International Conference on Engineering and Ecohydrology for Fish Passage

International Conference on River Connectivity (Fish Passage 2018)

Dec 13th, 1:30 PM - 3:10 PM

Hydraulic Approach for Dimensioning Fish Way Attraction Flow

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Bundesanstalt für Gewässerkunde

BAW Bundesanstalt für Wasserbau

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Hydraulic Approach for Dimensioning Fish Way Attraction Flow

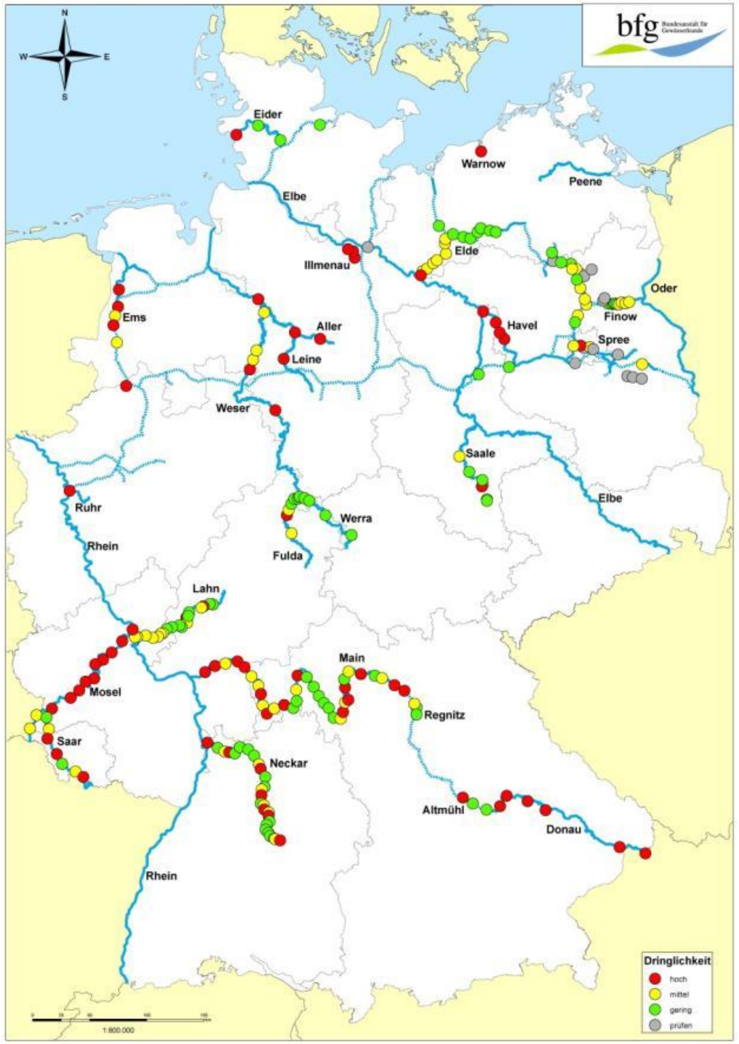
Fish Passage 2018

Albury, December 13th

BAW 2015

Situation

- German Federal waterways
  - Extensive use for navigation and hydropower
  - Approx. 250 barrages mostly on large rivers
  - Estimated financial effort 1 billion €
- Role of our institutes
  - Consulting German Ministry of Transportation
  - R&D for Consulting Waterways and Shipping Administration in establishing ecological connectivity (for fish) on Federal Waterways
- R&D framework
  - Fundamentals
  - Fish way attraction
  - Passage
  - Downstream migration



