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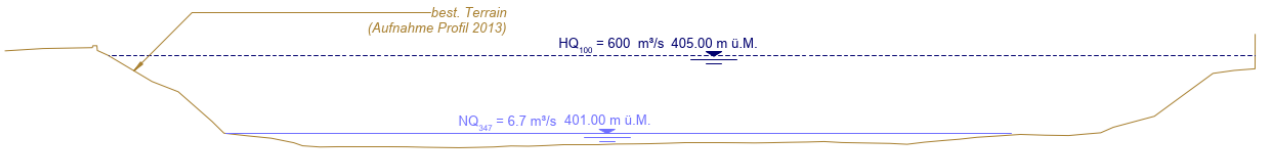
Revitalisation of the Limmat

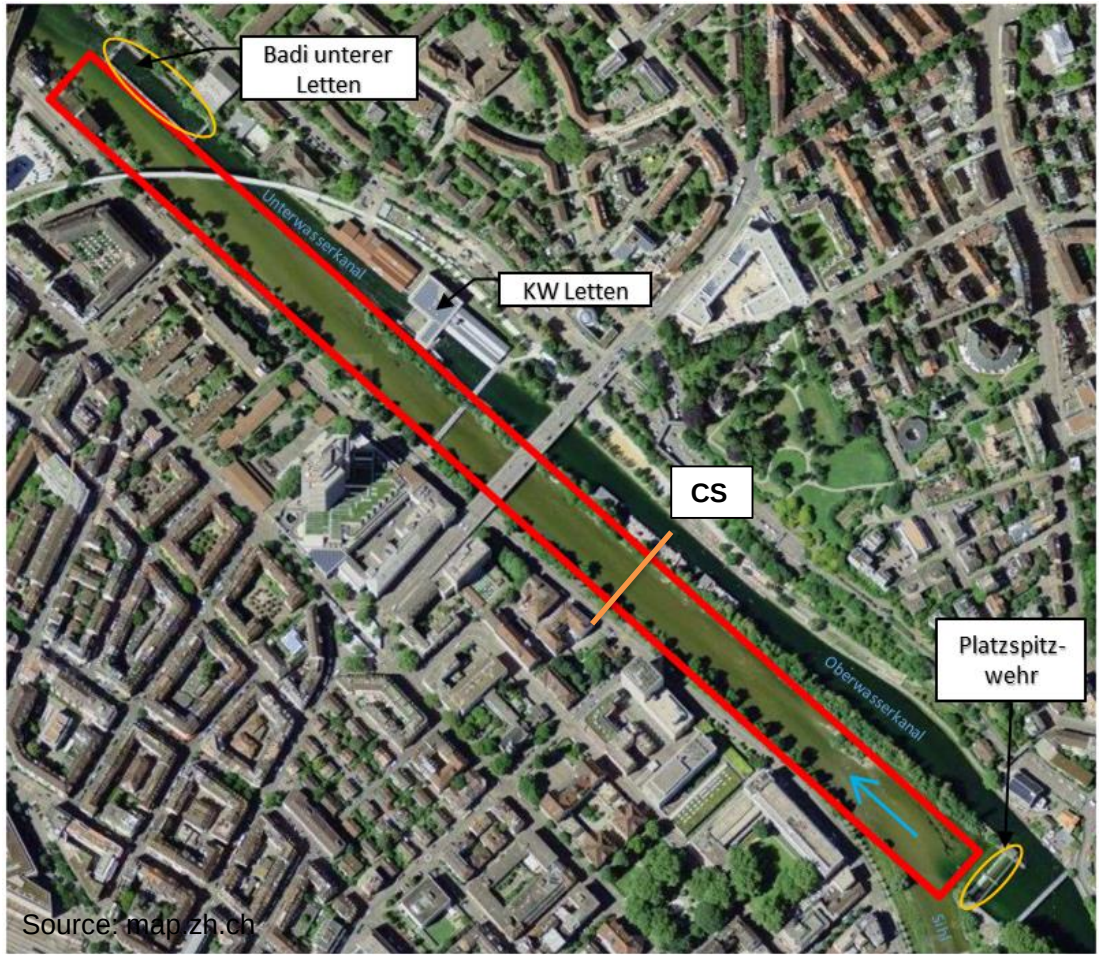
Instream structures and 2D simulation of the flow-structure interaction

Revitalisation of the Limmat

- River section: Residual flow section of the hydropower plant Letten (ewz)
- Length: ~1 km
- Width: ~50 m
- Slope: 2 ‰
- Cross section:



- Project phase: pre-project



Source: map.zh.ch

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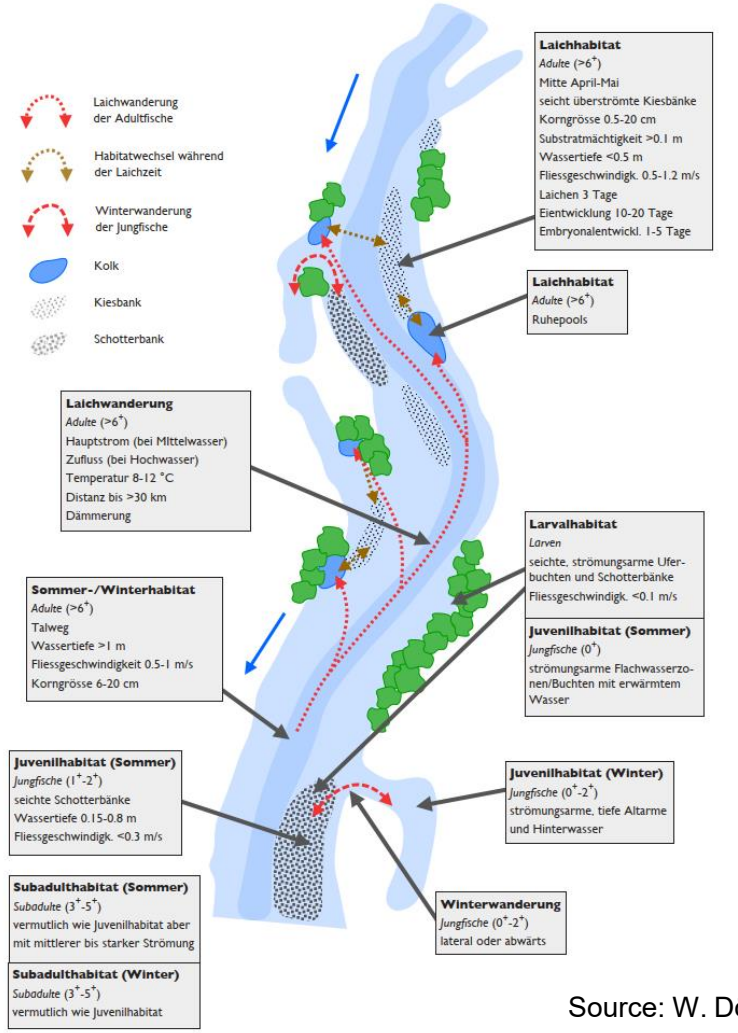
Revitalisation of the Limmat

