Universität Stuttgart
Germany

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Oslo, Norway, 27th – 29th May 2008

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Risikomanagement
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Hochwasserereignisse

Impact of shape and land use on sedimentation in green flood retention reservoirs

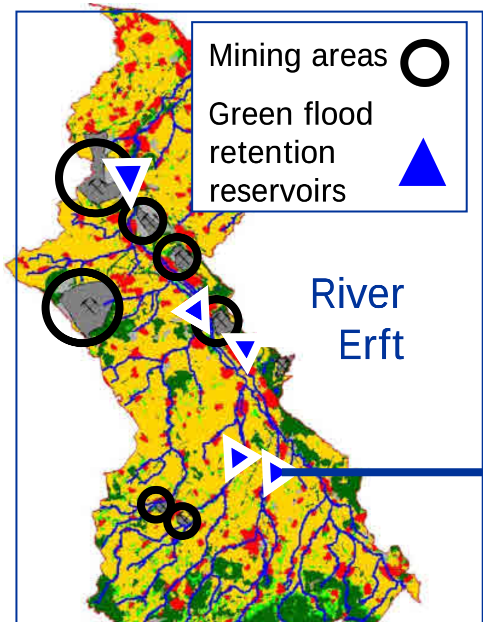
Development of an Integrated Management Strategy for Green Flood Retention Reservoirs and Polders for Flood protection

Sven Wurms

Motivation

Flood event

Emission	Immission



Green flood retention reservoir Horchheim/ Erft

Erosion
mobilisation of pollutants

Deposition
floodplains & retention reservoirs

Integrated management strategy for green flood retention reservoirs, polders and floodplains

- Quantity/ quality of deposited sediments?
- Factors influencing deposition in retention reservoirs as well as on floodplains?

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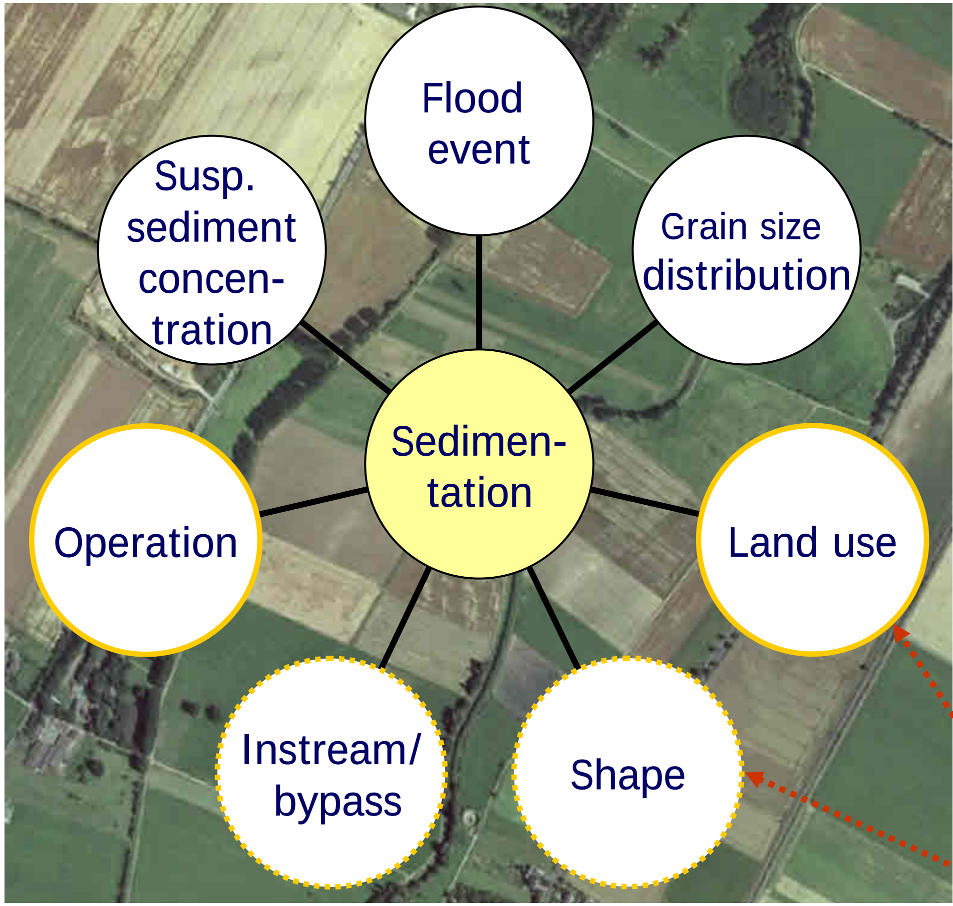
Overview

1. Aim
2. Quantifying transport processes in green flood retention reservoirs
3. Impact of reservoir shapes on sedimentation
4. Detailed transport simulations
5. Impact of land use on sedimentation
6. Conclusions

Aim



Factors influencing sedimentation processes in green flood retention reservoirs

Background
„Integrated management strategy“

<u>Enhancement of the environment by targeted retention of flood induced, released contaminated sediments</u> in green flood retention reservoirs?

Knowledge of effectiveness of factors influencing sedimentation and their interaction is essential!

Investigation of the impact of shape and land use on sedimentation in green flood retention reservoirs

Quantification of deposition in green flood retention reservoirs

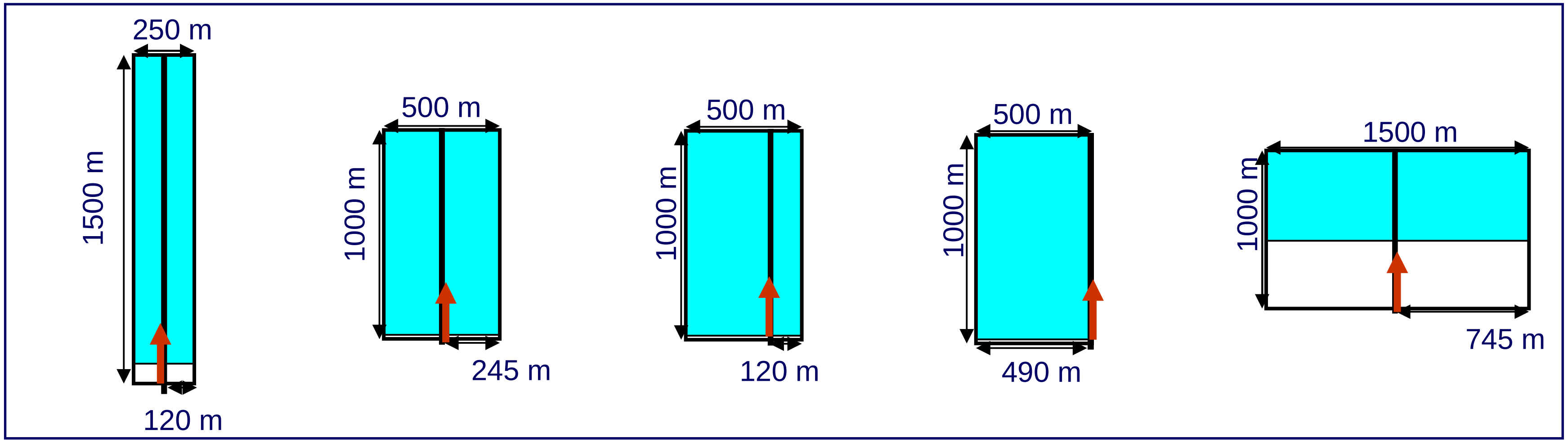
quantification	processes	database
filling and emptying phases unsteady → modelling • 2d-hn-modelling • physical modelling	• advection • dispersion • sedimentation • (erosion) • (sorption) • (degradation)	• Q(t) (in, out) • c(t) • cross sections • geo data • land use data • sediment specific parameters • (measured events)
time- and resource-intensive	complex	often not available