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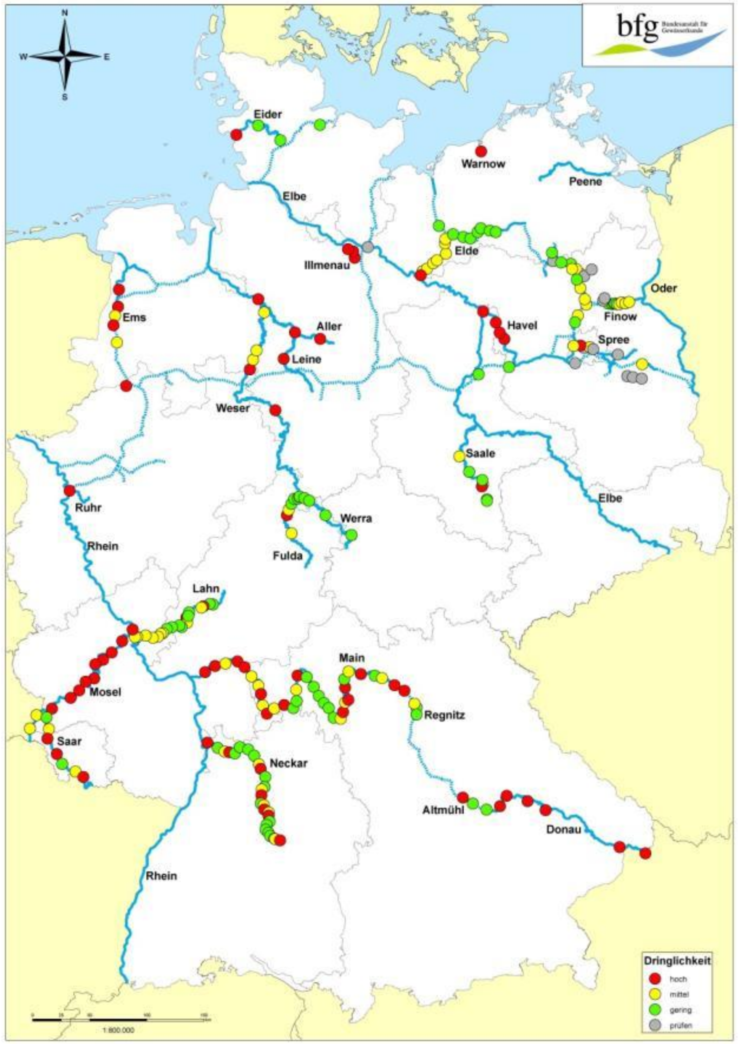
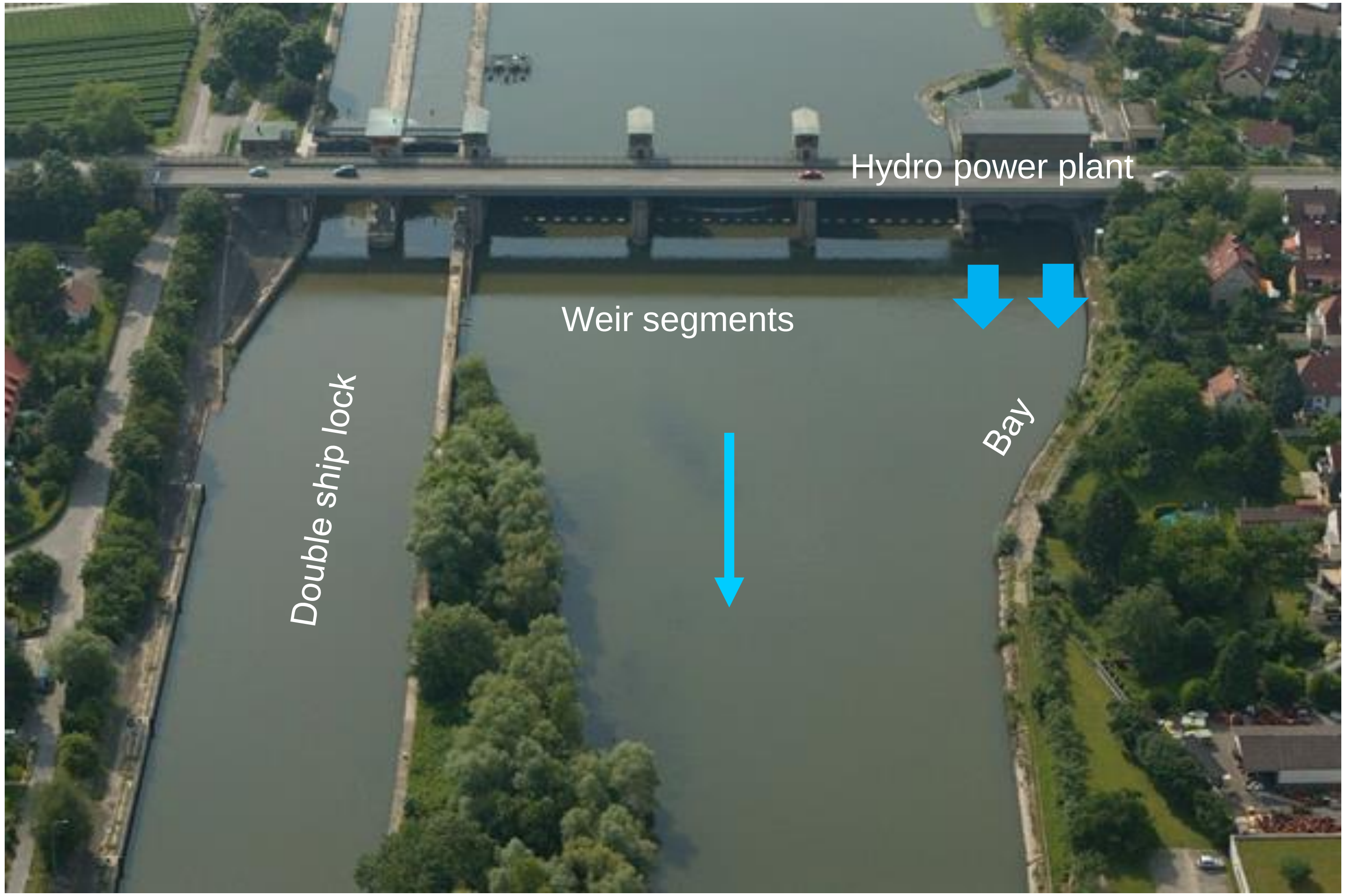


Attraction Flow Overview



Attraction Flow Overview

- **Postulate**
  - Upstream migrating fish are attracted to flow
- **Main entrance location**
  - Near the main flow
  - Near the obstacle
  - On the bank (other locations not considered here)
- **Biological demands**
  - Indicate fishway entrance
  - Steady (calm) flow
  - Maximum flow velocity according to fish performance
  - Maximum downstream propagation

(Auxiliary discharge may be needed)