- Ecomorphology: strongly restricted (AWEL, GIS ZH)
- Limited flow pattern and depth variability
- Fixed river banks (urban area)

Revitalisation of the Limmat

- Purpose:
  - Create habitats and spawning grounds for rheophile fish species: grayling, nase, spirlin
  - migration of the lake trout (longitudinal connectivity)
  - improve the lateral connectivity for invertebrates



Source: W. Dönni

Claim of target group: nase

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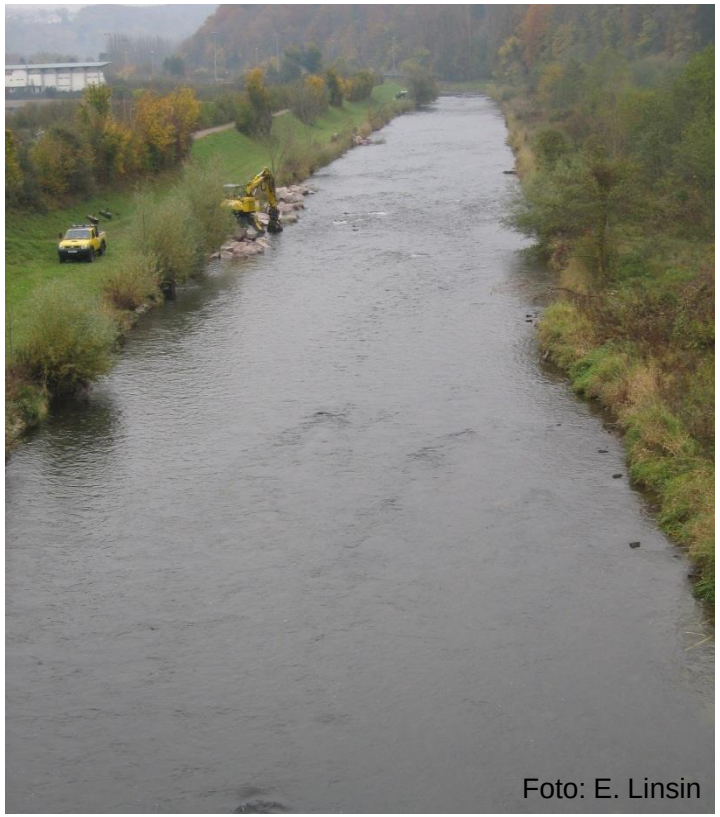
Instream structures

- Turbulent river flow = principal cause for morphological changes
- Flow diversity = depth variation + substrat sorting



Wutach at Waldshut-Tiengen before the revitalisation (Oct. 2009): Monotonous flow

Structures on the rivebed: flow diversity (depth variation + substrate sorting) through micro groynes

Instream structures

- Micro groynes: inclined structures consisting of stones
- Directly built in the riverbed, no intrusion in the levees
- The structures are submerged, typically protruding about 10 to 30 cm from the averaged riverbed level