large scope of investigations (TELEMAC-2D, SUBIEF-2D) concerning factors influencing sedimentation → simplifications necessary:

- sediment is considered to be medium of conservative contaminant transport (no desorption/ degradation)
- basic reservoir shapes, simplified concentration graphs as well as hydrographs
- no erosion (small flow velocities, vegetation)

Impact of reservoir shapes on sedimentation

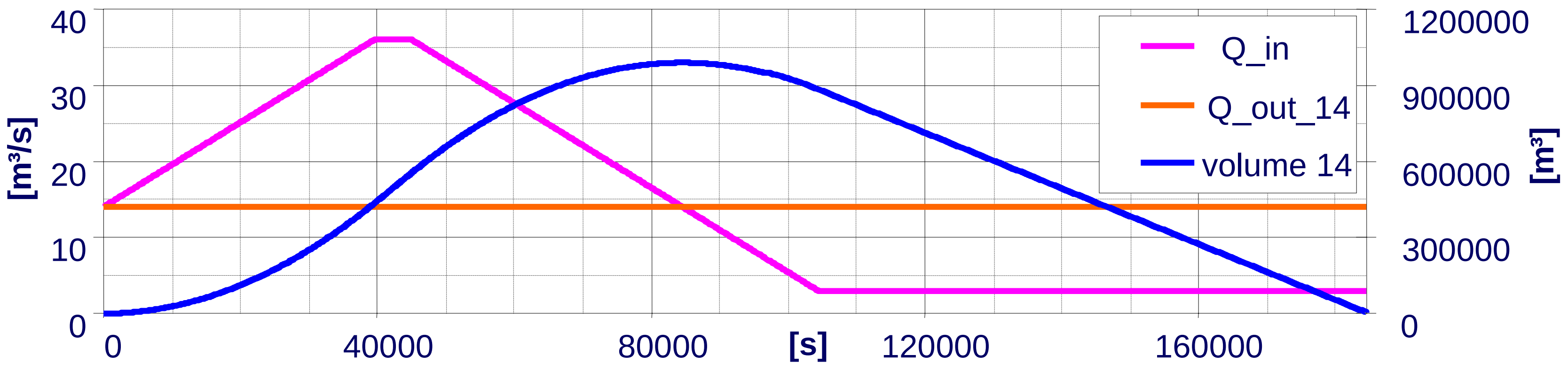
Objects under investigation: Rectangular instream green flood retention reservoirs, body of water = 10^6 m³ in each case, $k_{str,river}$ = 30 $m^{1/3}/s$, $k_{str,floodplain}$ = 20 $m^{1/3}/s$



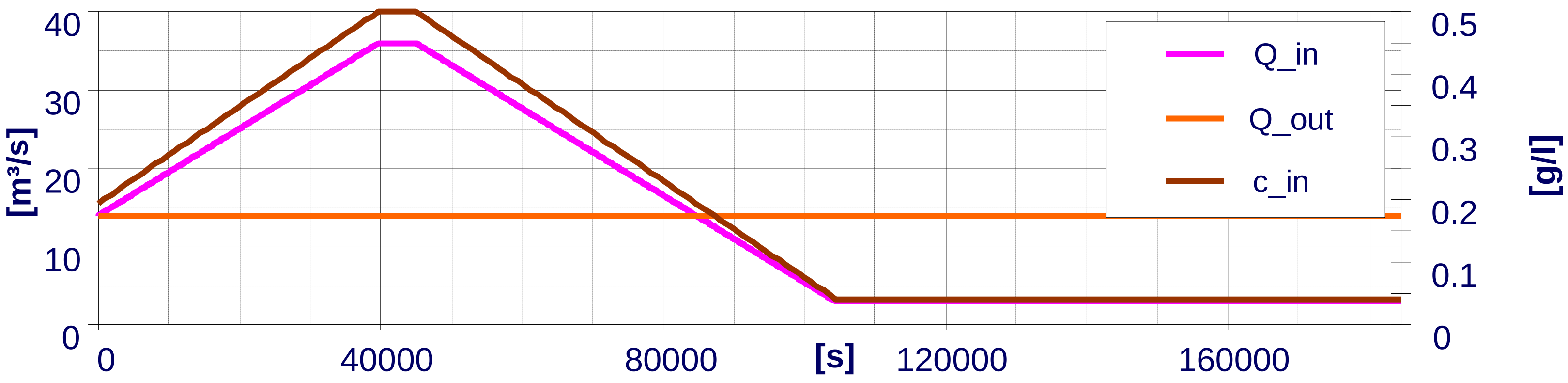
Sediment properties (Sedimentation flux $Q_d = W_c \cdot c\left(1-\left(u^* / u_d^*\right)^2\right)$)

Grain fraction [µm]	20	40	80	150
settling velocity [m/s]	$2.75 \cdot 10^{-4}$	$1.13 \cdot 10^{-3}$	$4.21 \cdot 10^{-3}$	$1.29 \cdot 10^{-2}$
critical shear velocity for deposition [m/s]	$6.7 \cdot 10^{-3}$	$2.7 \cdot 10^{-2}$	$9.9 \cdot 10^{-2}$	0.27