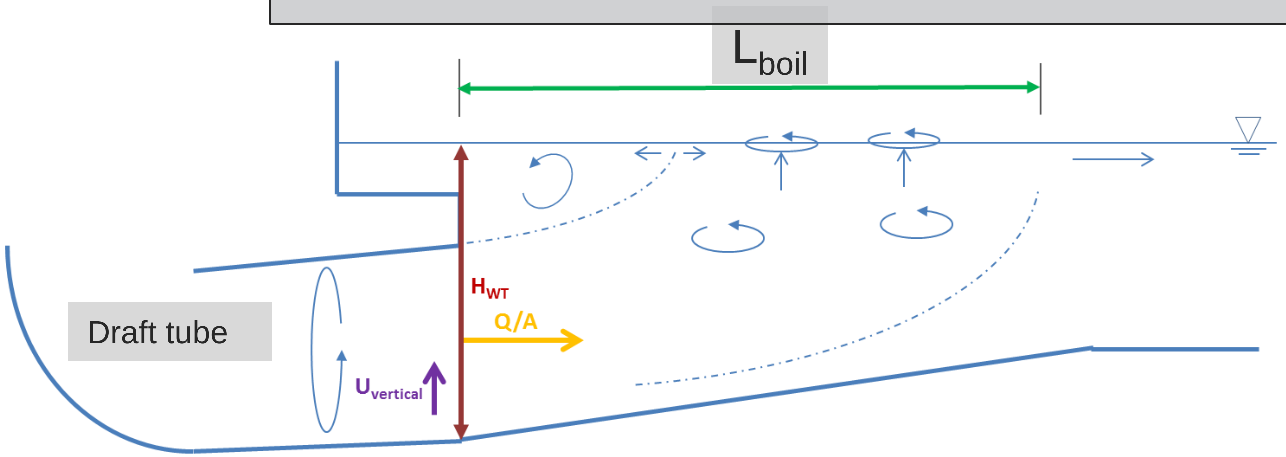
Attraction Flow Overview

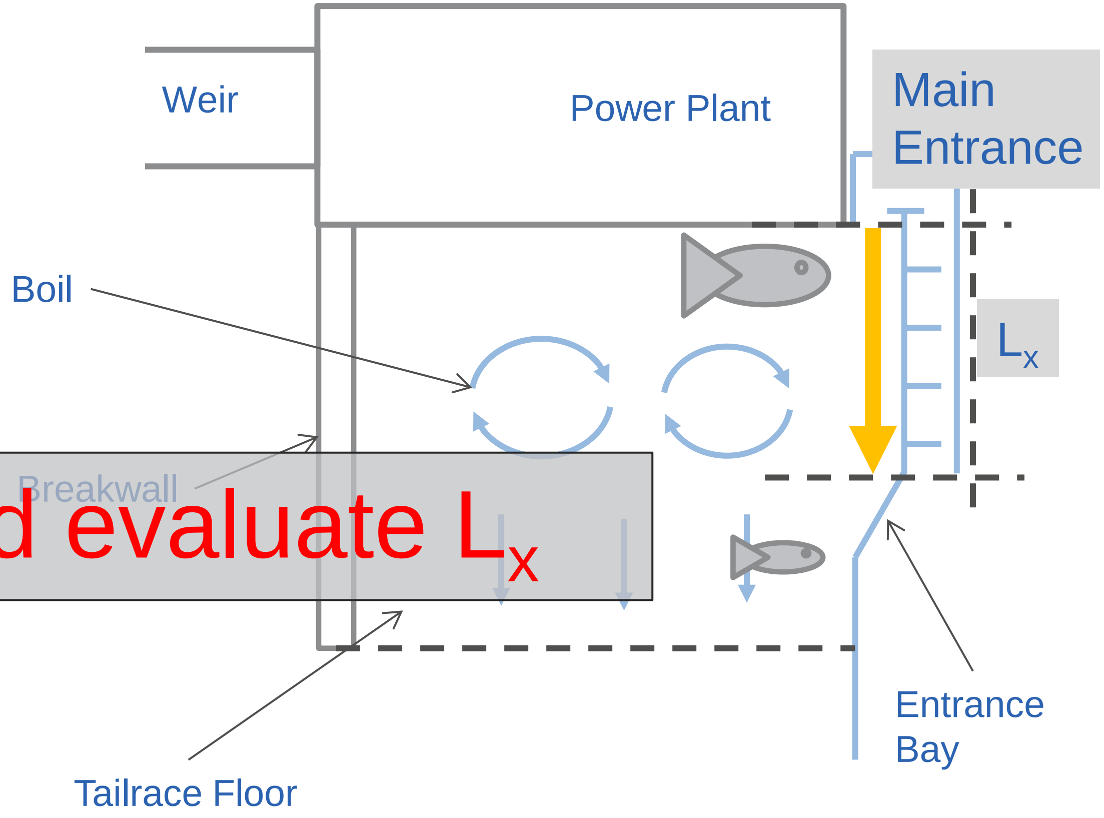
- Hydraulic challenges
  - Highly turbulent flow in the tailrace
  - Temporarily unsteady boundary conditions (e.g. water levels, turbine and weir management)
  - Varying site specific boundary conditions (e.g. tailrace geometry, bank shape, turbine characteristics)
- Constructional challenges
  - Large attraction flow rate requires auxiliary discharge
    - Large/complicated structures
    - Conflict with competing cultural interests (hydropower, water sports, ecology, navigation)
  - Small attraction flow rate leads to
    - Limited function/attraction
- Design attraction flow rate (state of the art)
  - Existing guidelines recommend between 0.5 and 10 % of competing flow
    - No universal definition of 'competing flow'
    - Site specifics other than flow rate are neglected

Attraction Flow Overview

- Biological demands
  - Steady (calm) flow
  - Maximum downstream propagation L_x
- Required L_x is considered e.g. by means of
  - boil propagation L_{boil}
  - Tailrace floor length L_{trf}
  - Site and fish specifics