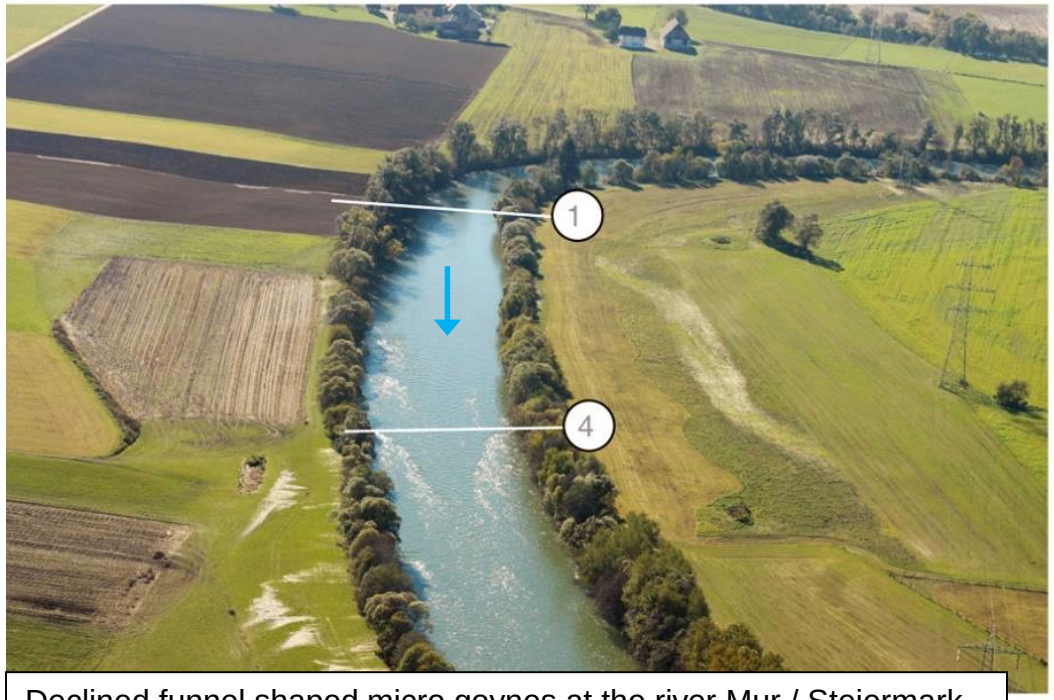
  →Bank protection

  →Flow / Bed morphology diversity

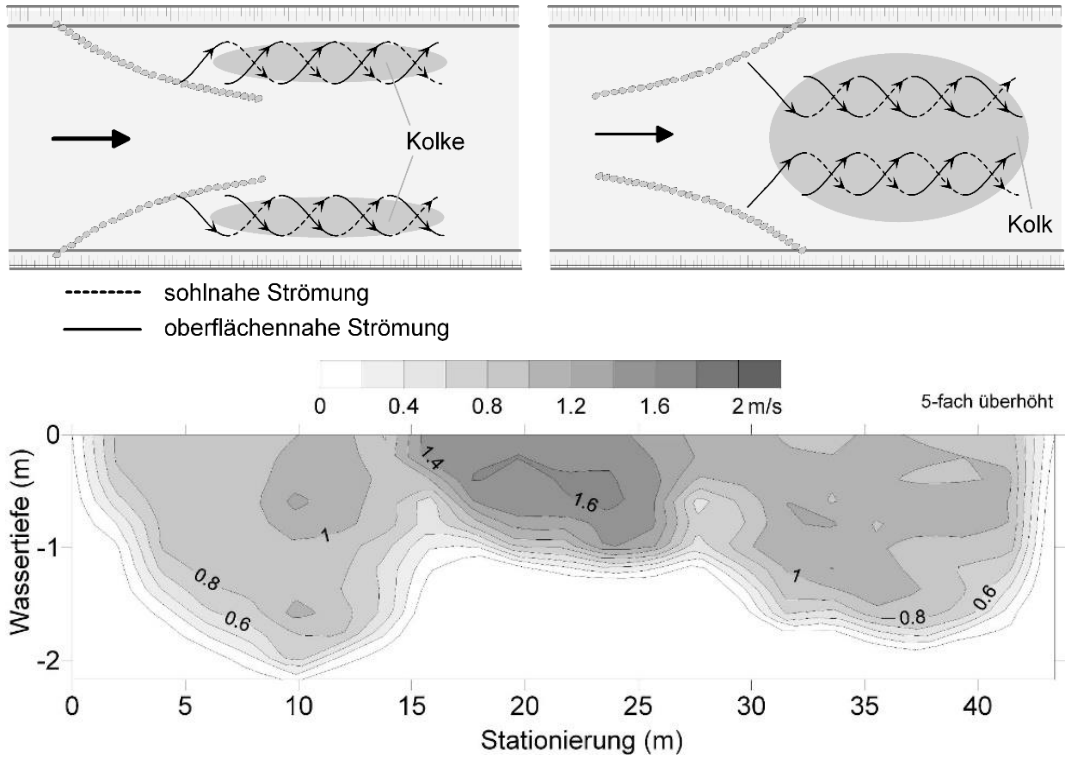
Micro groyne by low flow at the river Mur / Steiermark

Instream structures

Inducing large-scale helicoidal secondary flows with funnel shaped micro groynes



Declined funnel shaped micro goynes at the river Mur / Steiermark



Hydraulic and morphology of declining and inclining funnel shaped micro groynes, Sindelar & Mende 2009

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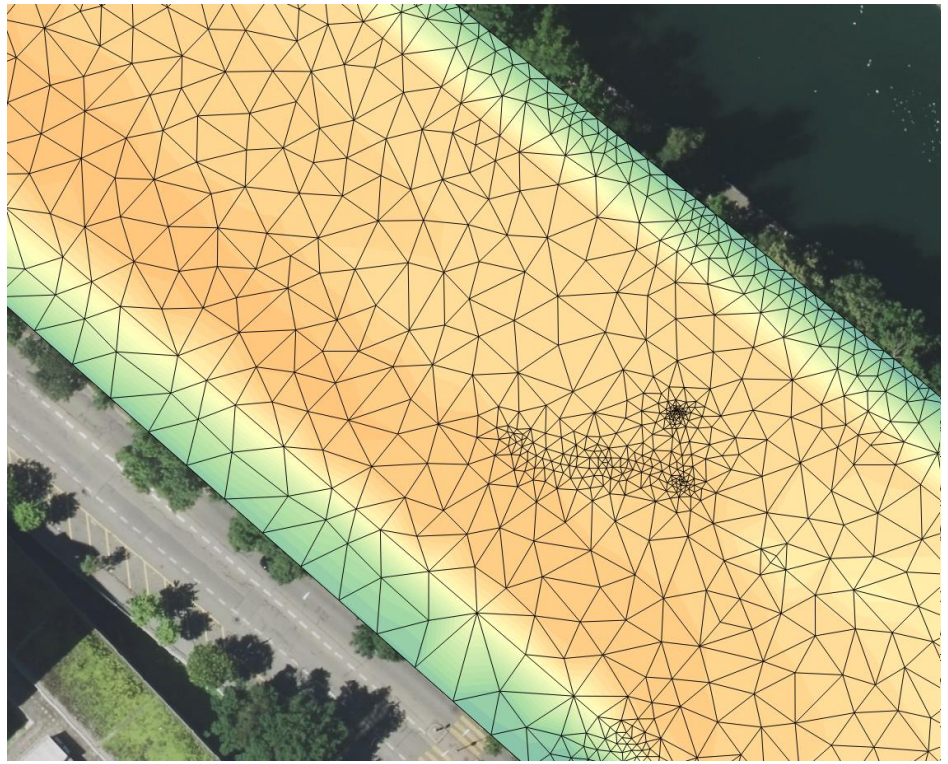
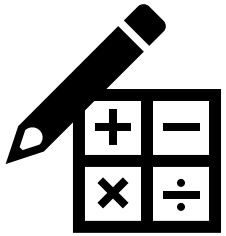
2D simulation of the flow-structure interaction