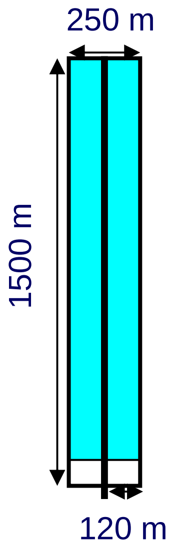
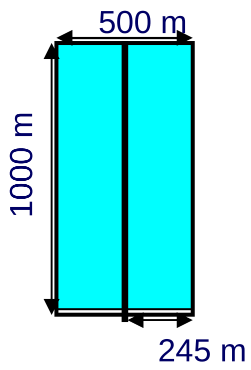
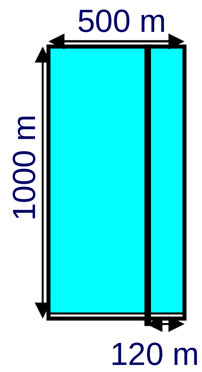
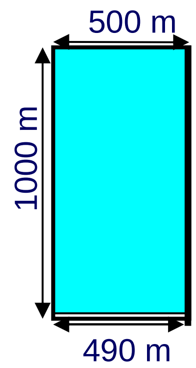
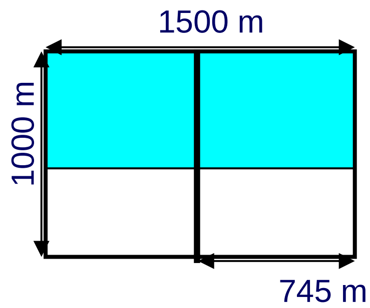
Flow BC: idealised inflow hydrograph $Q_{in}(t)$, Q_{out} = const. in each case



Transport BC for suspended sediments

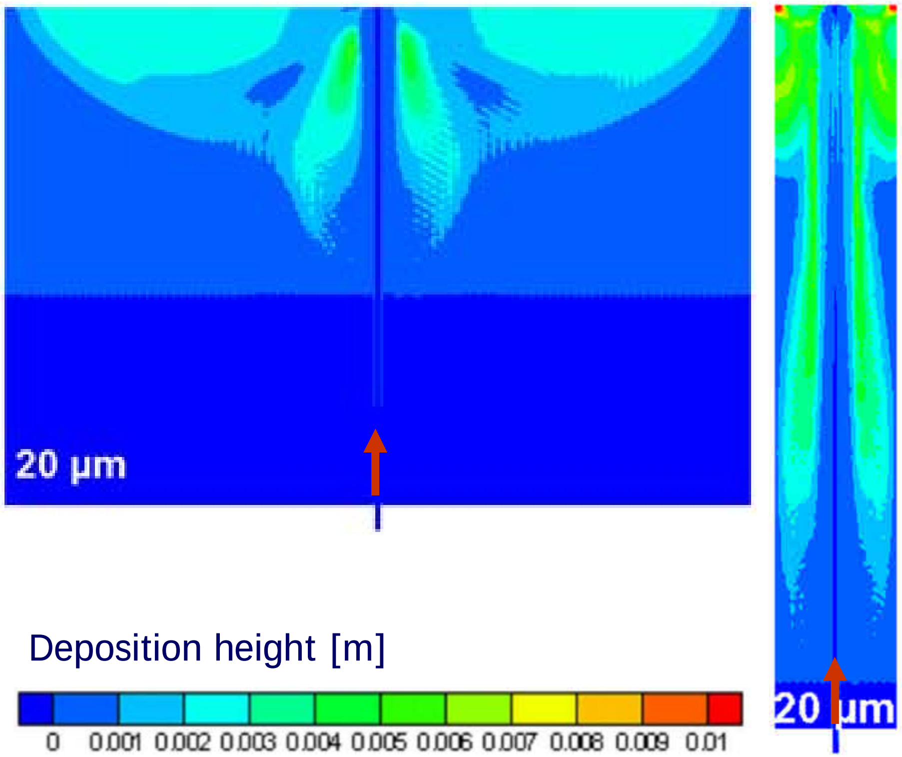


Deposited sediment (percentage of total incoming sediment); Q_{out} = 14 m³/s

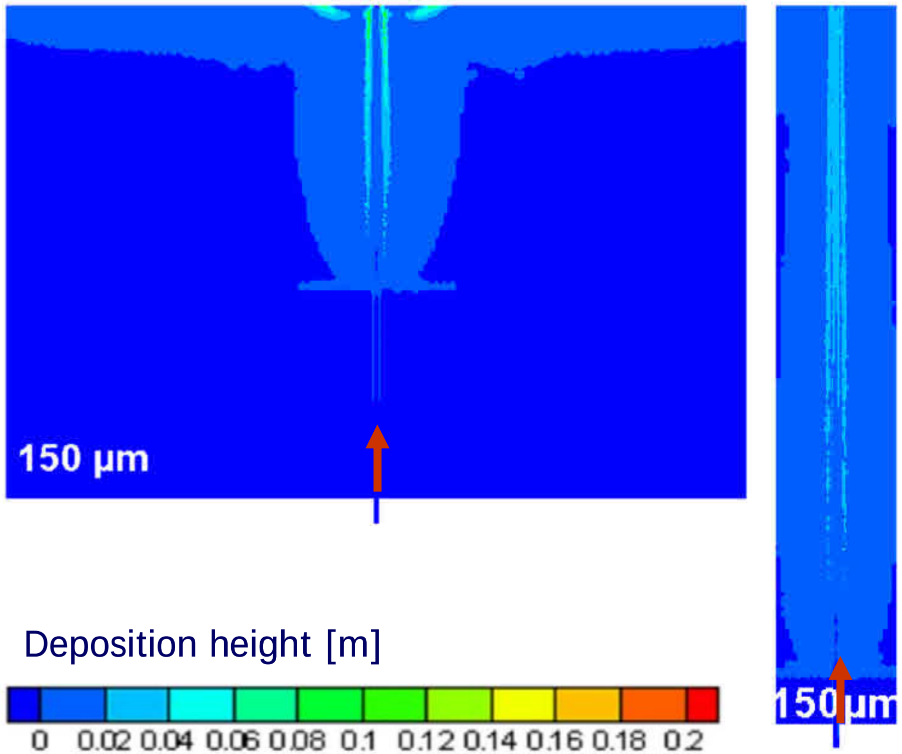
grain fraction					
20 µm	38.7 %	42.1 %	42.5 %	43.1 %	44.3 %
40 µm	56.4 %	49.0 %	50.4 %	49.0 %	46.6 %
80 µm	70.6 %	58.2 %	60.4 %	56.3 %	48.9 %
150 µm	78.3 %	66.5 %	69.3 %	64.9 %	51.8 %

