Civil Engineering and Hydraulic Structures Applications of CAESES

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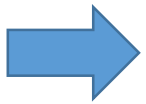
Hydraulic structures

„one step behind“ in CFD and optimization
- very conservative compared to mechanical / aero / ship engineering
- conservative – emphasize the safety

- every project is usually unique
- scale-up option limited

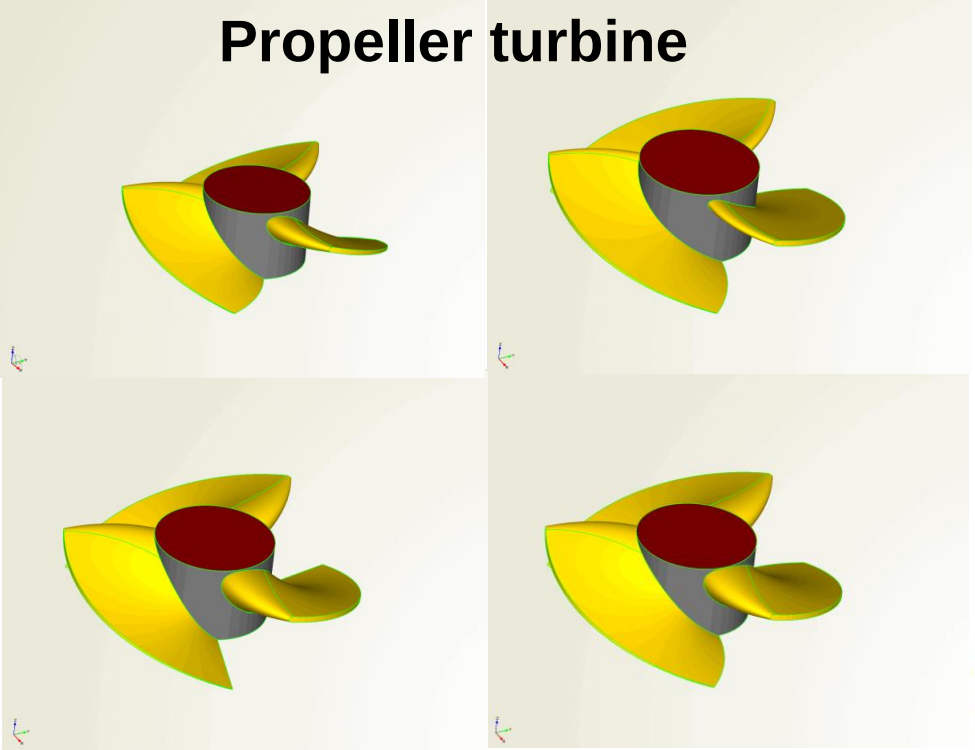
- somewhere in between the civil and mechanical engineering

Optimization goals
→ Energy efficiency - profit / savings
→ Enhanced safety
→ Enabling the construction