We need to define and evaluate L_x

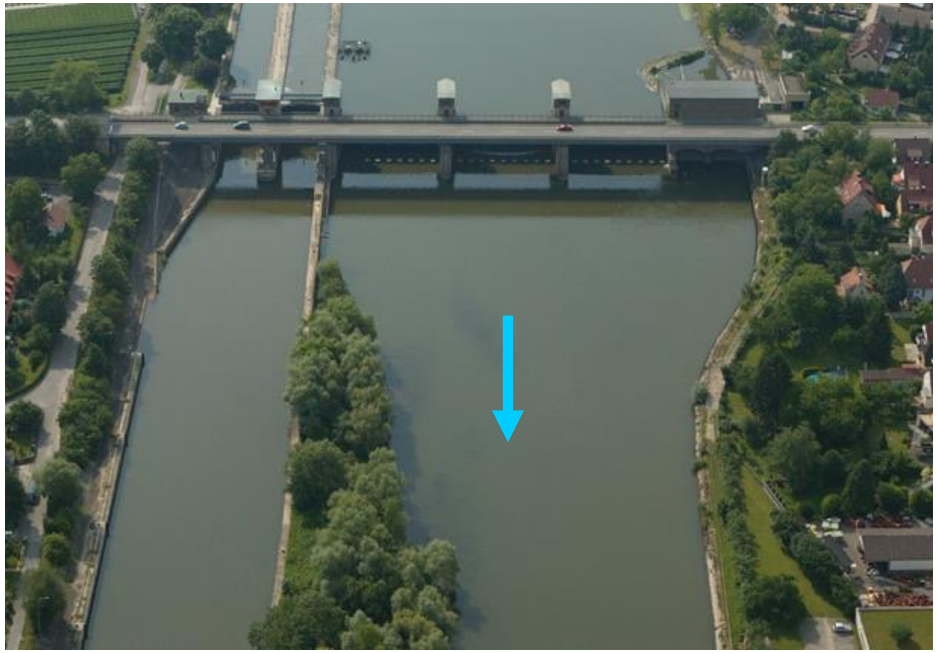




Typical Tailrace at Hydropower site

Flow evaluation

- Site specific modelling
  - Physical scale model
    - Scales 1:5 to 1:10
    - Turbines approximated by stationary blades
    - Calibriation by means of ADCP measurements
    - Velocity measurement in model (ADV, LDA)



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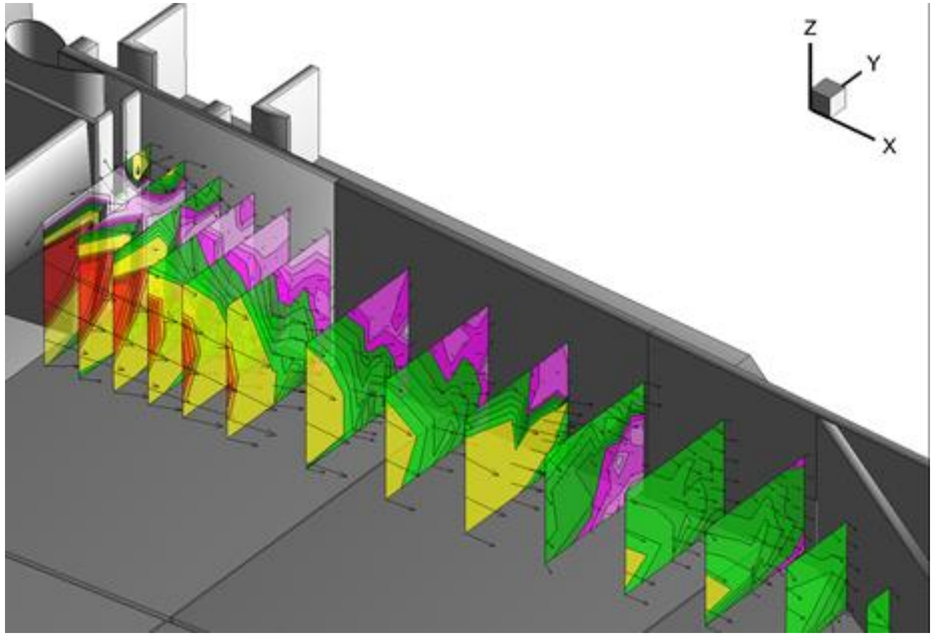
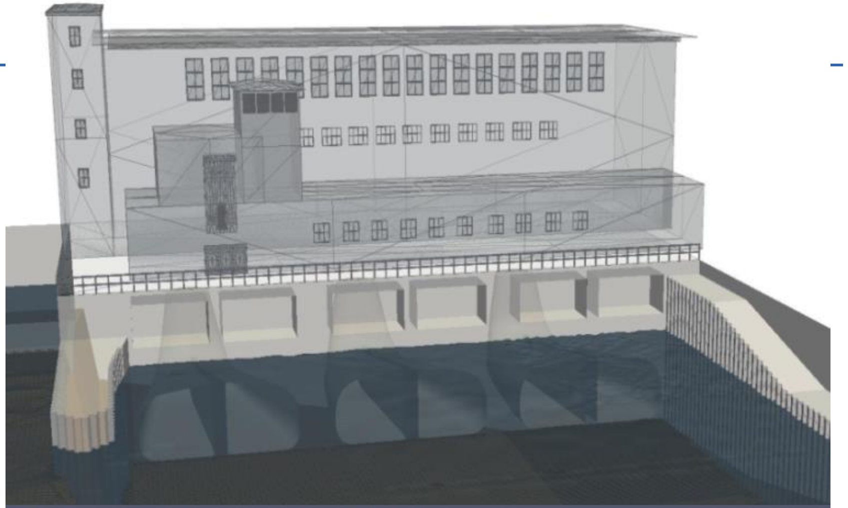
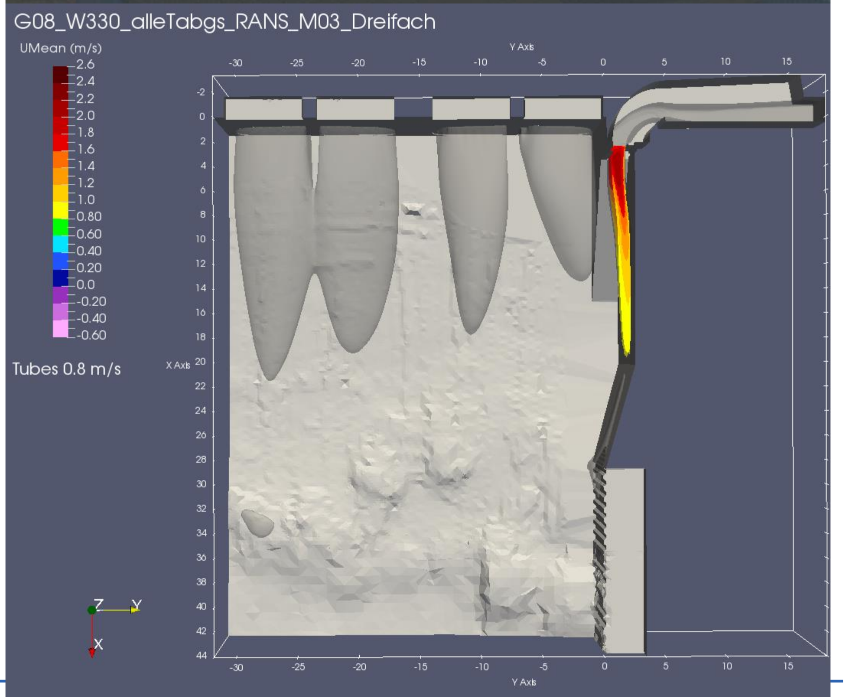