Deposition pattern; Q_{out} = 14 m³/s

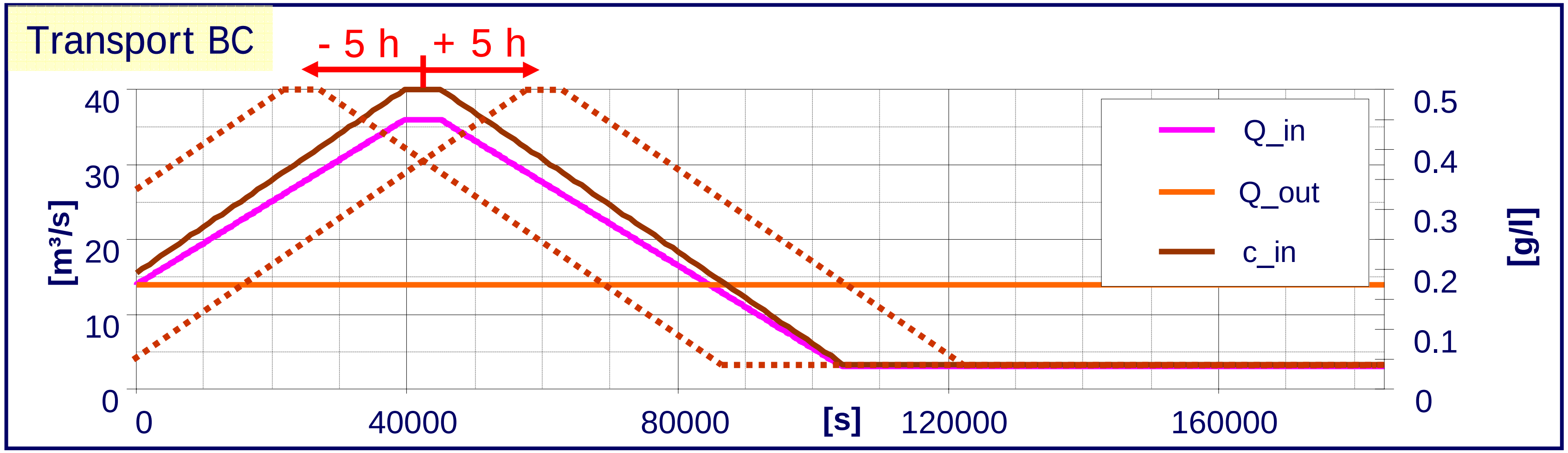
d = 20 µm

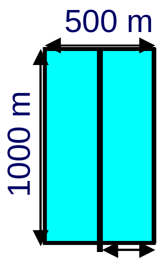
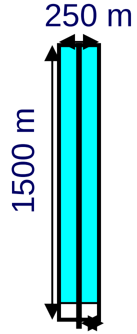