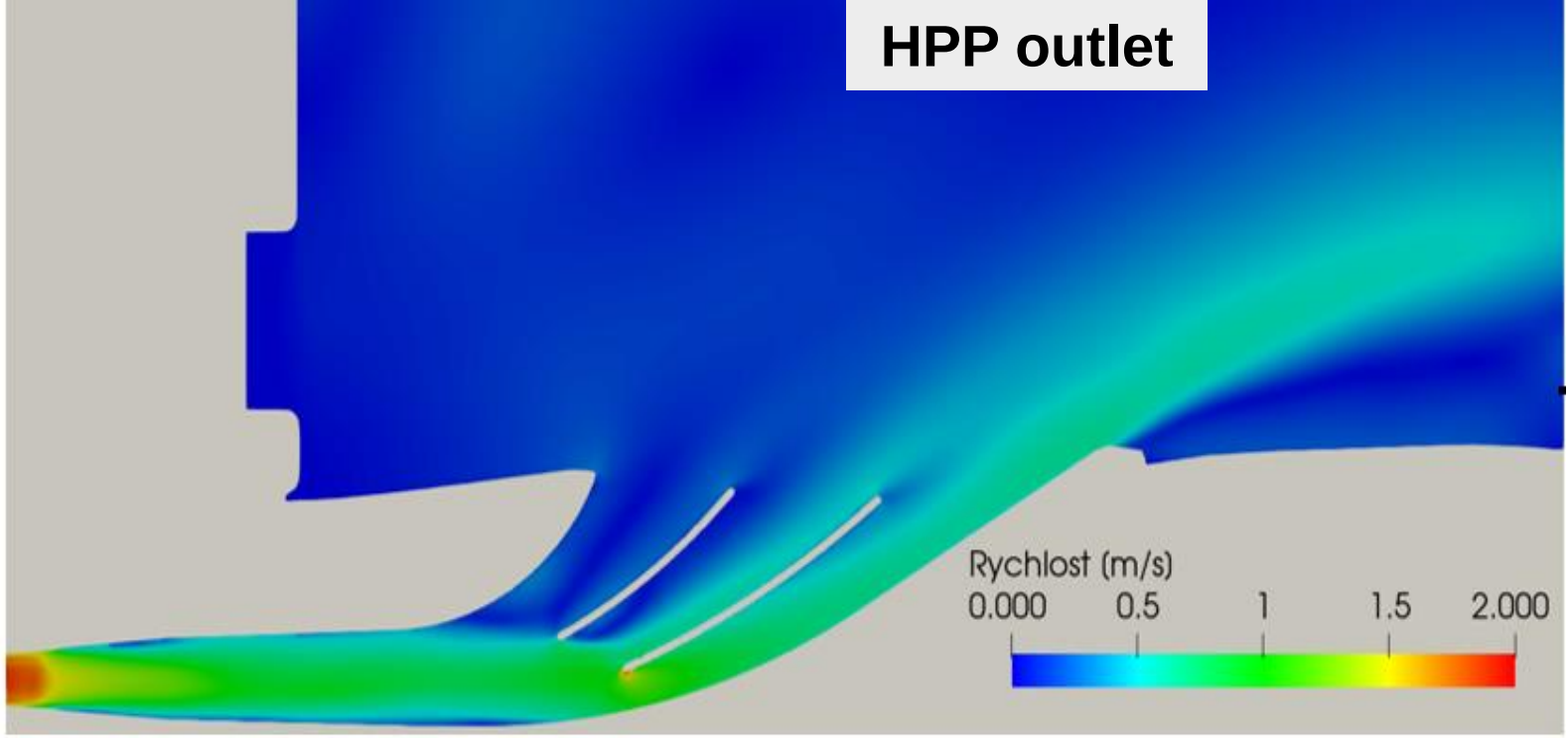


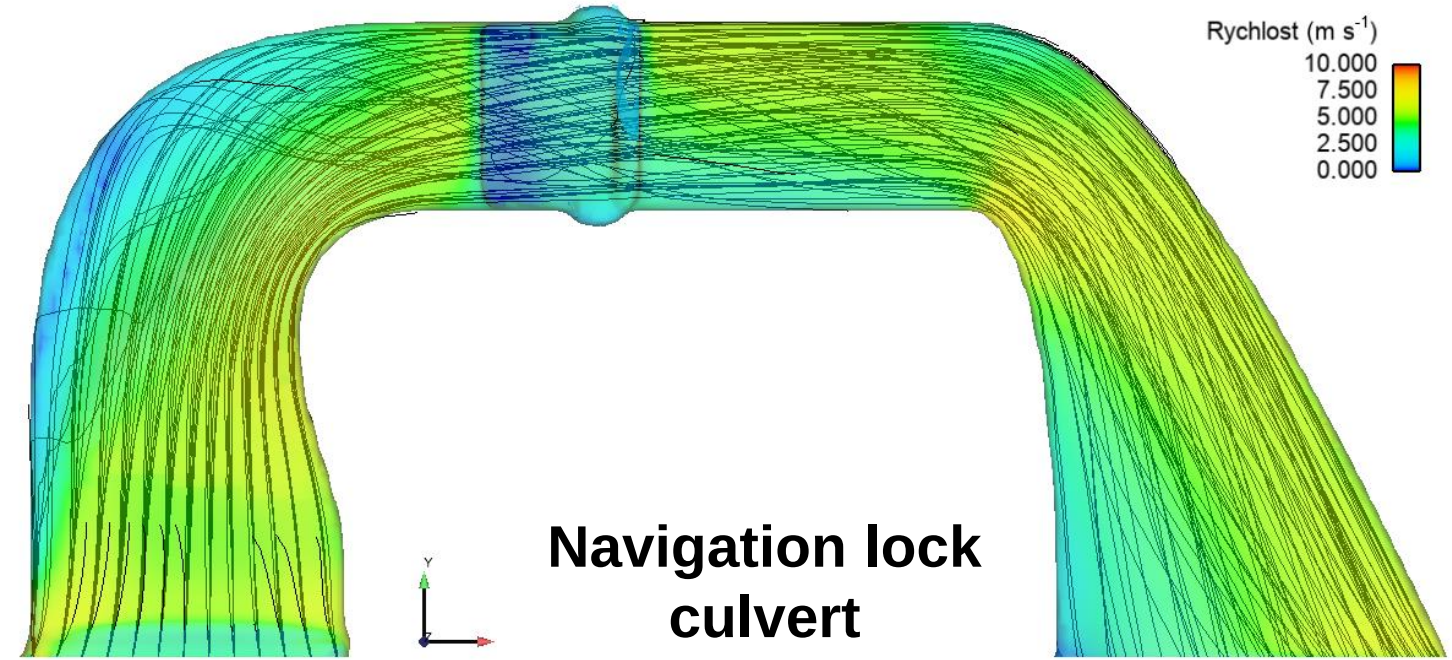
Let‘s give it a try

Propeller turbine

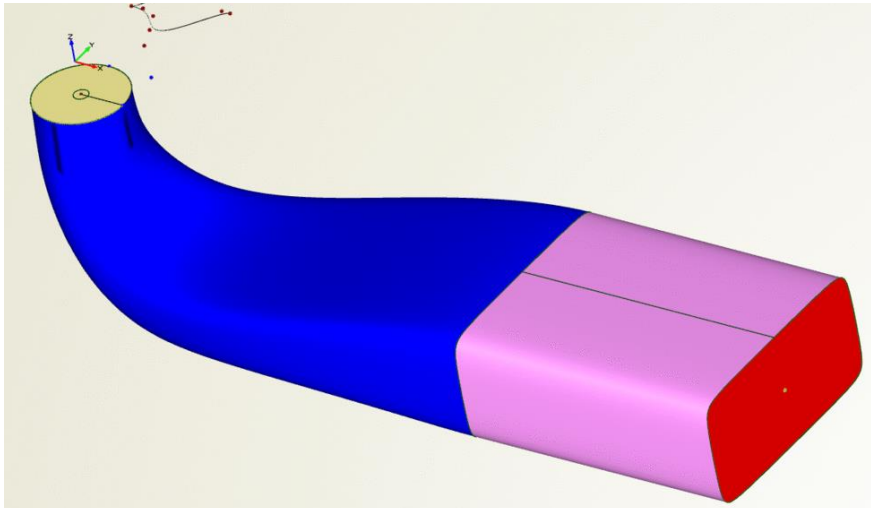


HPP outlet





Navigation lock culvert