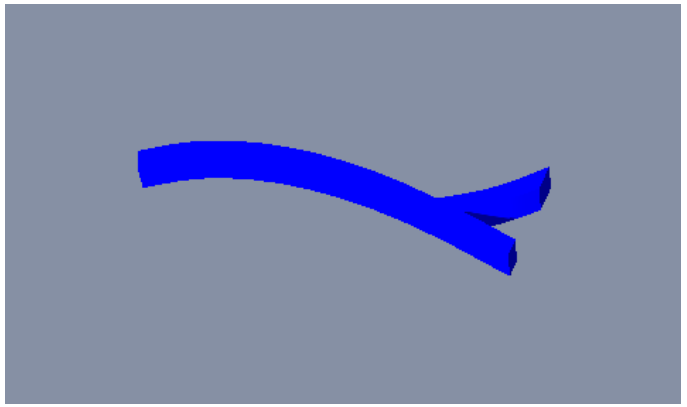
- Goals:
  1) Impact of the instream structures on water level during flood event (HQ_{100})
  2) Influence of the micro groynes on the flow path by low flow
  3) Visualisation of their effect on flow diversity and turbulence
- Limitations:
  - Pre-project = first design
  - Only hydraulic simulation
- Software:
  - BASEMENT v3.0.2
  - QGIS v3.12.0. & BASEmesh v1.4.5

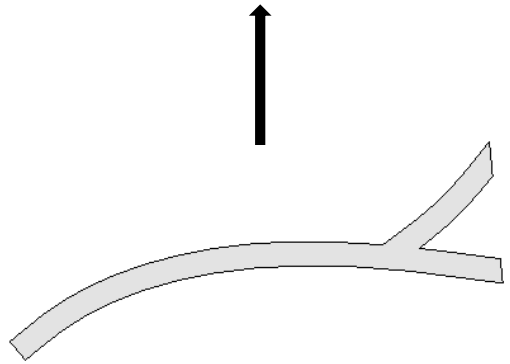
Computational mesh

- Data:
  - Cross section (GEWISS-Adr.) of the Limmat and Sihl (2013, 2017)
  - DTM (Bank/Levee, 2015)
- Instream structures
  1) Design of instream structures (height, size and location)
  2) Modell of instream structures in 3D (CAD, Allplan,…)
  3) Export of breaklines and elevation points
  4) Preprocessing in QGIS







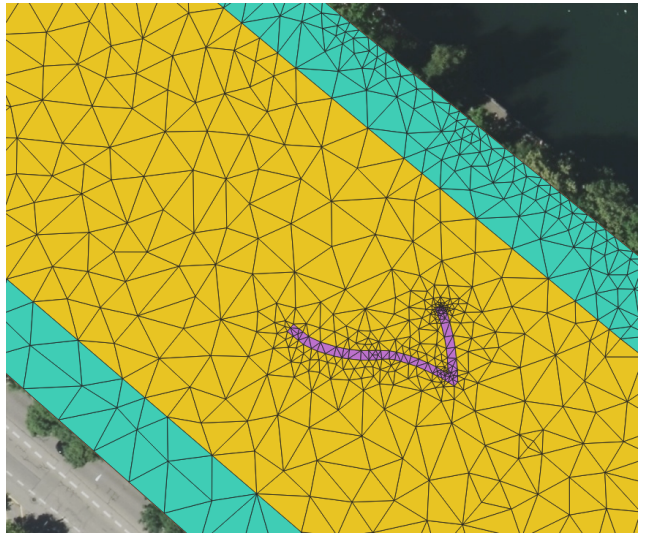


Computational mesh and parameters

- Interpolation method:
  - Micro groynes: maximum
  - Riverbed: minimum
- Number of cells: 27'200
- Friction coefficient

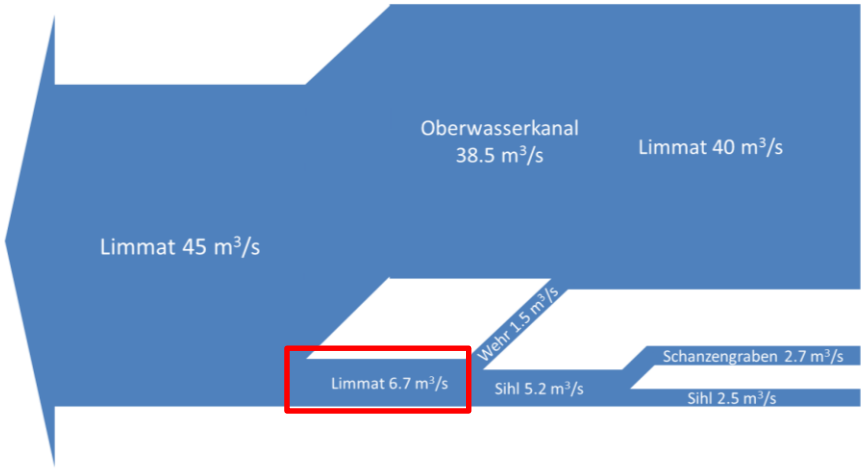
Material	Strickler kst [m1/3]
Riverbed	32
Riverbank	27
Micro groynes	40

- Challenges:
  - Small structures
  - Mesh quality
  - Elevation mesh
  - BASEmesh 1.4.5 & 2.0.0



Hydrology & boundary conditions

Low flow conditions:



Discharge:

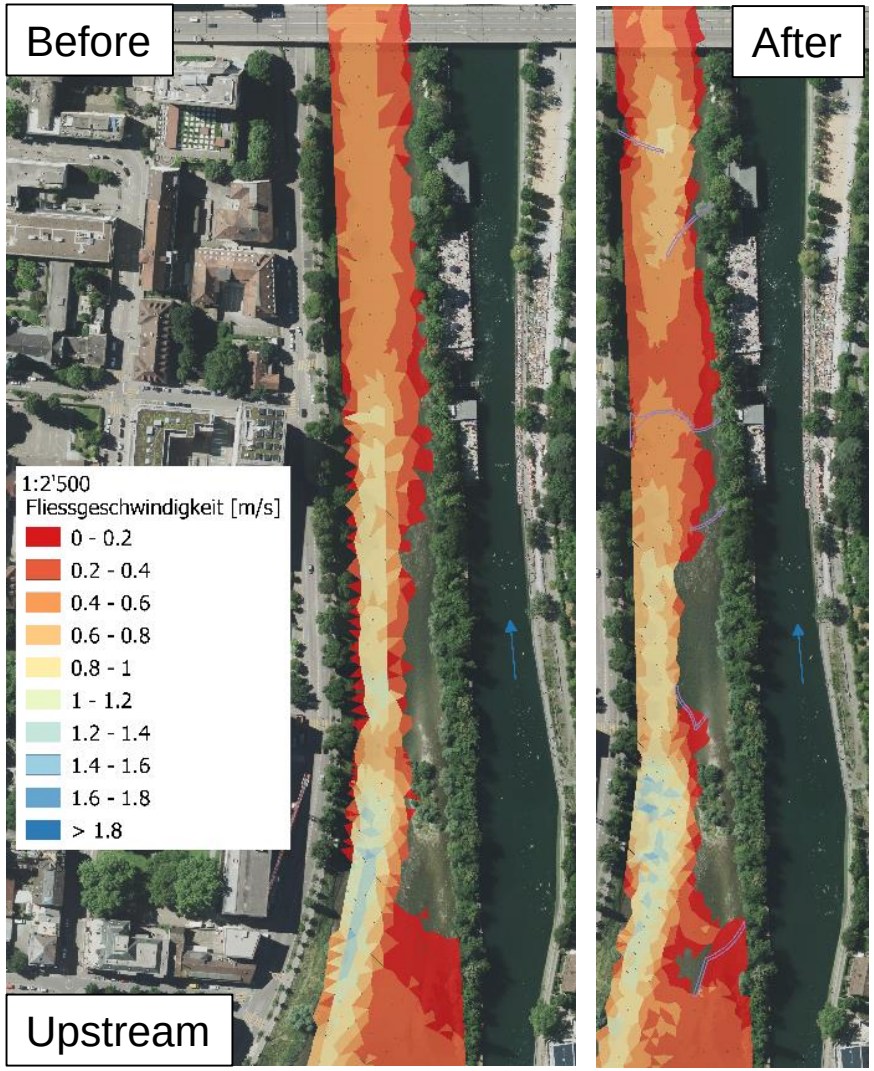
	Q_{Sihl}	$Q_{Platzspitzwehr}$	$Q_{hppLetten}$
Residual water	5.2 m³/s	1.5 m³/s	38.5 m³/s
Flood, HQ_{100}	270 m³/s	330 m³/s	20 m³/s

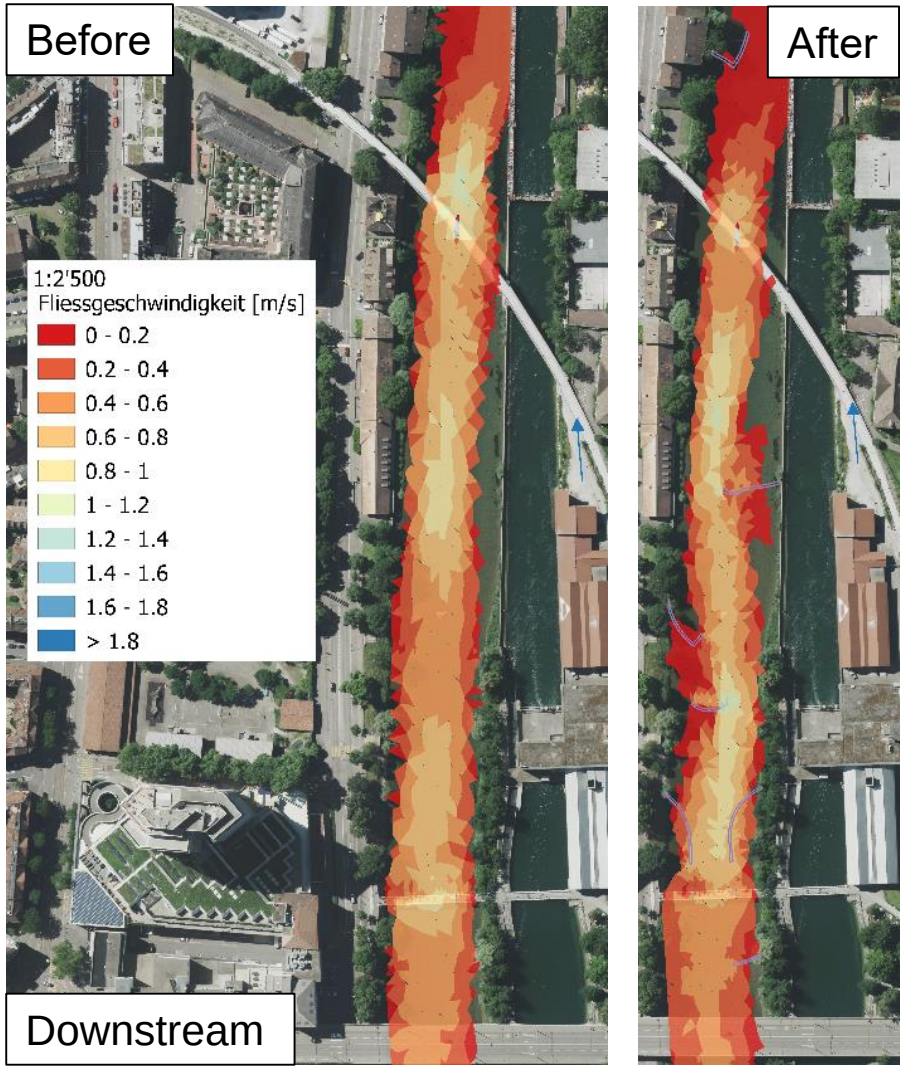
Boundary conditions:

- Inflow Sihl — Discharge file (t-Q)
- Inflow Platzspitz — Discharge file (t-Q)
- Inflow Letten — Discharge file (t-Q)
- Outflow Unterhard — H-Q relation

