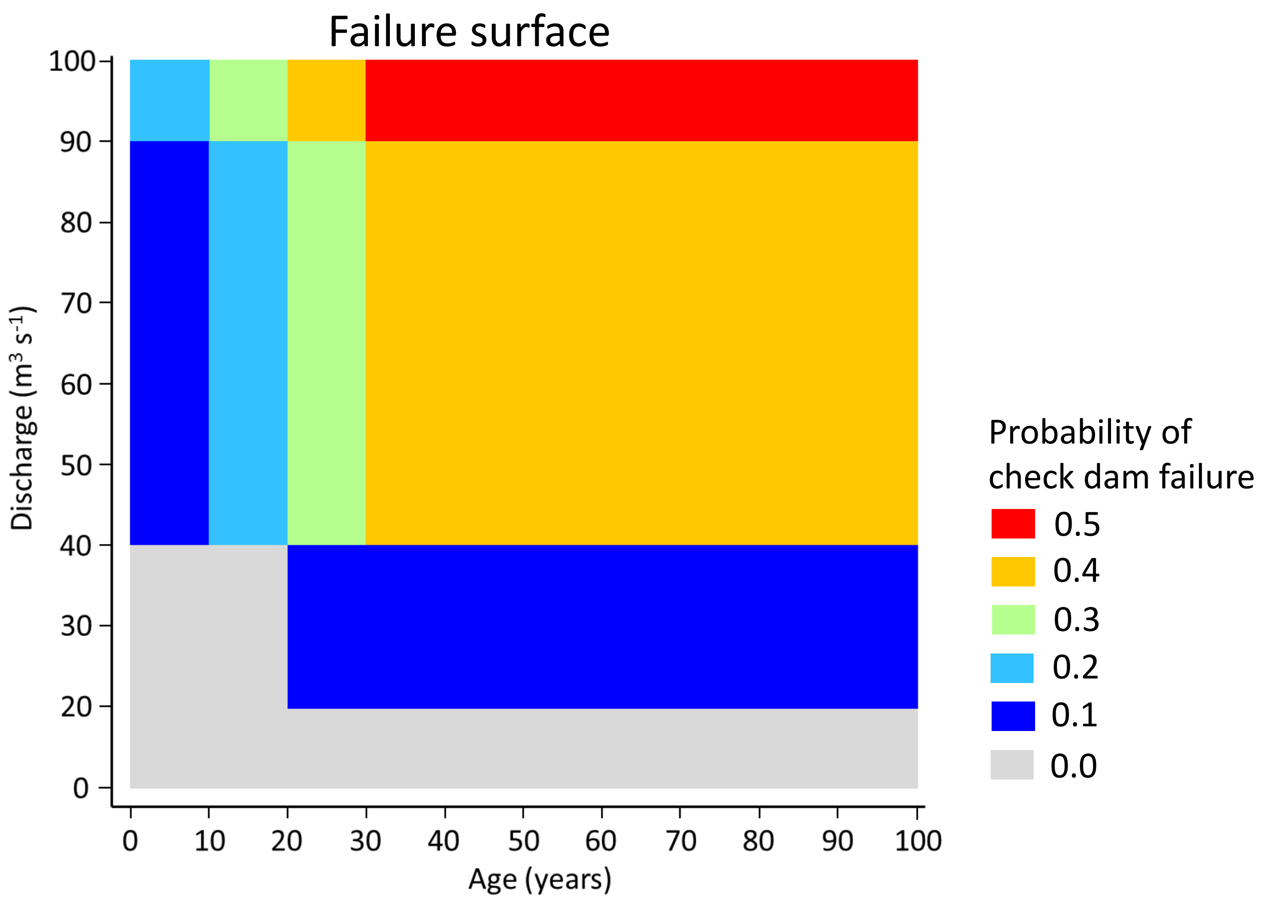




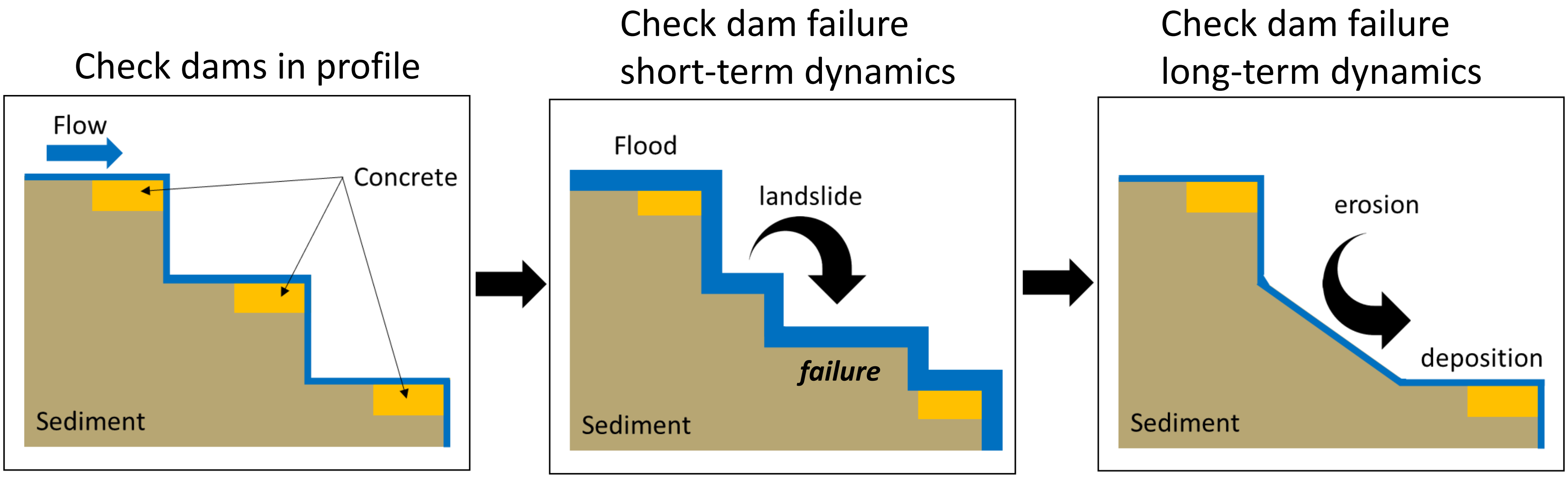


Check dam failure rules

- Expert knowledge used to develop rules
- Check dam failure determined through combination of **check dam age** and **discharge**
- Maintained check dams do not fail