Elbow draft tube

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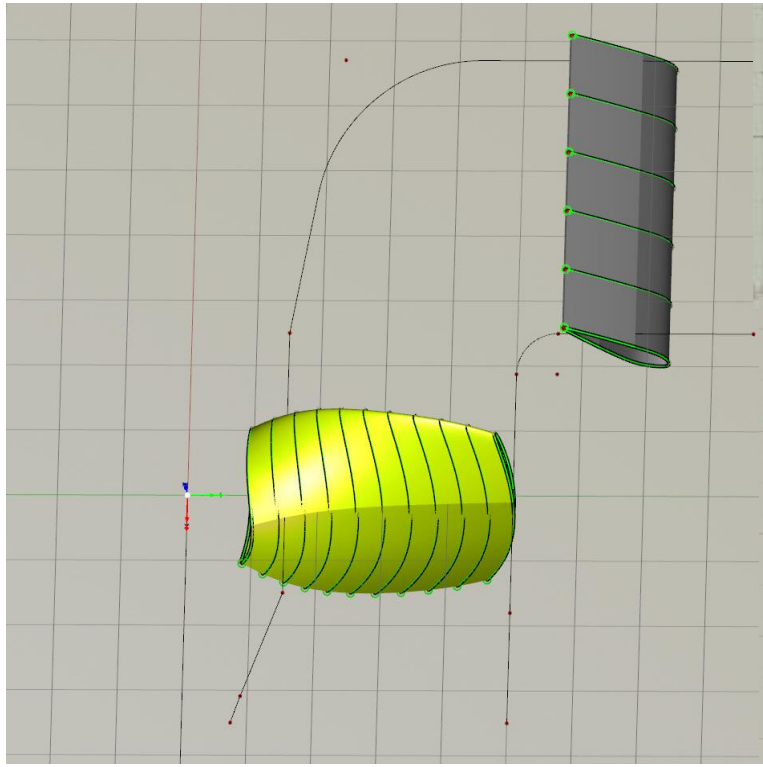
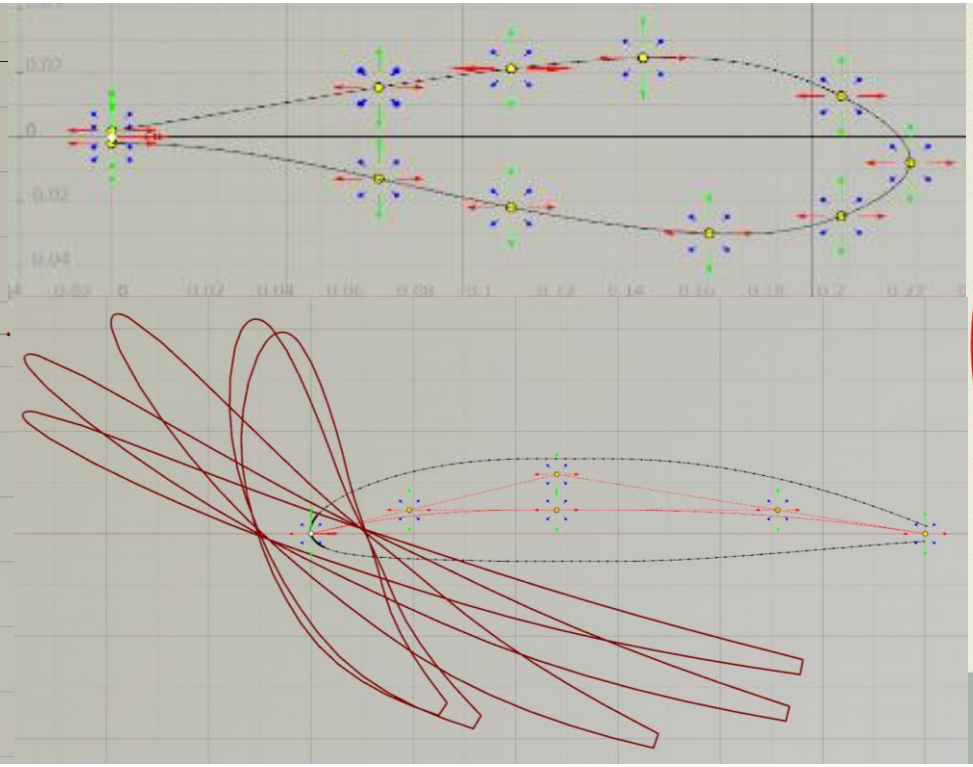
CAESES User Conference
Sep 21 - 22, 2022