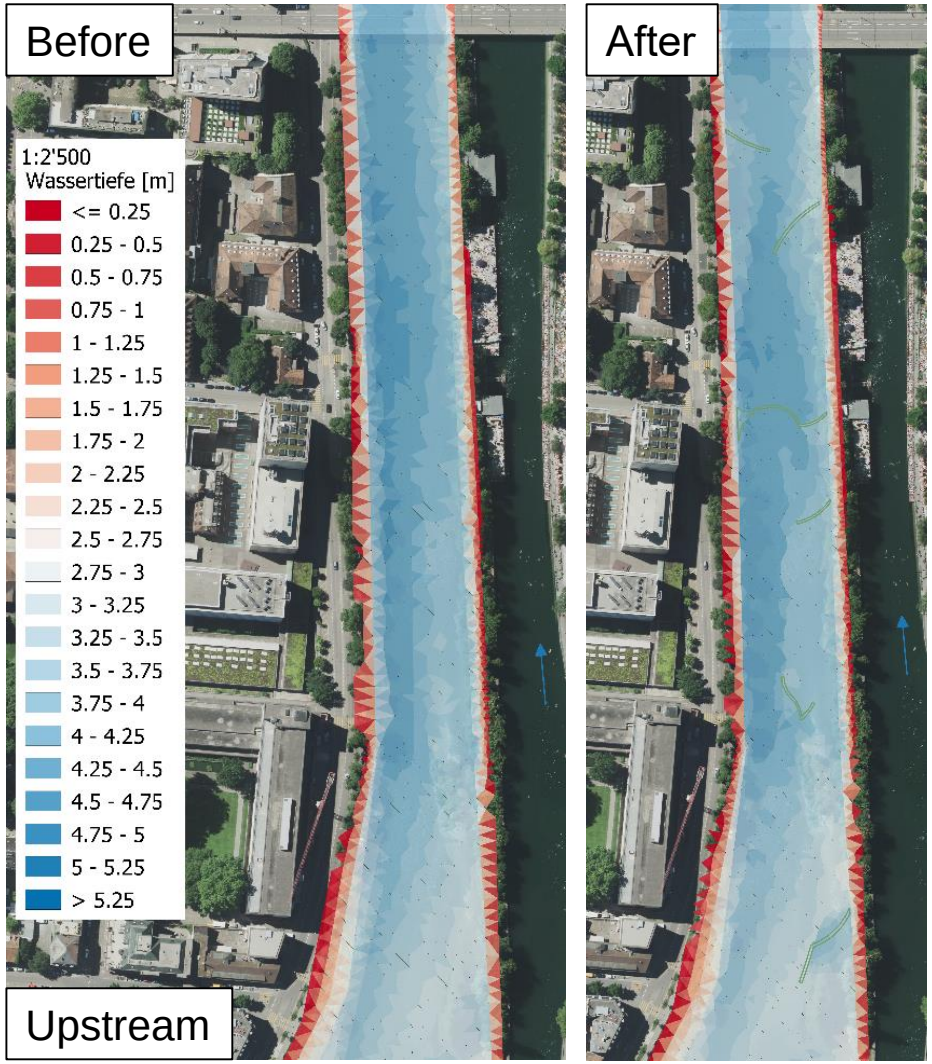
– Data:
  - Hydrological station: Zürich, Unterhard (outflow boundary)
  - Inflow from Sihl and lake of Zürich (hpp Letten & weir Platzspitz)

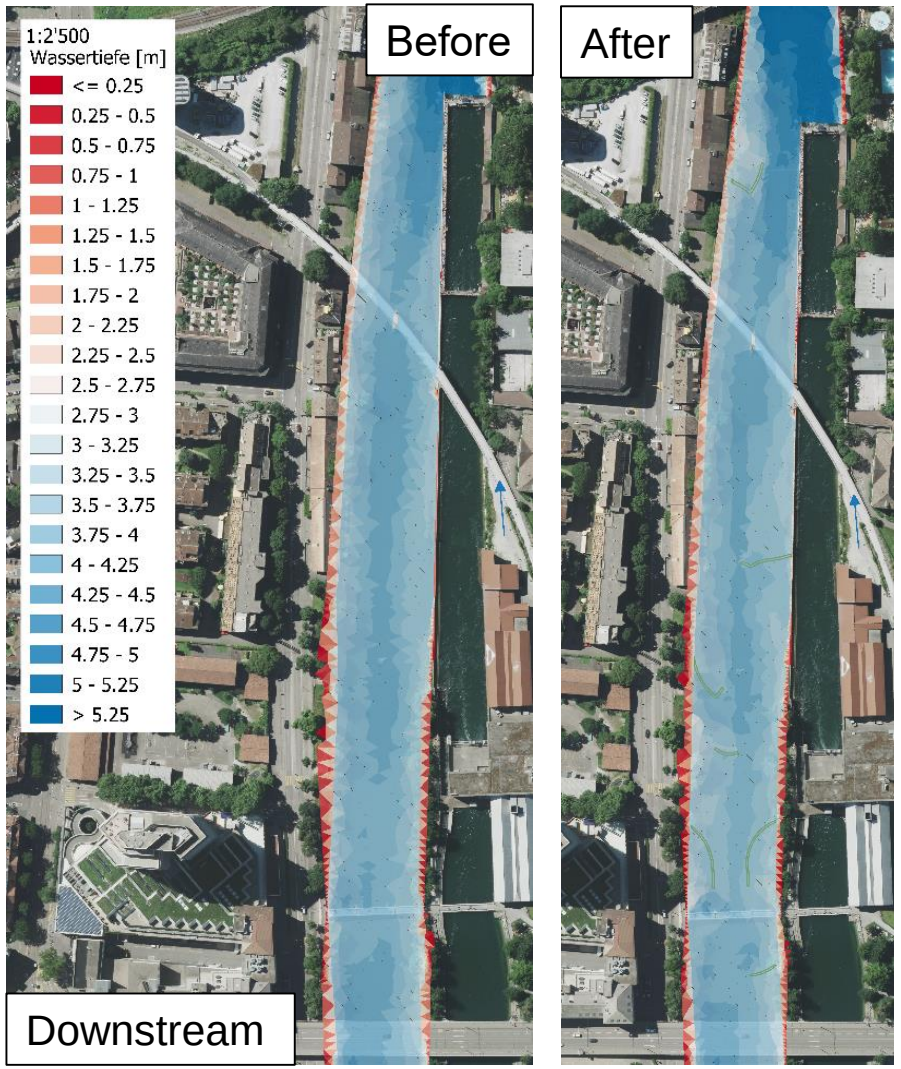
Flow-structure interaction: residual water