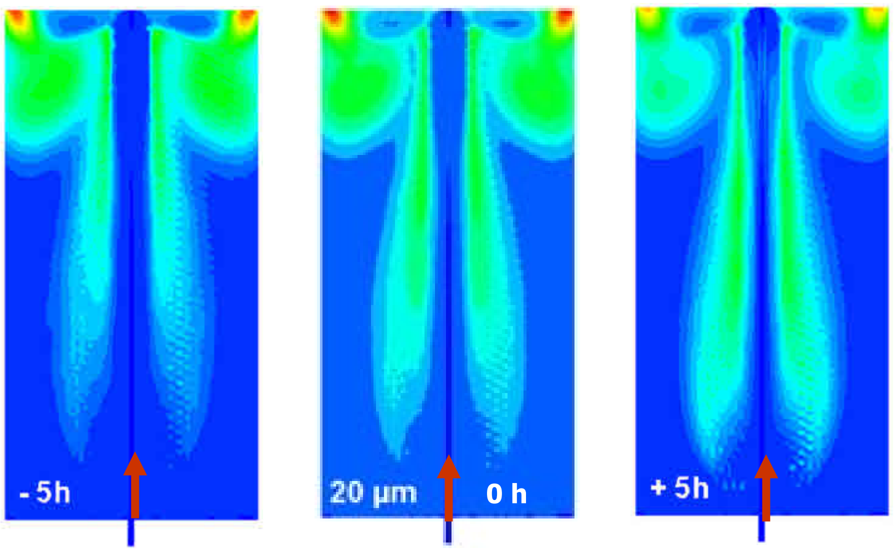
d = 150 µm



Time dependency of sedimentation processes

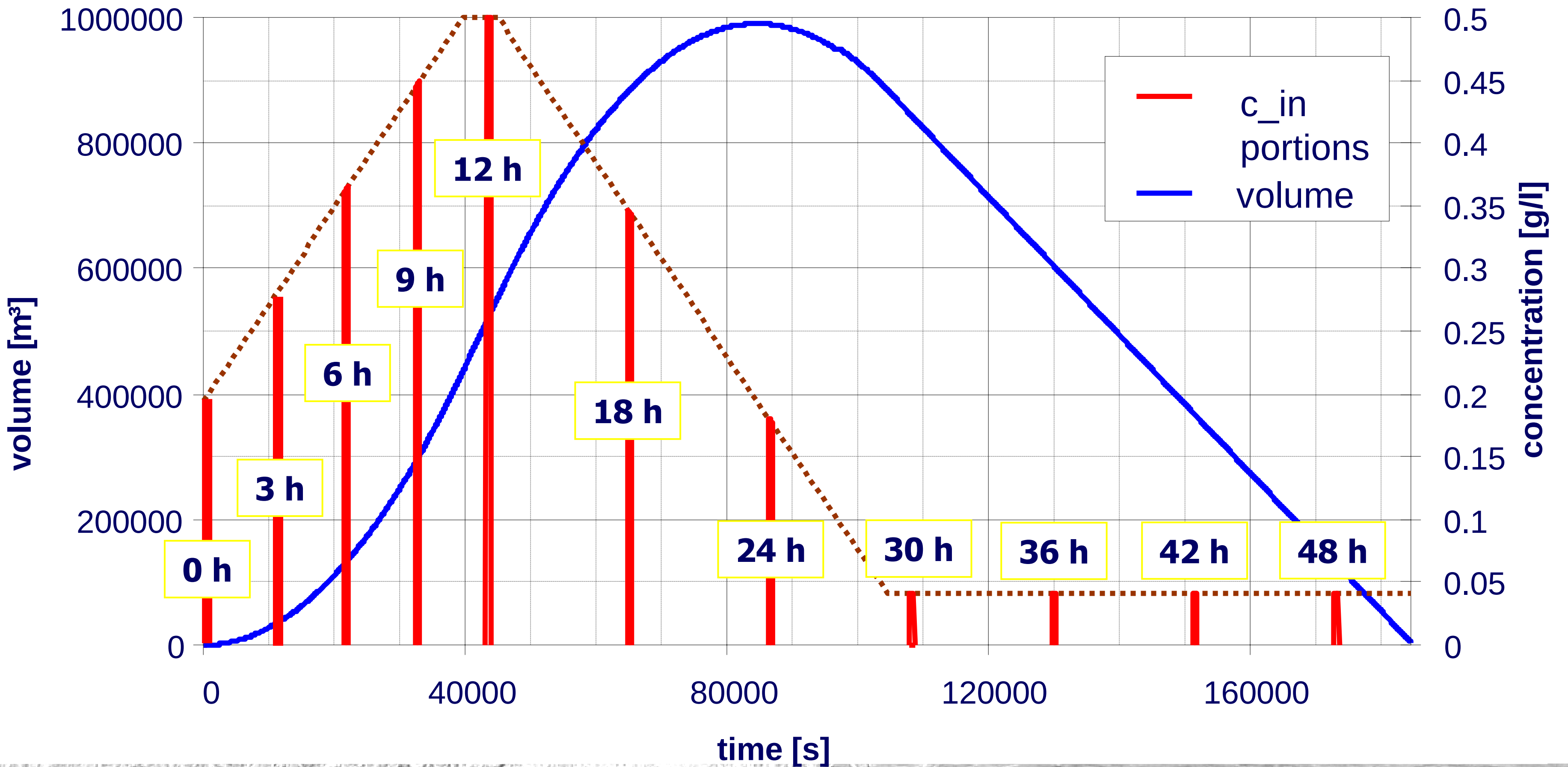


temporal shift of concen-tration		
-5 h	41.4 %	36.4 %
0 h	42.1 %	38.7 %
+5 h	41.4 %	40.9 %



Detailed transport simulations

Input of several portions of suspended sediment at different levels of filling into the reservoir instead of continous sediment input→ 1 simulation per input portion (d=20 µm, Q_{out}=14 m³/s)