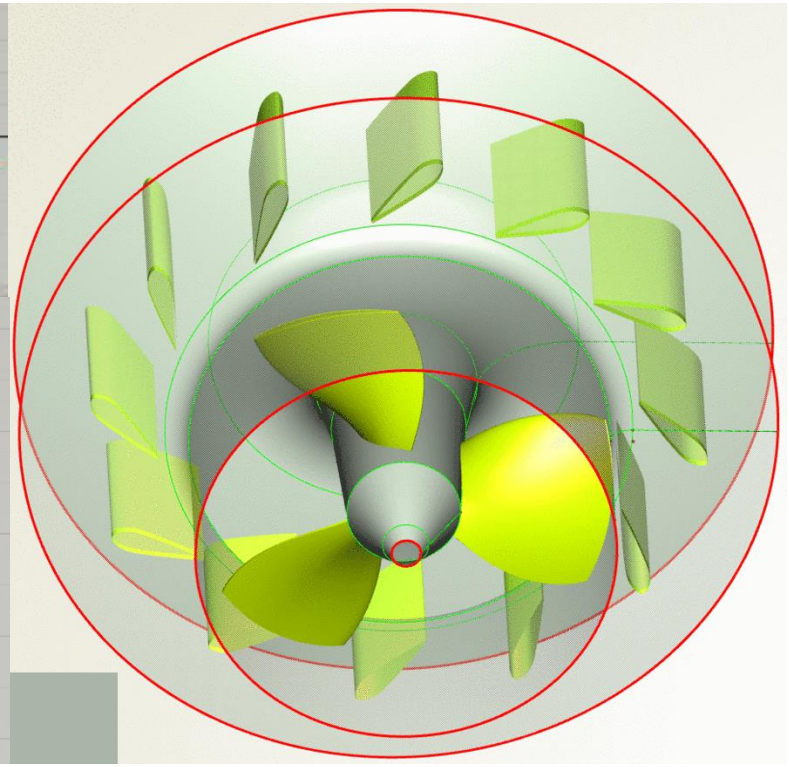
Variable speed propeller turbine

optimization presented on CAESES Users conference in 2019

UJEP







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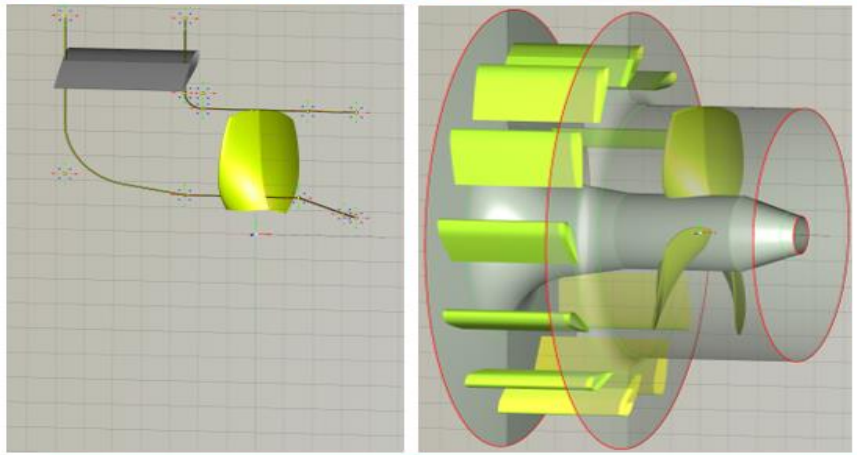
PARAMETRIC MODELS OF GEOMETRY



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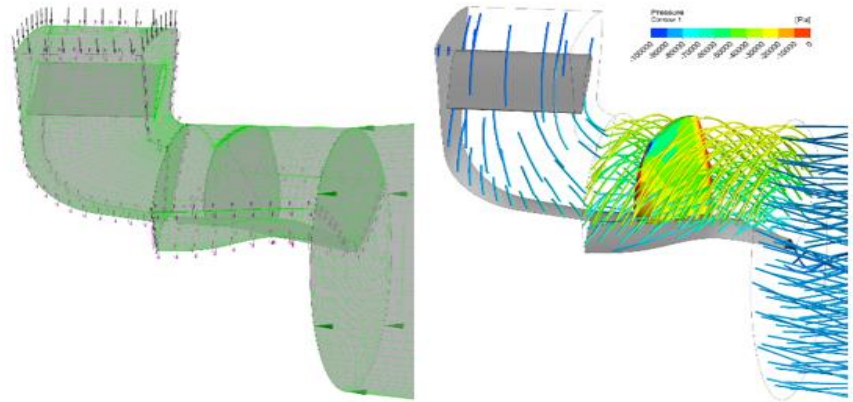
FLUID FLOW ANALYSIS