Flow evaluation

- Site specific modelling
  - Physical scale model
    - Scales 1:5 to 1:10
    - Turbines approximated by stationary blades
    - Calibriation by means of ADCP measurements
    - Velocity measurement in model (ADV, LDA)
  - CFD
    - 3D models uRANS or DES/LES
    - Grid resolution 0.01 m to 2.0 m
    - Turbines approximated
    - Calibriation by means of ADCP measurements
    - Bathymetric data for digital elevation model





Flow evaluation

- Shortcomings of site specific modelling
  - Precise boundary conditions of the prototype are fluctuating and hard to evaluate
  - ADCP not designed for evaluation of unsteady flow (calibration data)
  - True unsteady modelling is not yet feasible
  - Scale effects
  - Very time consuming (and expensive)
  - Not applicable for planning engineers

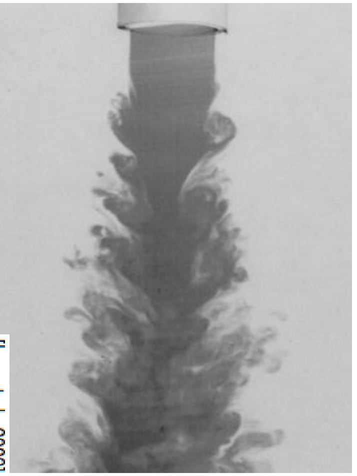
⇒ There is no exact modelling of tailrace flow

⇒ Keep it simple!

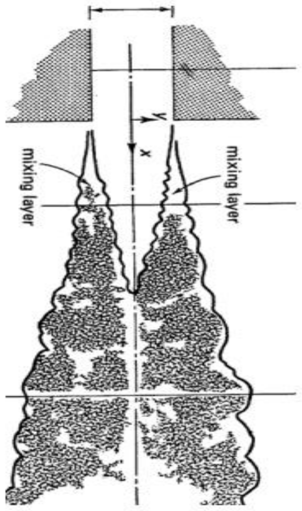
But: we do need sophisticated models to develop new approaches!

New Approach

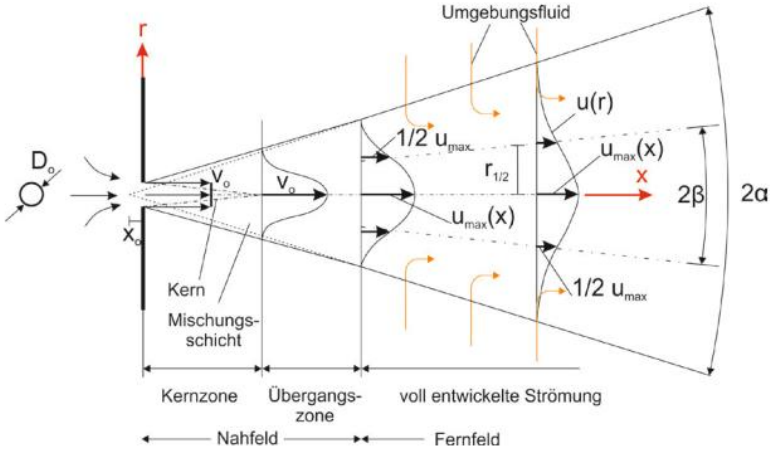
- Demands for new approach
  - Use of available parameters (not just competing flow)
  - Easy application (easier than site specific modelling)
  - Reliable estimation (better than 0.5 to 10 % of competing flow)
- Application of jet theory
  - Lots of research available
  - **But:** References mostly for nozzles