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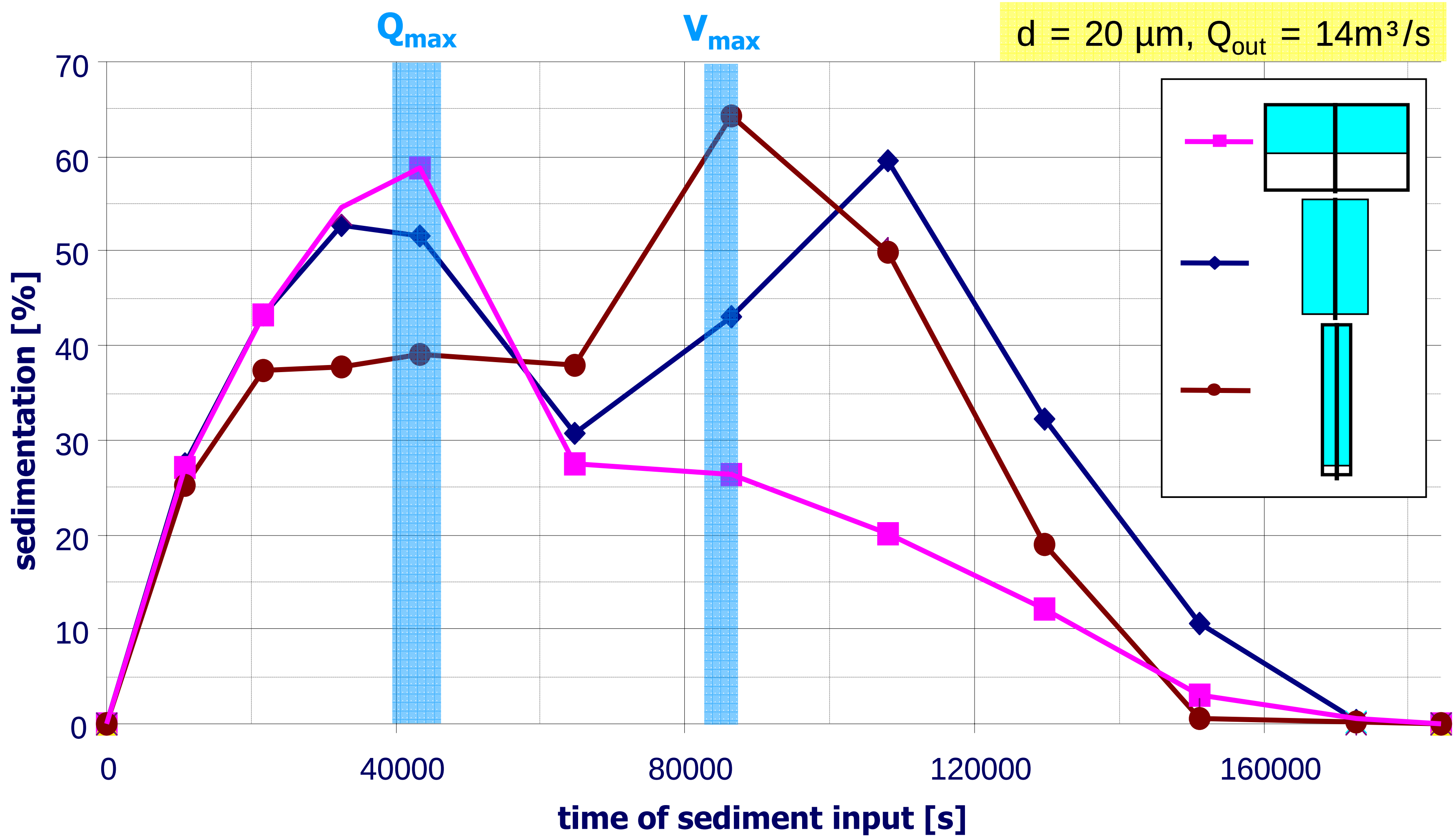
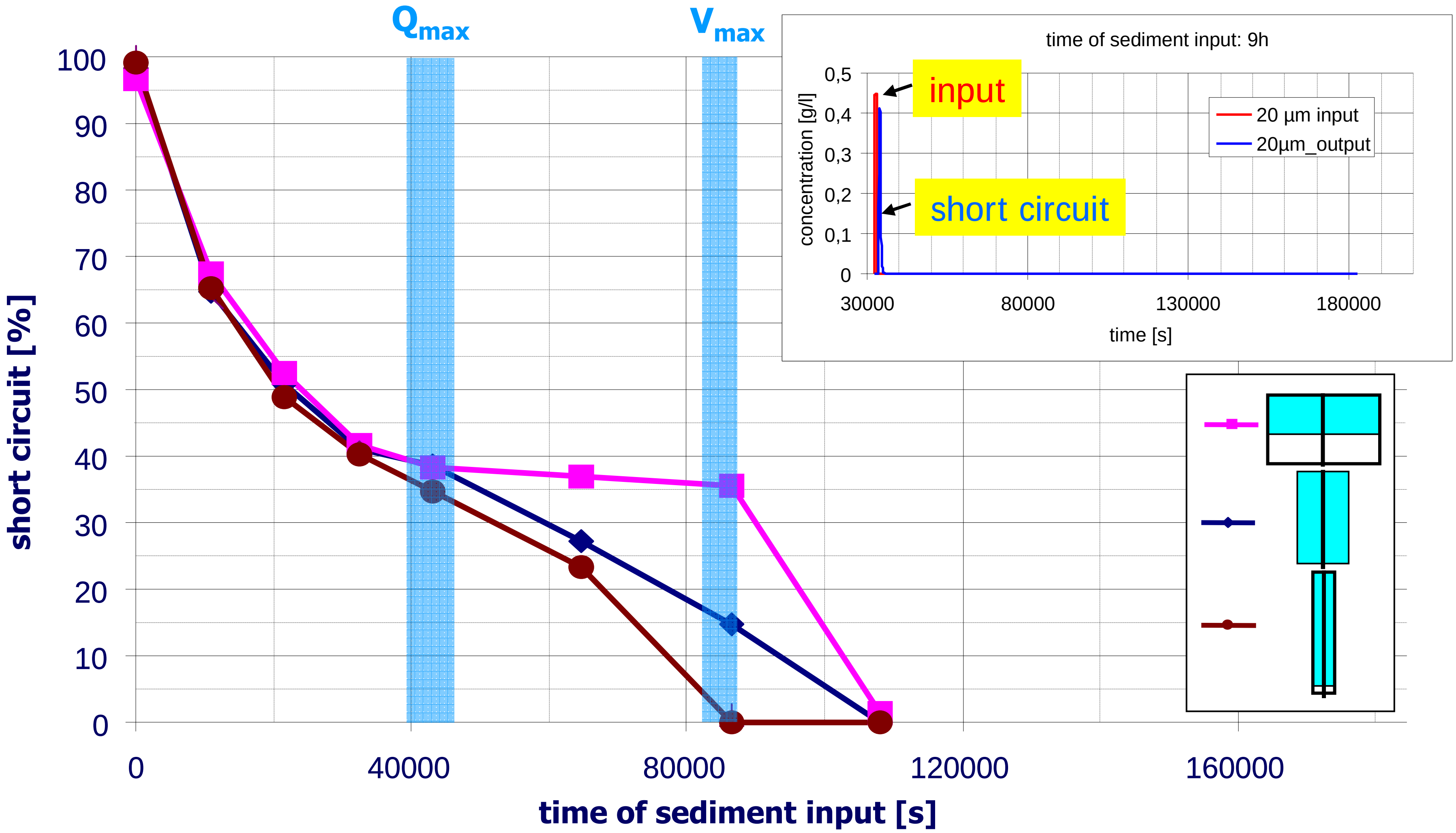
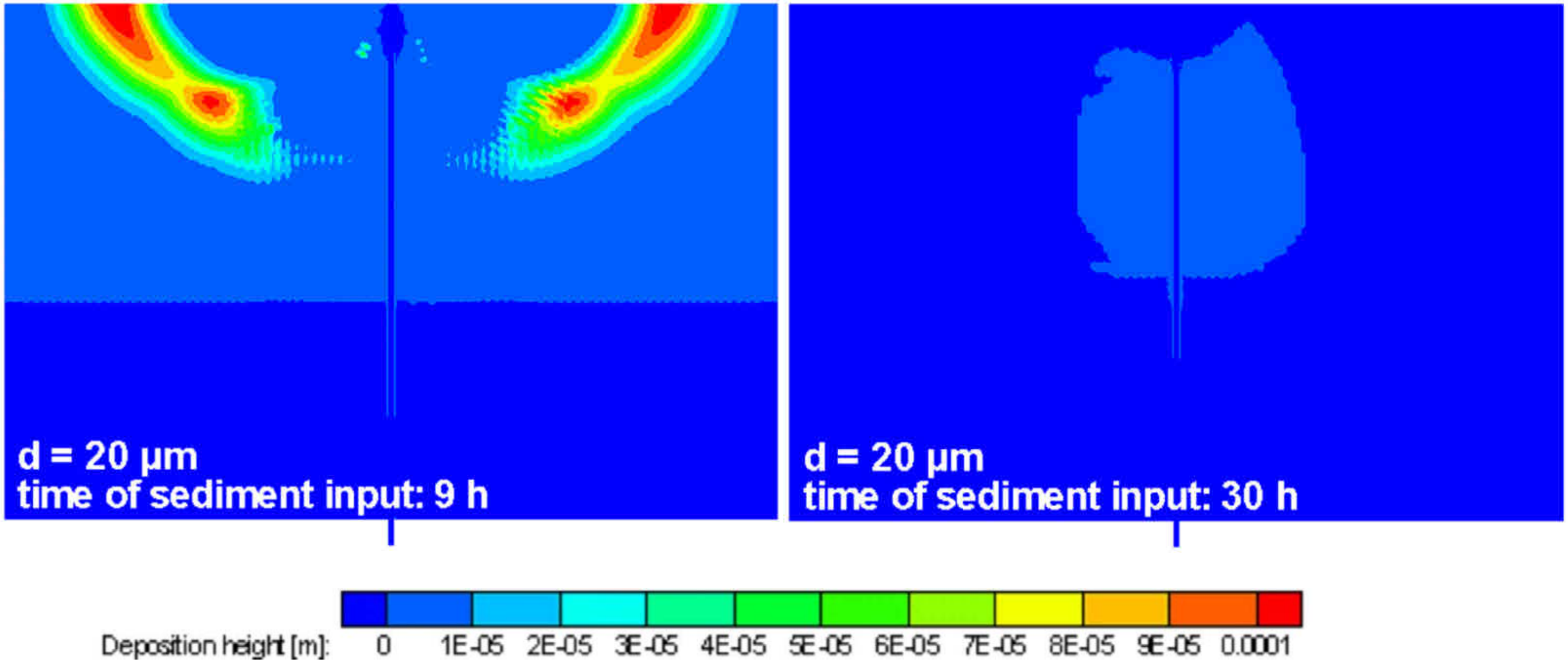
Result: Deposition (percentage of total incoming sediment); f (time of sediment input)