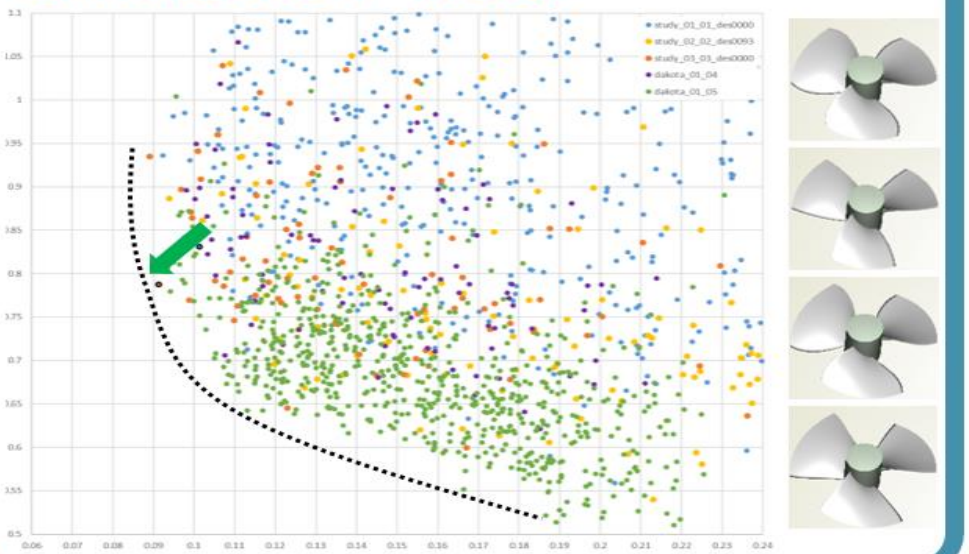


SW CONNECTION

DAKOTA

Explore and predict with confidence.

OPTIMIZATION - MOGA



SENSITIVE ANALYSIS

Variable speed propeller turbine

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simple mechanical construction

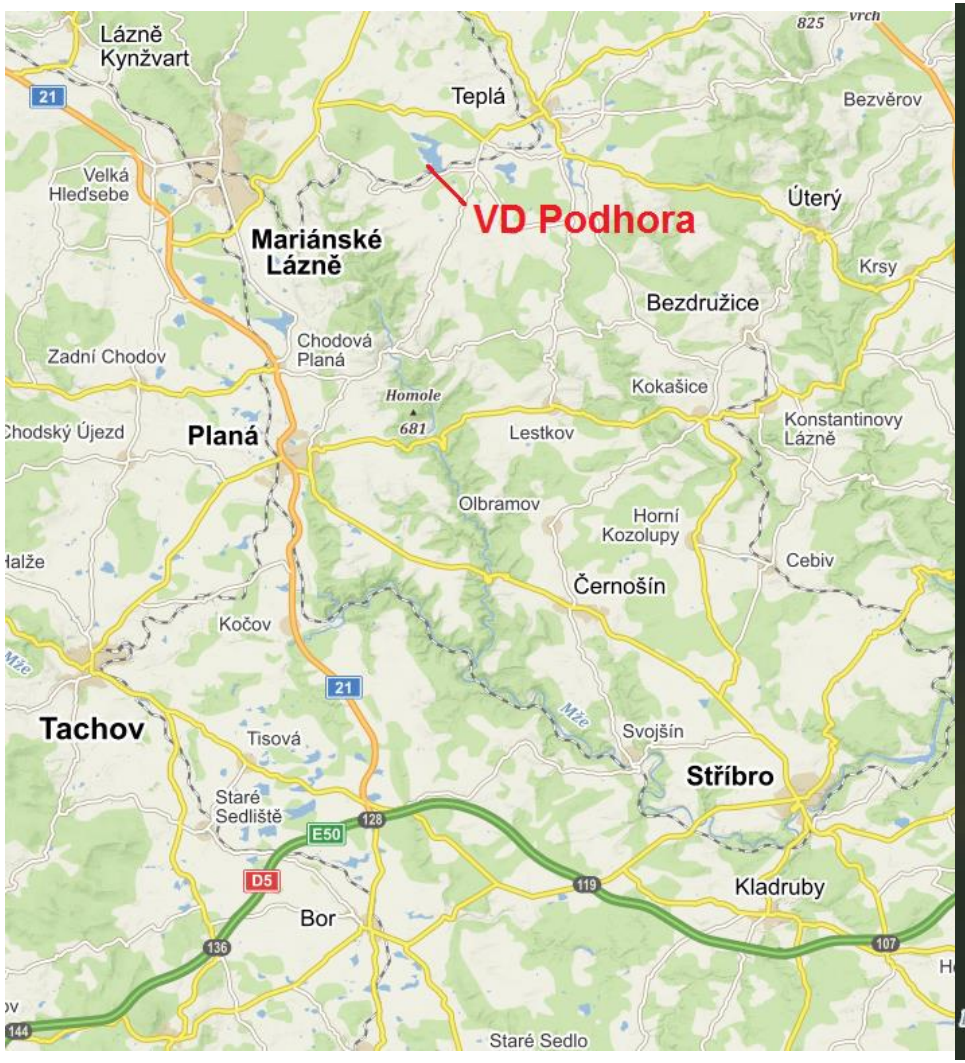
- no adjusting mechanism of runner blades
- simple hydraulic profile – cylindrical runner chamber
- lowering investment and operational costs

double regulated turbine – guide vanes + operation speed

- wide regulation range with respect to flow and head
- soft starting and stopping
- high cavitation resistance