[Lee et al., 2003]



[Tennekes et al., 1972]

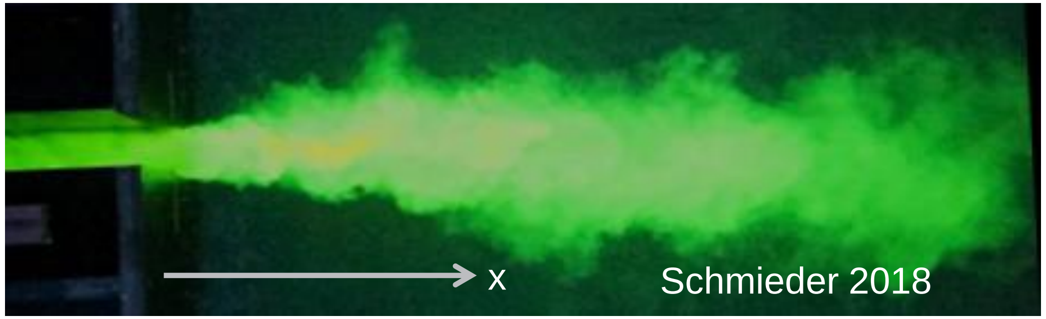


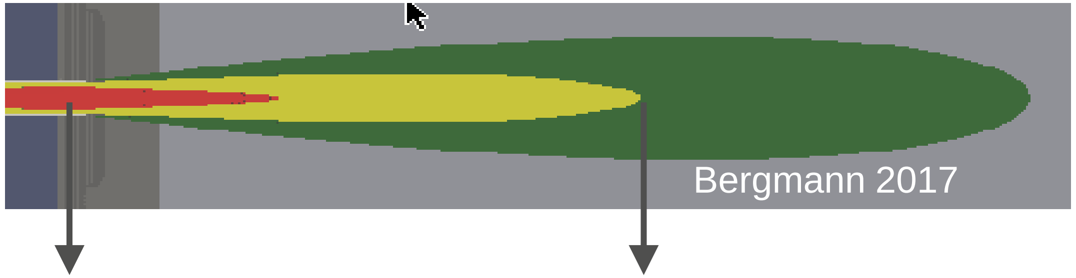
Jet Approach

- Undisturbed rectangular free surface jet
  - Jet theory is applicable
  - Symmetric turbulent diffusion
  - Velocities u(x) decrease with x
- Definition of design velocities u_0, u_{attr}