Flow-structure interaction: Flood event

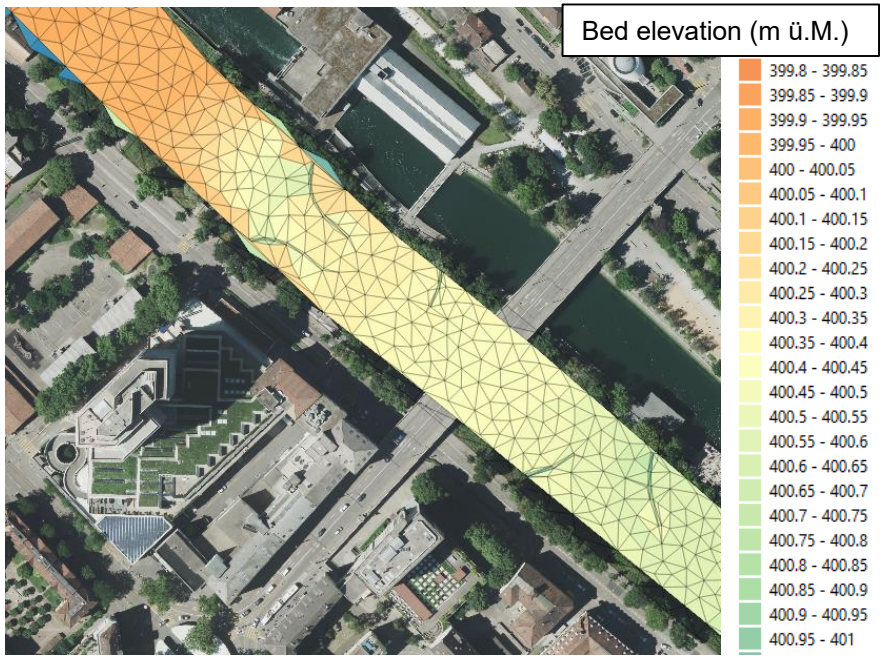




Flow-structure interaction

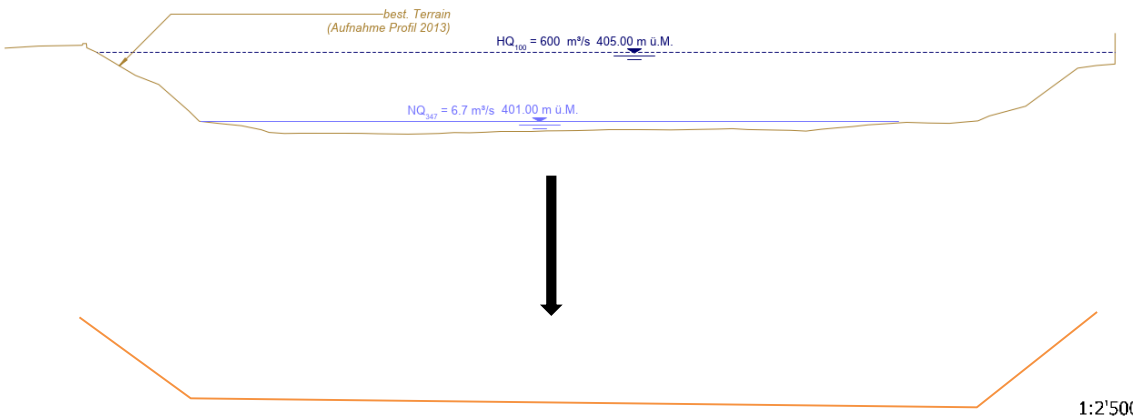
- Goals:
  1) Impact of the instream structures on water level during flood event (HQ_{100})
  2) Influence of the micro groins on the flow path by low flow
  3) Visualisation of their effect on flow diversity and turbulence

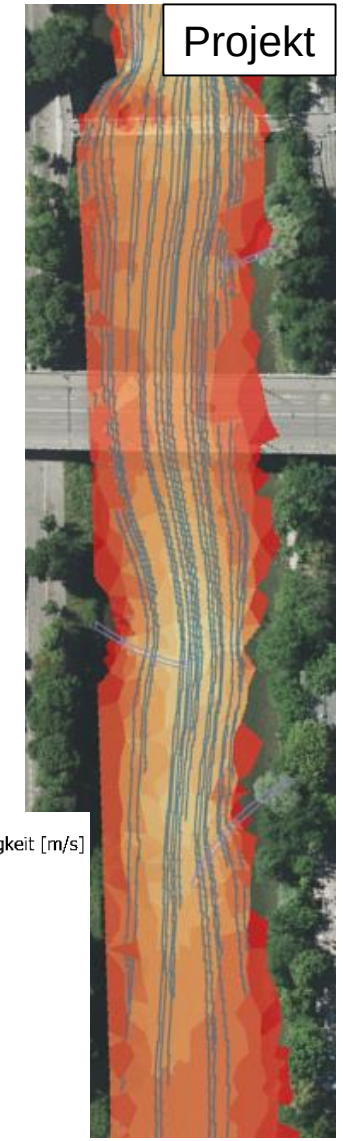
- Test and optimization:
  - Small reach with "ideal" bed elevation
  - Use of passive tracer for flow visualisation
  - Software: BASEMENT v3.1, BASEmesh v1.4.5