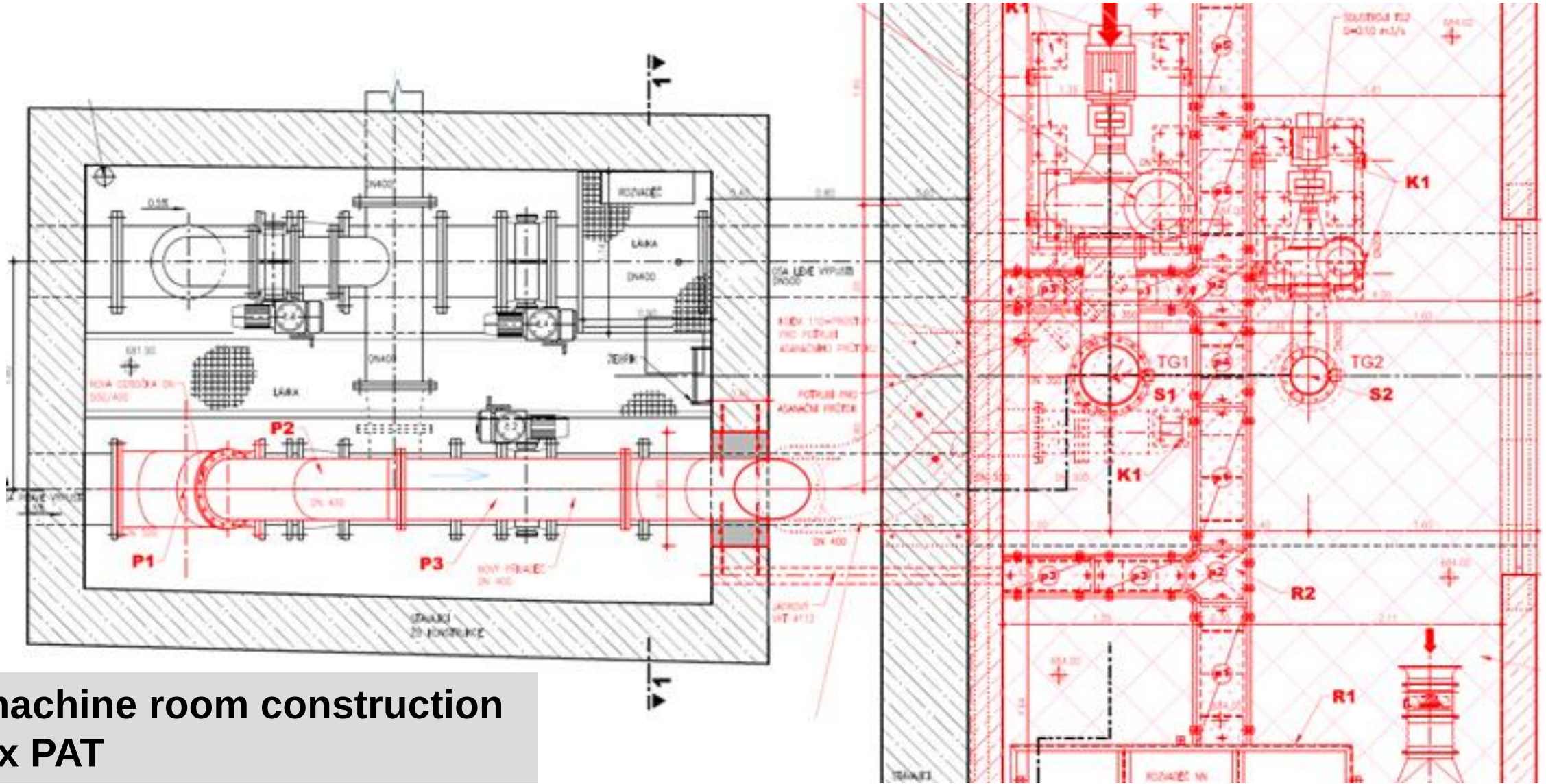
This research was supported by the Czech Technological Agency as a part of the project TH04010140 „Inovative design of compact Kaplan micro-trubine“, 2019 – 2021.