$$L_{x,undist.}(0.5u_0) = 48\, r_{hy}, \qquad r_{hy} = wh/(w + 2h)$$

- For vertical slots (h > w) L_x can be controlled by slot width b



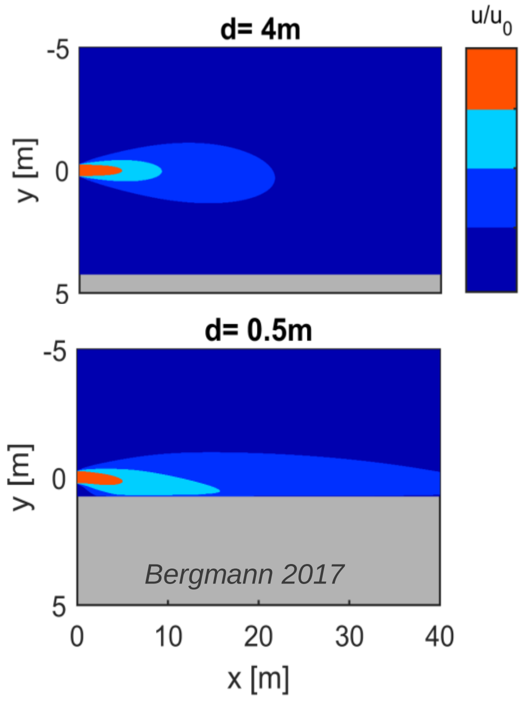


x = 0; u_0

x = L_x; u_{attr}

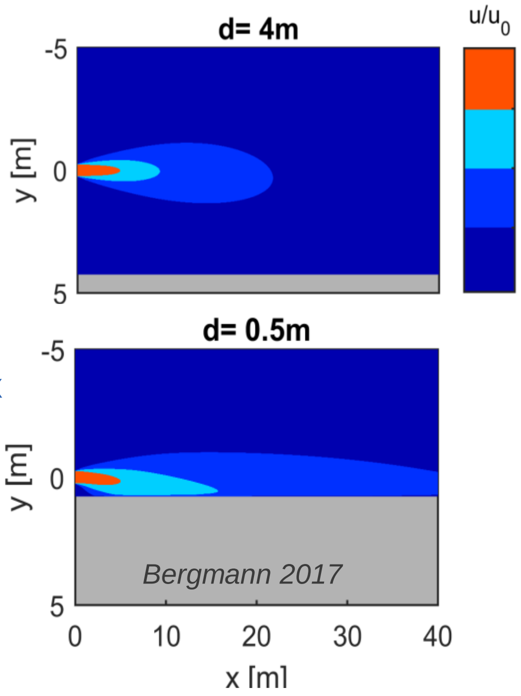
Jet Approach

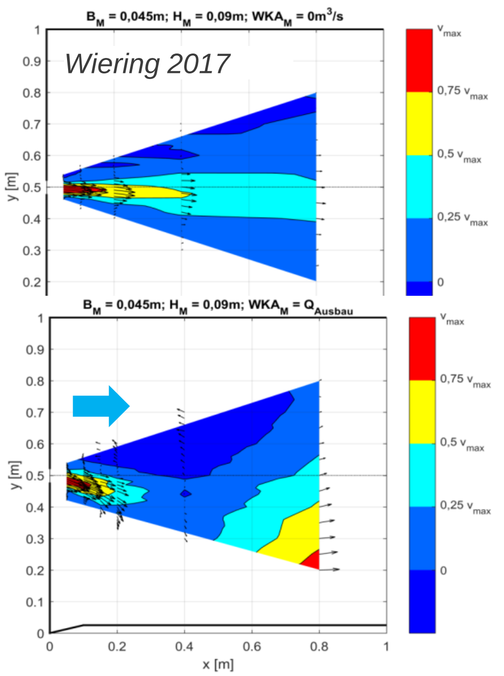
- Jets are normally not undisturbed (i.e. disturbed)
- Wall jet (bank or bed) increases L_x
  - Distance to the bank
  - River bed connection



Jet Approach

- Jets are normally not undisturbed (i.e. disturbed)
- Wall jet (bank or bed) increases L_x
  - Distance to the bank
  - River bed connection
- Competing flow (e.g. power plant outflow) decreases L_x





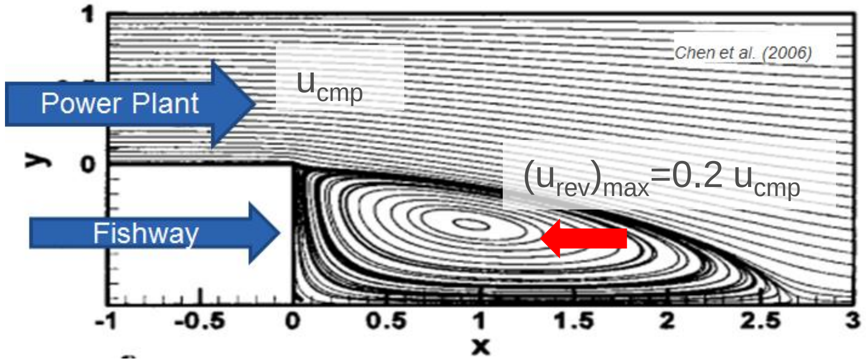
$$L_x = L_{x,undist.}\ C_1\ C_2\ \ldots$$

Use of existing literature and

Calibration via prototype CFD models

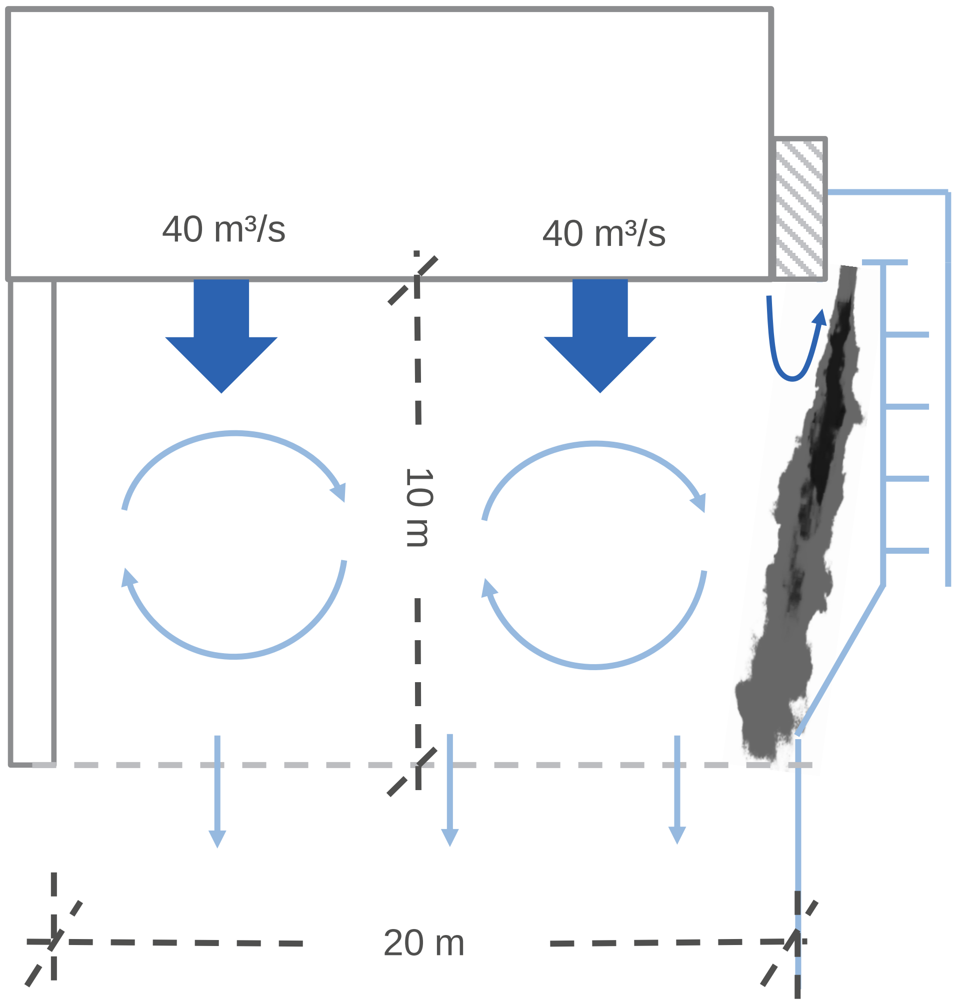
- Further influences on L_x
  - Upstream flow/inlet condition (entrance pool)
  - Slot edges
  - ….