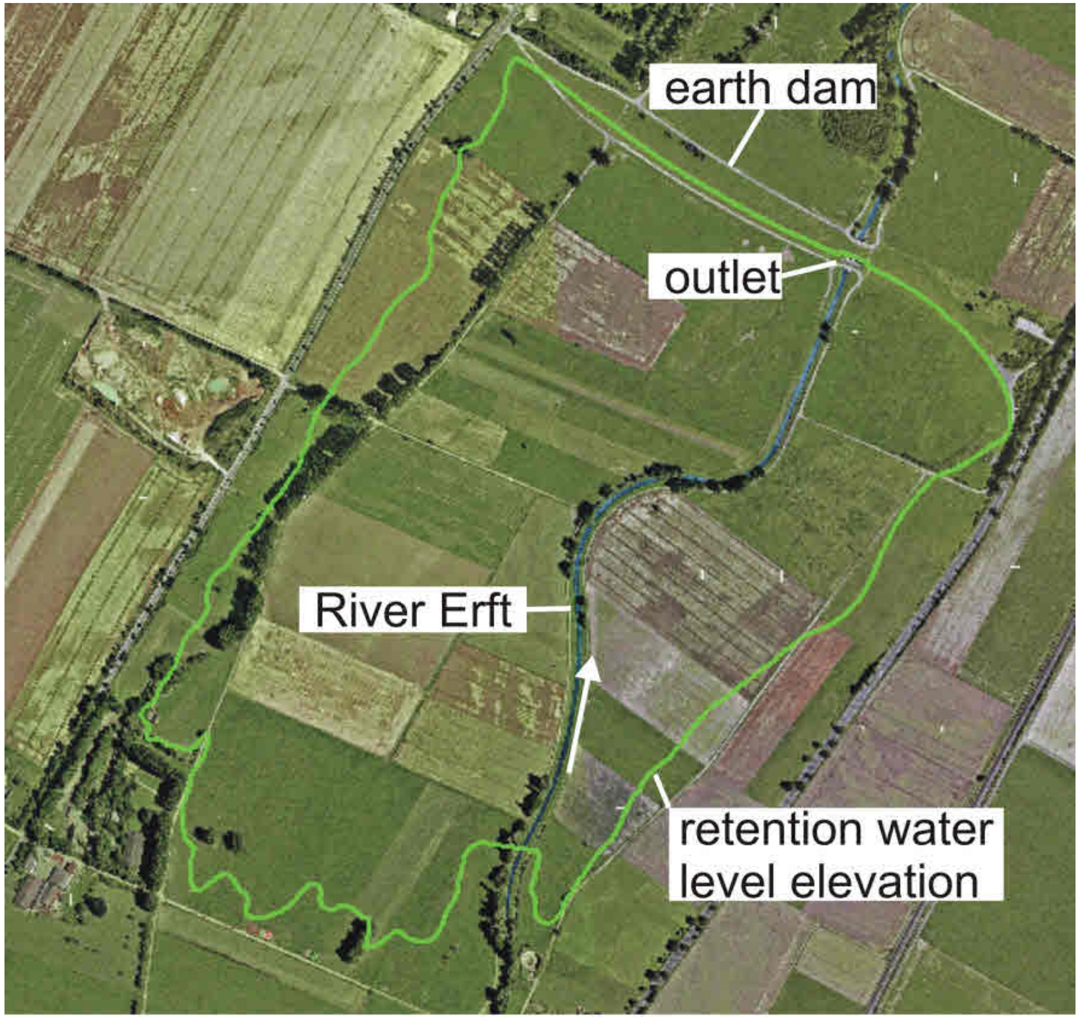
Result: Short circuit (percentage of total incoming sediment); f (time of sediment input)



Example of deposition pattern f (time of sediment input)



Impact of land use on sedimentation



- Impact of seasonal changes/ different types of land use on sedimentation?

- Degree of uncertainties concerning calculated deposition masses due to estimation of roughness parameters?

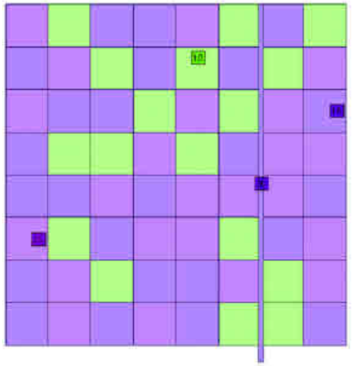
Simulations with varying roughness distributions within green flood retention reservoir

Range of amount and pattern of deposited sediments

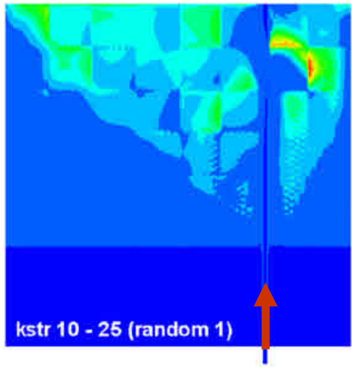
Simulations with varying roughness distributions