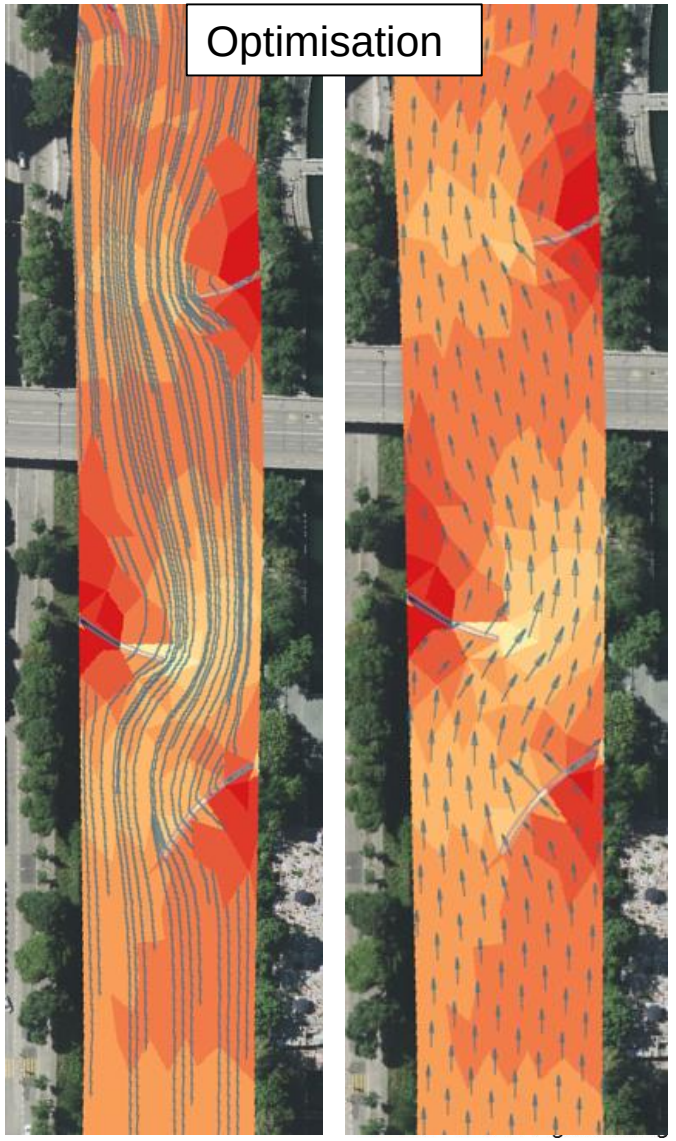


Optimisation and tracer

– Streamlines v
  > 0.3 m/s







Optimisation and tracer

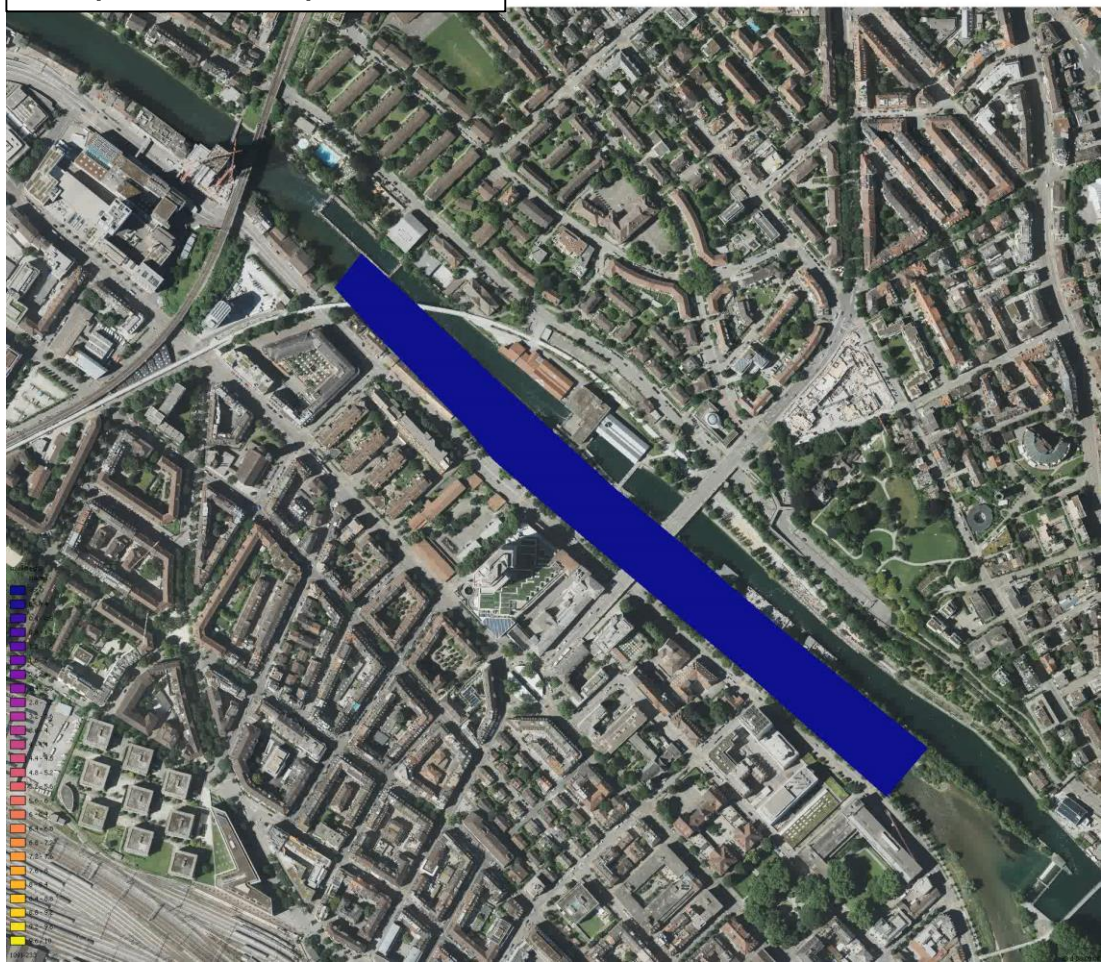
- Tracer:
  - "type": "region_defined"
  - "num_tracers": 1,
  - "tracer_density": [1000.0],
  - "tracer_diffusivity": [0.0025]

- "data1_file"

…
1900.00 0.00
2000.00 0.10
2040.00 0.10
2060.00 0.00
…

- Constant discharge: 6.7 m^3/s

Output timestep = 10 s



Conclusion

- 2D Simulation of micro groynes with BASEMENT v3
  + Ideal for a first design
  + Interpolation method
  + The use of tracer
  - Laborious process to obtain a reasonably good mesh (small structures)

- Next steps
  - Turbulence
  - BASEmesh v2

Thank you!