Considered by standardization



Example

- Site specifics
  - **Power Plant**
    - 2 turbines 40 m³/s each
    - Draft tube cross section 3.5 m x 8.5 m
  - **Fishway**
    - u_0 = 1.6 m/s (constant for all water levels)
    - w_{min} = 0.45 m
    - h = 1.2 – 2.2 m
  - **Attraction flow**
    - L_x = 10 m; u_{attr} = 0.8 m/s
    - $L_{x,undist.}$ = 48 r_{hy}; L_x = $L_{x,undist.} C_1 C_2$
    - C_1 (wall jet) = 1.18; C_2 (competing flow) = 0.61
    - Entrance width w = 0.7 m -> auxiliary discharge
    - Q_{attr} = 1.2 m³/s to 2.2 m³/s
    - **-> approx. 5% of adjacent turbine flow**



Conclusions

- Attraction flow is a major criterion for the function of fishways
- Existing guidelines are ambiguous
- Precise modelling of attraction flow is complicated (if at all feasible)
- Objective: Straight forward approach to estimate attraction flow propagation

->Jet approach can be applied for vertical slots

  - Site specifics are considered over a set of coefficients
  - Objective estimation of attraction flow rate
  - Required downstream propagation and core velocity has to be defined (by biologists)
- Outlook
  - Finish development of C1, C2
  - Standardization in progress
  - Peer Review

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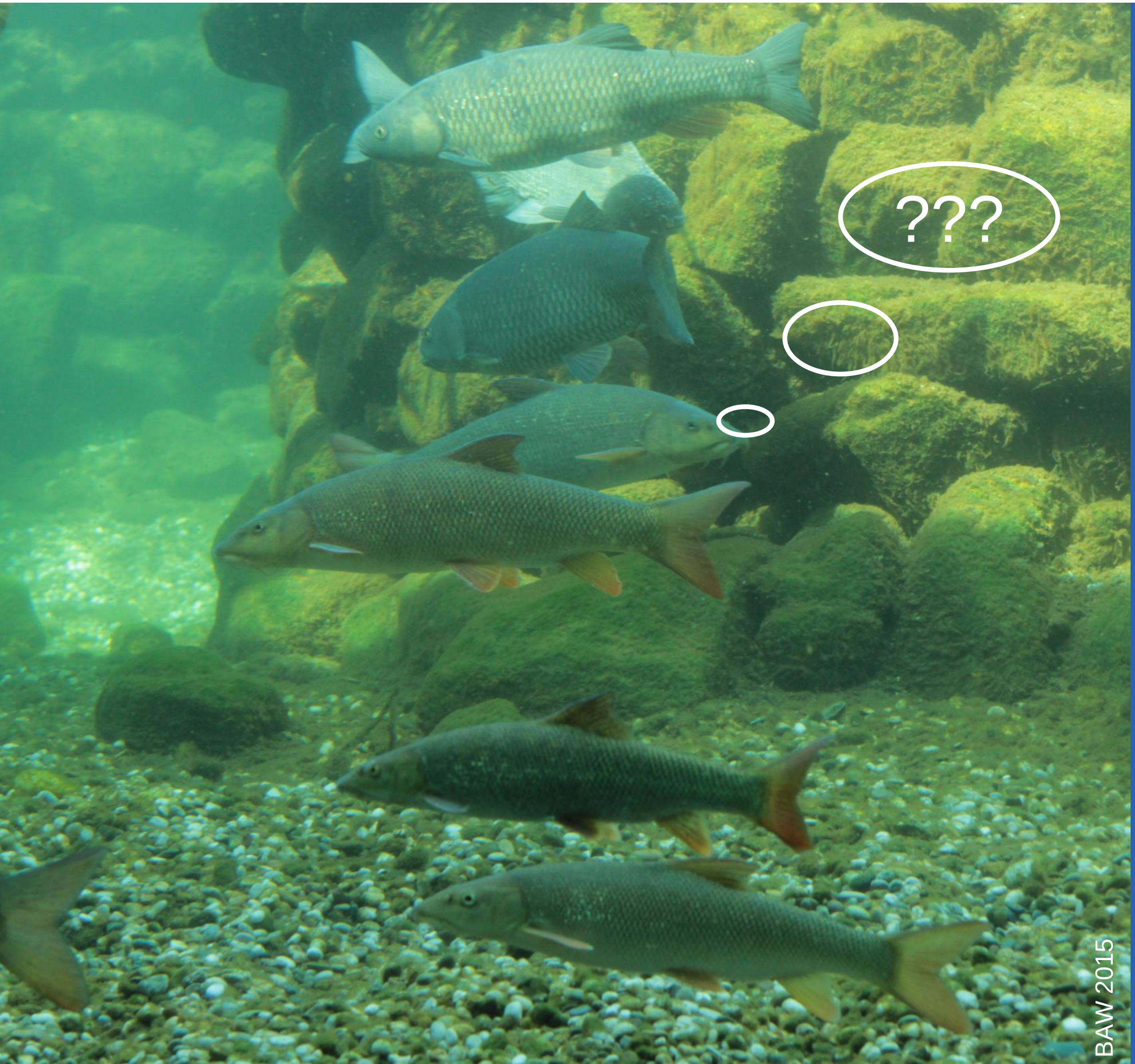

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Many thanks to:

Lena Mahl, Markus Zinkhahn, Linda Bergmann, Veronica Wiering, Henrik Schmieder

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