Inovative design of SHPP – „tailor-made“ solution



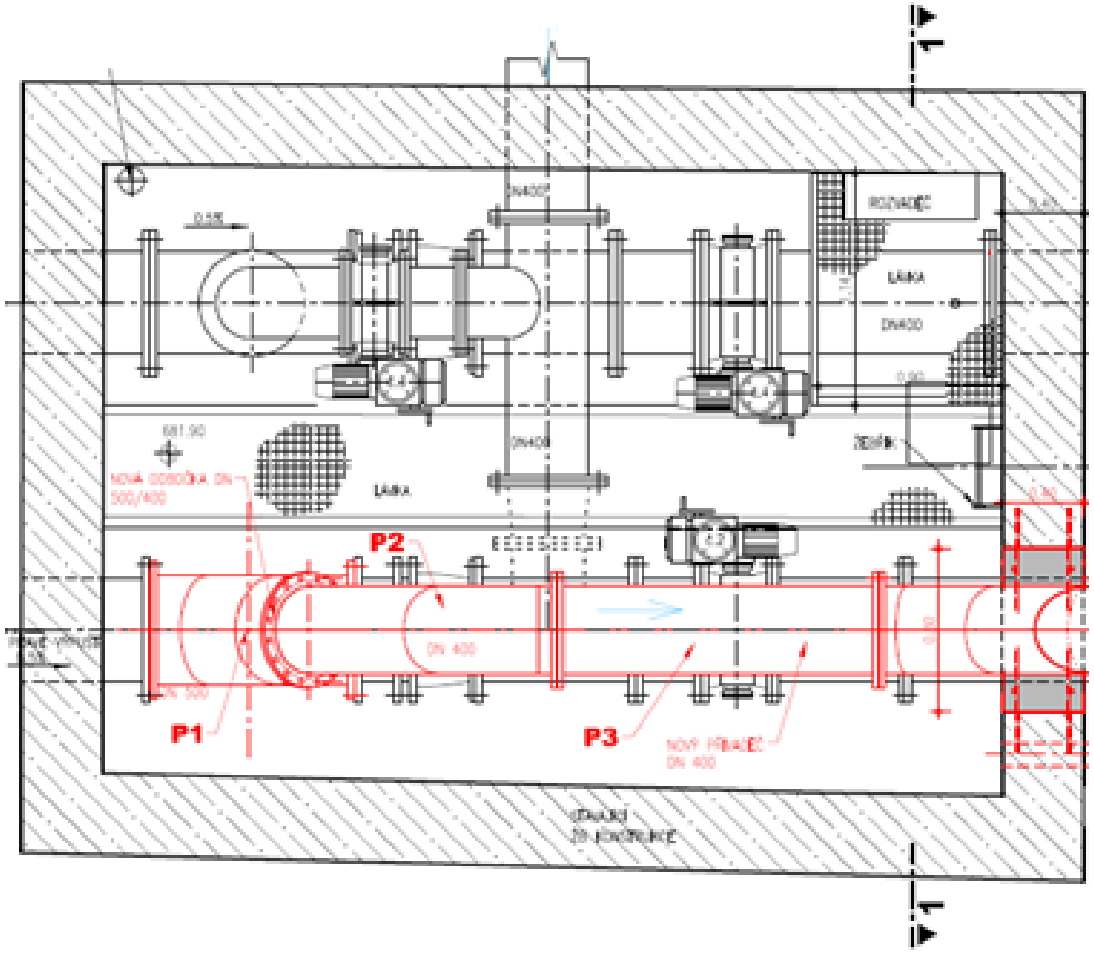
Prototype - HPP for highly restricted sites