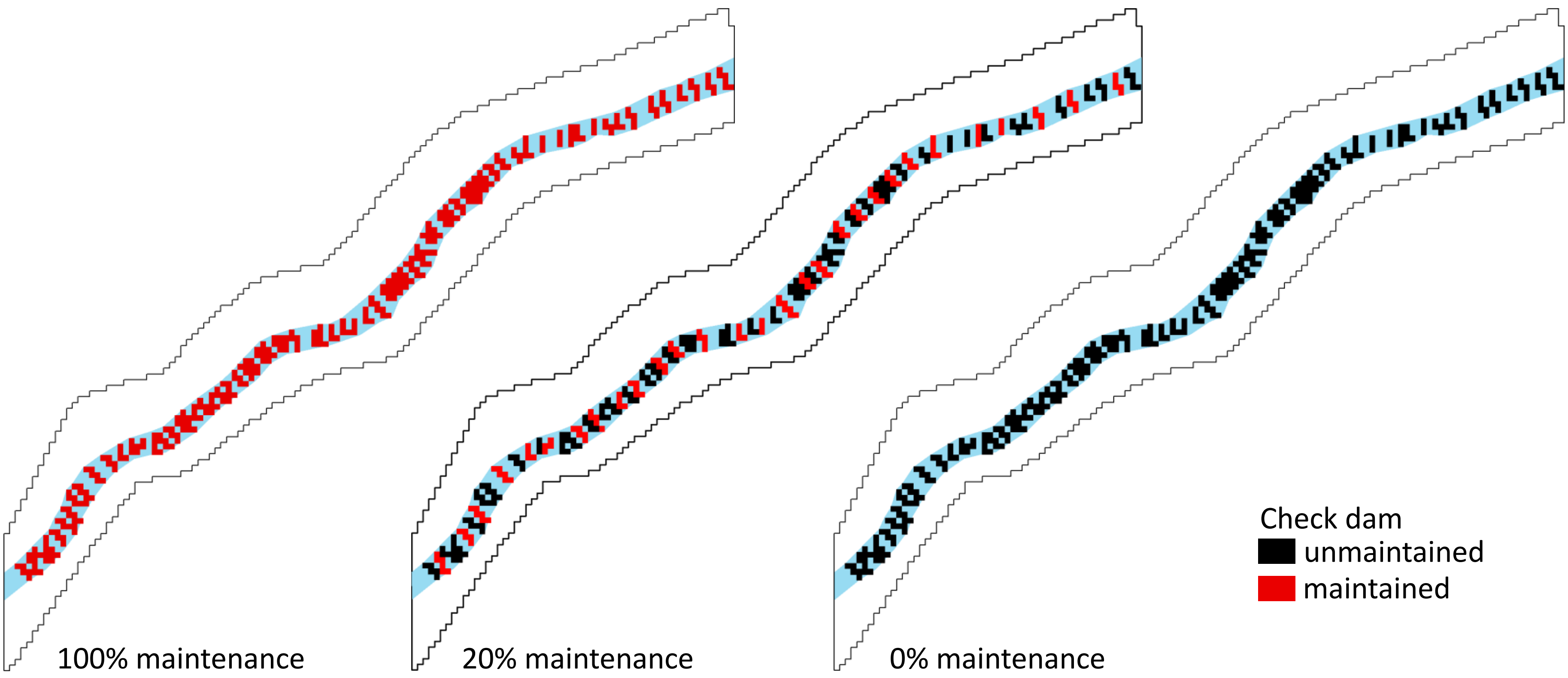


Check dam failure implementation



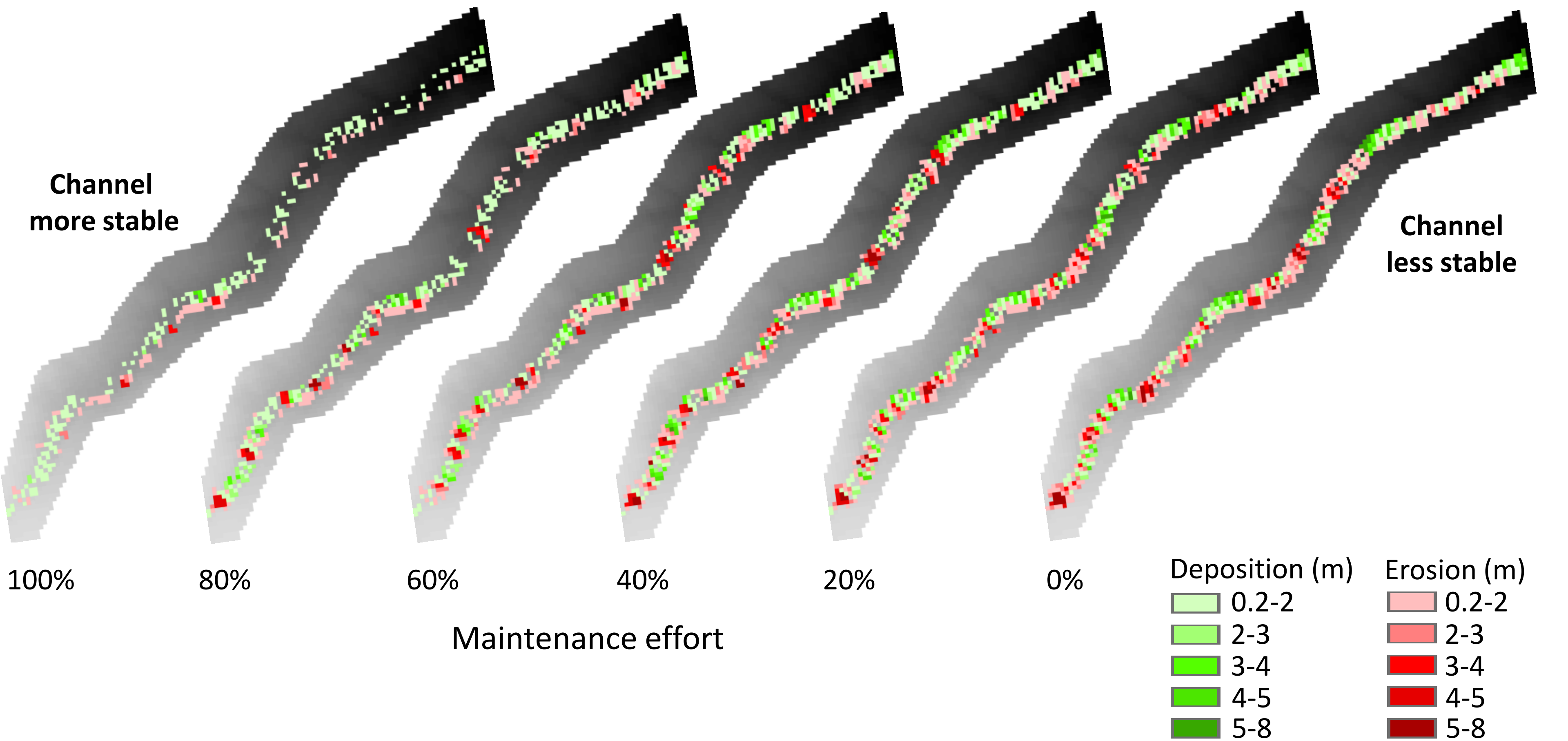
Check dam maintenance scenarios

- 6 scenarios trialed
- 0-100% maintenance effort in increments of 20%
- Maintained check dams selected in spatially equal intervals



