Self-formed levees and floodplains in an annular flume

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Objective

Various river channel patterns have been produced in experiments recently, including meandering. However, experiments to date only produced wide floodplains or bedload-generated levees and overbank splays, but not the classical levee with decaying thickness and particle size away from the channel.

Columbia river crevasse splay

The objective of our work is to understand the balance between inundation level, flow velocity and sediment properties, and to design experimental conditions that form levees in channel pattern experiments

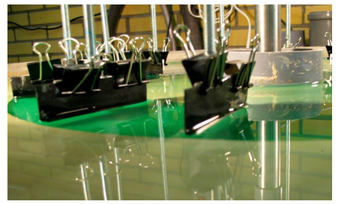
Methods

We designed and built an annular flume with fixed floodplains where flow is driven by vanes in a preformed channel. This setup allows:
- Constant water depth on the floodplain
- Constant flow velocities

In order to create overbank deposits silica flour (D_{50} 30µm), representing silt, was added to coarse river sand (D_{50} 480µm)

Flume parameters	Value
Channel width (mm)	100
Channel depth (mm)	15
Inundation level of the floodplain (mm)	0,5-10
Bend radius (cm)	20
Flow velocity channel (m/s)	0,12-0,30
Reynolds no. on the floodplain <5mm inundation	<500
Reynolds no. on the floodplain >5mm inundation	500-1550
Froude no. channel	0,30-0,45

The annular flume was made by recycling materials that would otherwise have been thrown away



The flow in the channel is driven by vanes inserted 3mm into the 15mm deep channel

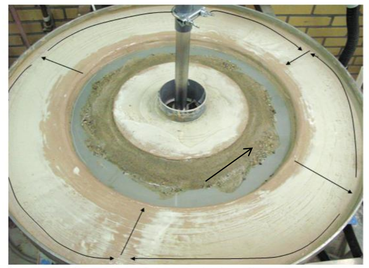
Results

Flow patterns on the floodplain
- Chanel flow velocities of 0,19m/s resulted in stable flow conditions and were used in the levee forming experiments
- With low inundation levels on the floodplain (0,5-5,0mm) zones of convergent and divergent flow were present
- With higher inundation levels on the floodplain (5-10mm) the water moved along with the flow in the channel

Low inundation levels were characterized by large floodplain circulation cells

Overbank morphology
- Higher water levels on the floodplain resulted in shear velocities preventing settling of silica flour
- Low water levels caused silica flour sedimentation on the distal part of the floodplain
- Minimal floodplain water levels only allowed overbank sedimentation close to the channel

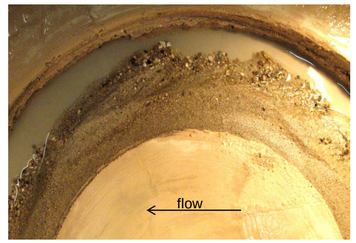
Minimal inundation levels (0,5mm) resulted in silica flour deposition along the channel



Low inundation levels caused silica flour deposition on the floodplain, apart from the zones of converging circulation

Transition from levee to floodplain at the arrow

Channel morphology
- Strong spiral flow scoured the outer bend
- Spiral flow created a transverse bedslope around 33° along the inner bend
- There was sorting of the sediment along the inner bend
- Using a finer sediment type as bulk bed load resulted in hydraulic smooth boundary condition and no silica flour entrainment



Sorting pattern of bed load sediment along the inner bend of the flume channel

Transverse bed slope measurements of the inner bend morphology

Discussion

- Results indicate a very narrow (or nonexistent) range of floodplain depth and particle size for levee formation in experiments
- Implications for experiments with self-formed meandering rivers: forming levees in addition to wider floodplains is very difficult for constant discharge
- This result, and observations of Van Dijk et al. (poster EP21B-0676), van de Lageweg et al. (oral EP33E-04) and modelling by Kleinhans (oral EP44A-02) suggest that varying water levels during floods will be more conducive to experimental levee formation

Conclusions

- Experiments represent sharp gravel bed river bends with steep transverse bed
- Silt-sized sediment settles on distal floodplain for low inundation depth but does not settle for larger depth due to high floodplain flow velocity
- Results suggest floods are required to form experimental levees

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