grain fraction d = 20 µm

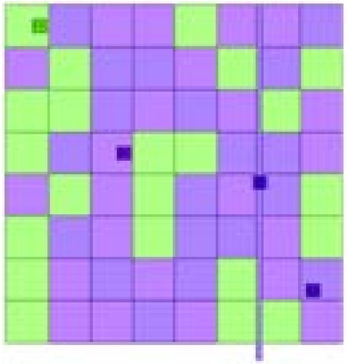
k_{str}=10–25 $m^{1/3}/s$ random 1



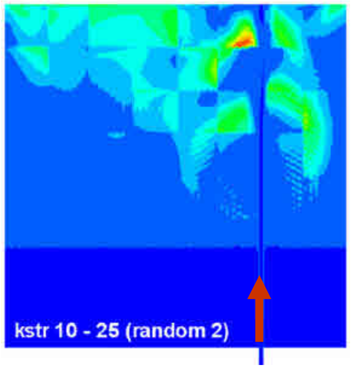
Deposition:
46.0 %



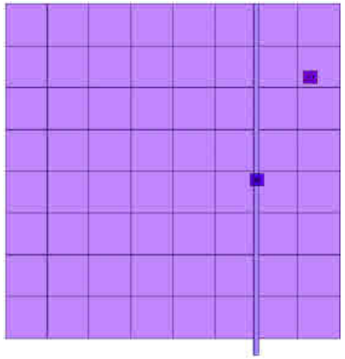
k_{str}=10–25 $m^{1/3}/s$ random 2



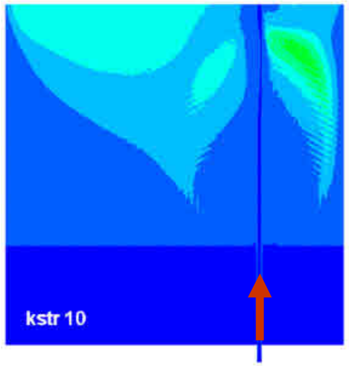
Deposition:
45.6 %



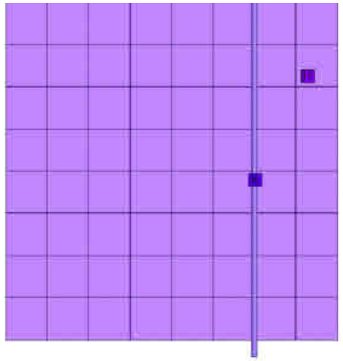
k_{str}=10 $m^{1/3}/s$



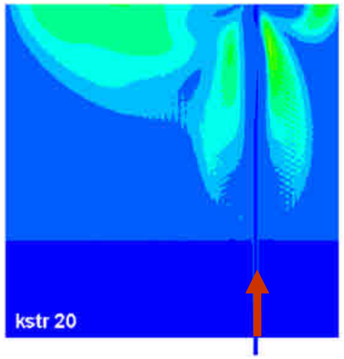
Deposition:
43.5 %



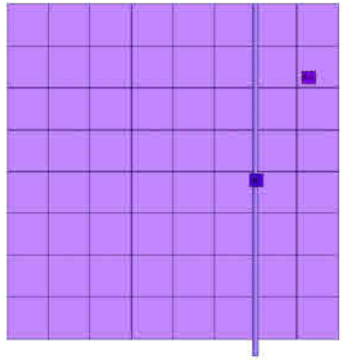
k_{str}=20 $m^{1/3}/s$



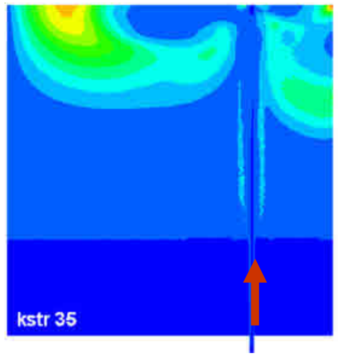
Deposition:
45.3 %



k_{str}=35 $m^{1/3}/s$

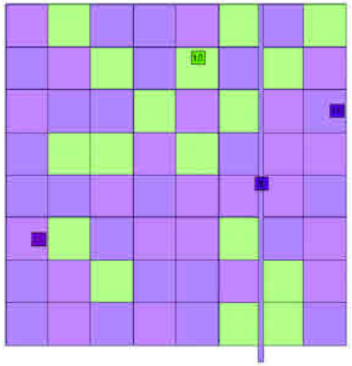


Deposition:
46.0 %

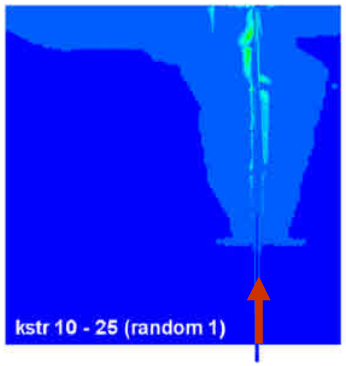


grain fraction d = 150 µm

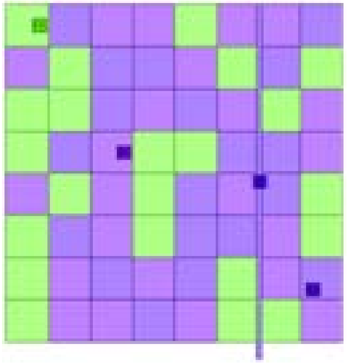
k_{str}=10–25 $m^{1/3}/s$
random 1



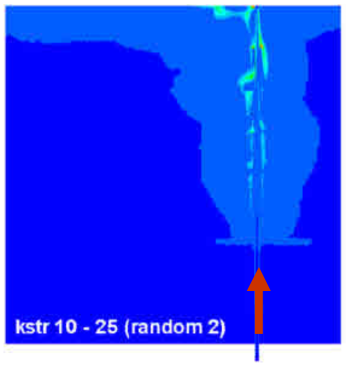
Deposition:
63.0 %



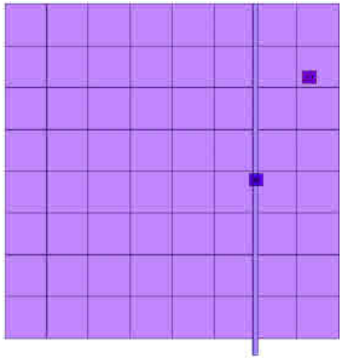
k_{str}=10–25 $m^{1/3}/s$
random 2



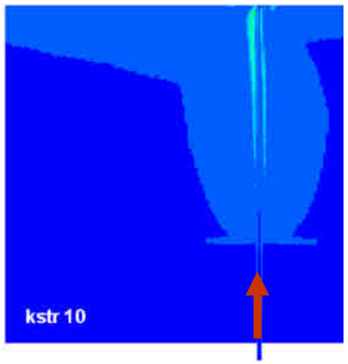
Deposition:
63.4 %



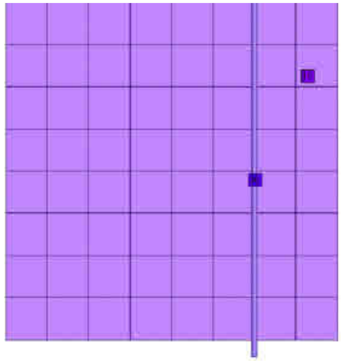
k_{str}=10 $m^{1/3}/s$



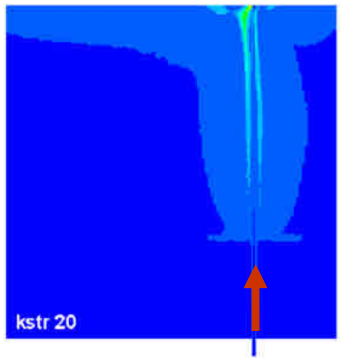
Deposition:
57.2 %



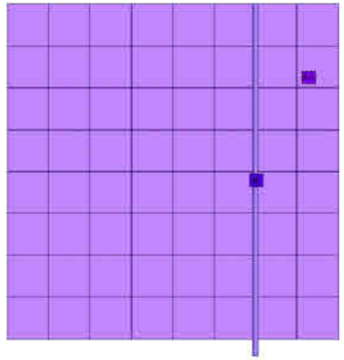
k_{str}=20 $m^{1/3}/s$



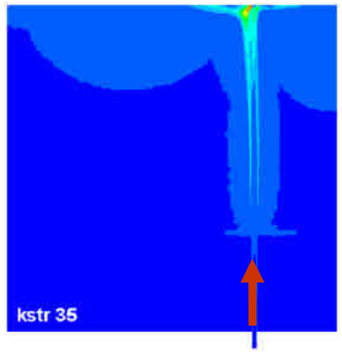
Deposition:
58.1 %



k_{str}=35 $m^{1/3}/s$



Deposition:
63.4 %



Conclusions

- Effectiveness of sediment retention in green flood retention reservoirs strongly depends on the combination of grain size and reservoir shape
- The bigger the grain size, the smaller the area of deposition and the smaller the impact of shape and land use on sedimentation pattern and masses
- One mean value is not suitable for the description for the effectiveness of sediment retention for a given reservoir due to the strong dependence on time of sediment input
- Different shaped reservoirs have their maximum effectiveness of sediment retention at different stages of filling (knowledge is important for an adaptive reservoir operation)
- The short circuit of suspended sediment flow reduces the effectiveness of sediment retention enormously, this can be influenced by modified operation or reservoir design
- Land use has only a small influence on sedimentation, modelling errors due to rough estimation of parameters are small

Thank you very much for your attention!