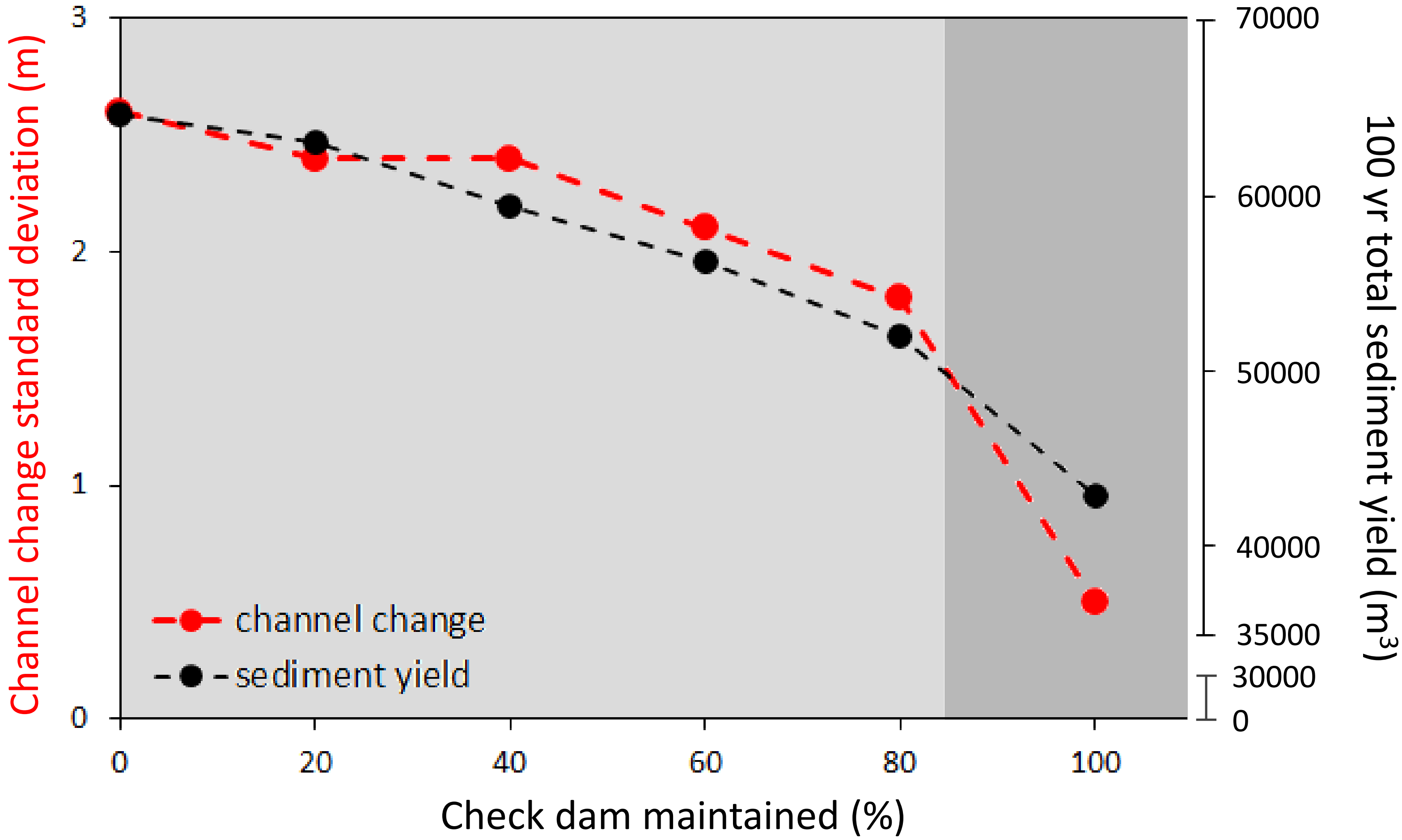
Results: Channel change

- Channel change = DEM year 0 – DEM year 100
- Major changes in channel elevation



Results: Sediment yield

- 50% increase in sediment yield between 100% and 0% maintenance of check dams
- >80% of the check dams are needed to maintain a stable river



Conclusion & Future work

- The proof of concept model responds to check dam failure including **changes in channel elevation** and **sediment yield**
- Preliminary model results suggest that **more than 80%** of the check dams are needed to maintain a stable river → how many more?

Future work

- Scenarios between 80-100%
- Different failure rules
- What is the effect of model resolution?
- When is the channel the most (un)stable during the 100 years?
- Generate plausible discharge and sediment inputs for the reach

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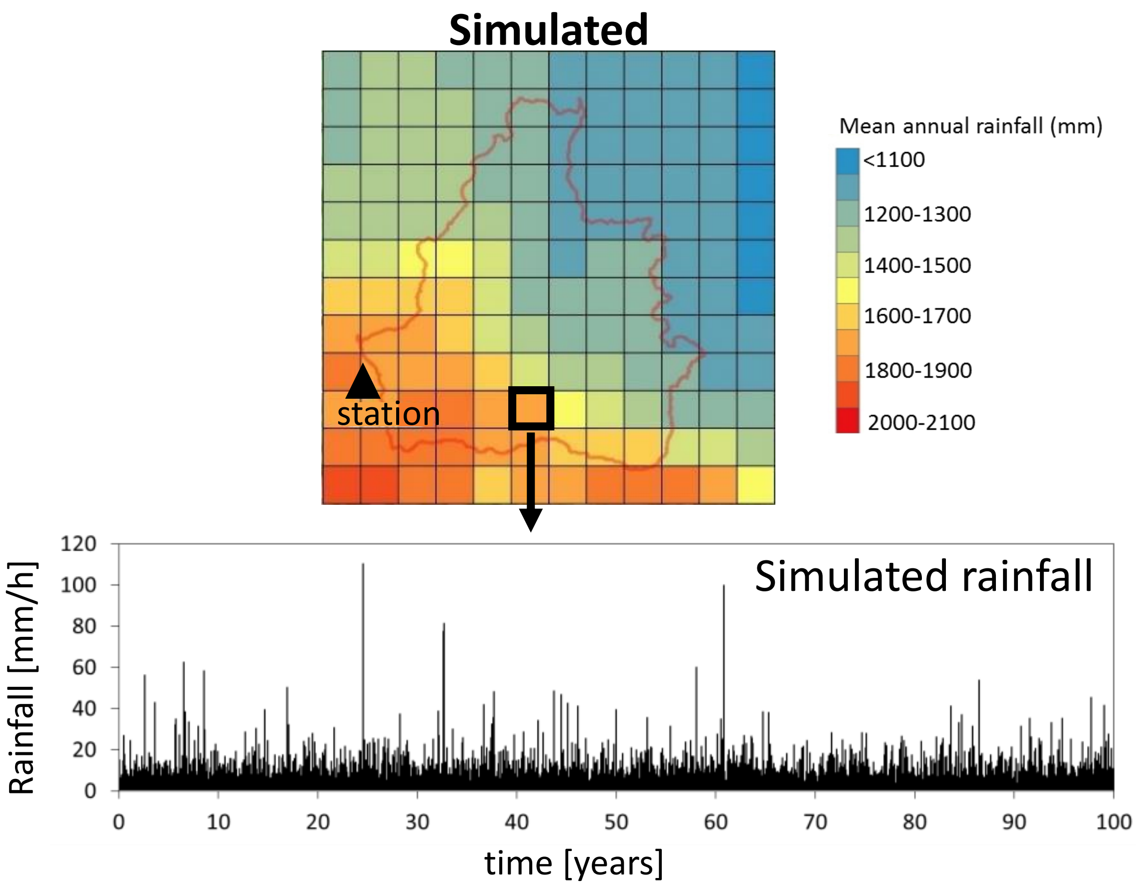
Future Work: Simulated rainfall

- Raster rainfall generated by AWE-GEN-2d (**A**dvanced **WE**ather **GEN**erator for **2-D**imensional grid)
- Rainfall is simulated at hourly and 1-km resolution
- Combines: rain-gauges, weather radar system



Peleg et al. (2017)