Conventional design of SHPP



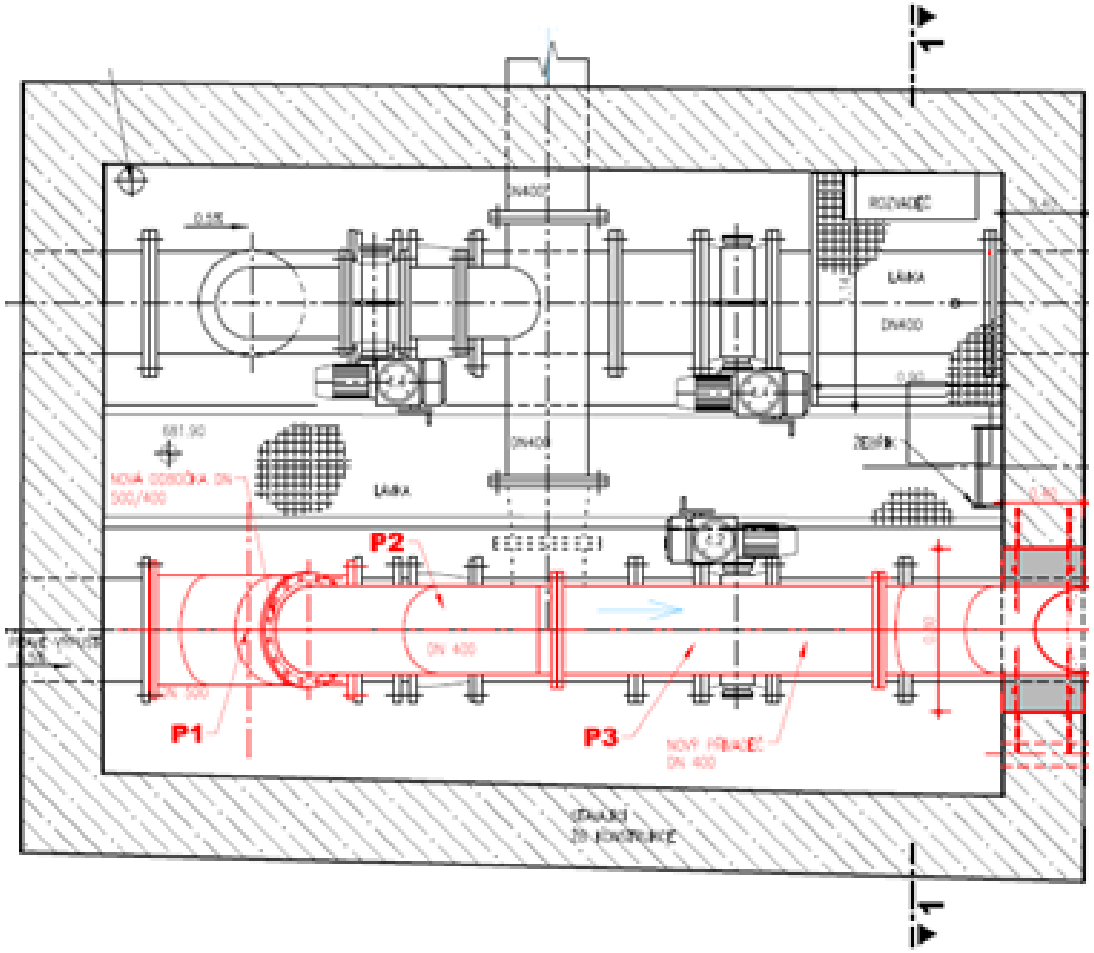
machine room construction
2x PAT

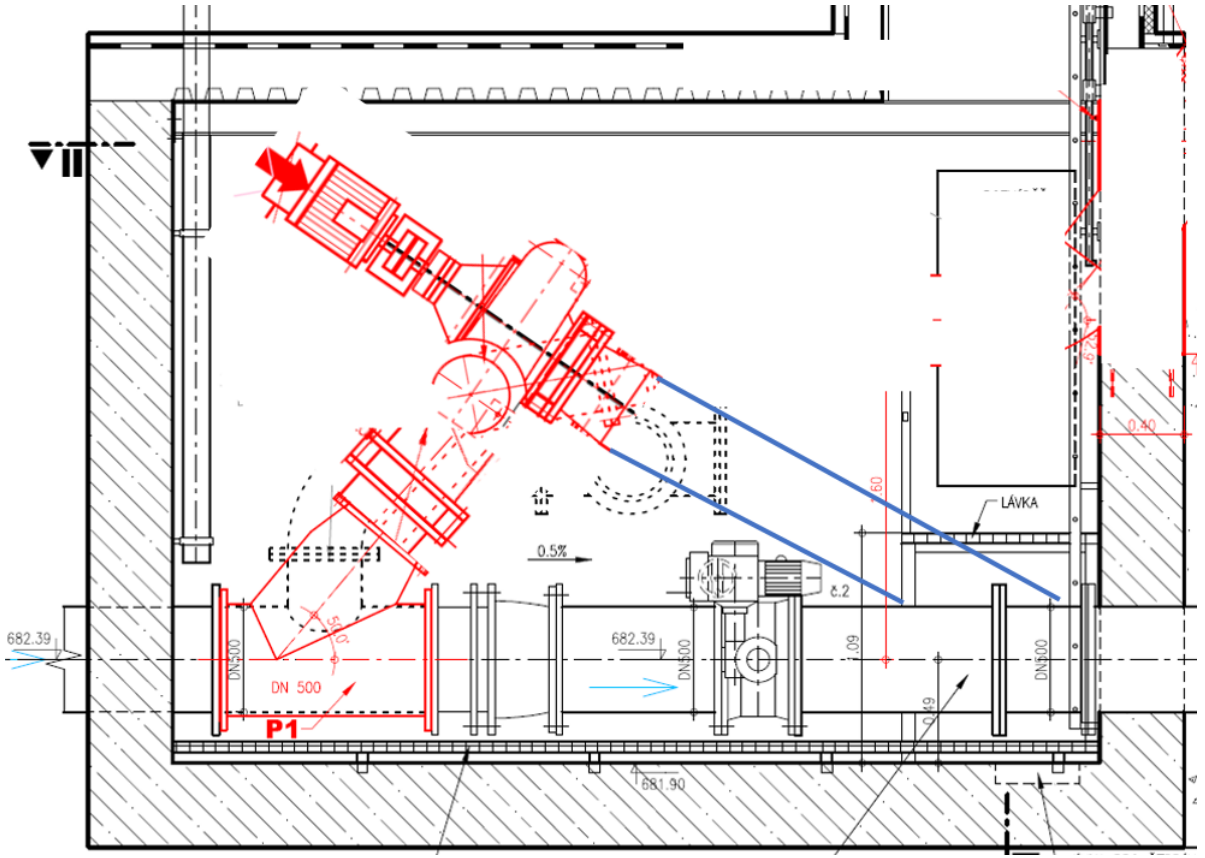
Inovative design of SHPP – „tailor-made“ solution



MINIMIZING INVESTMENT COSTS
- use of the existing structures
- ideally no construction works
⇓
efficiency of the whole process

Inovative design of SHPP – „tailor-made“ solution





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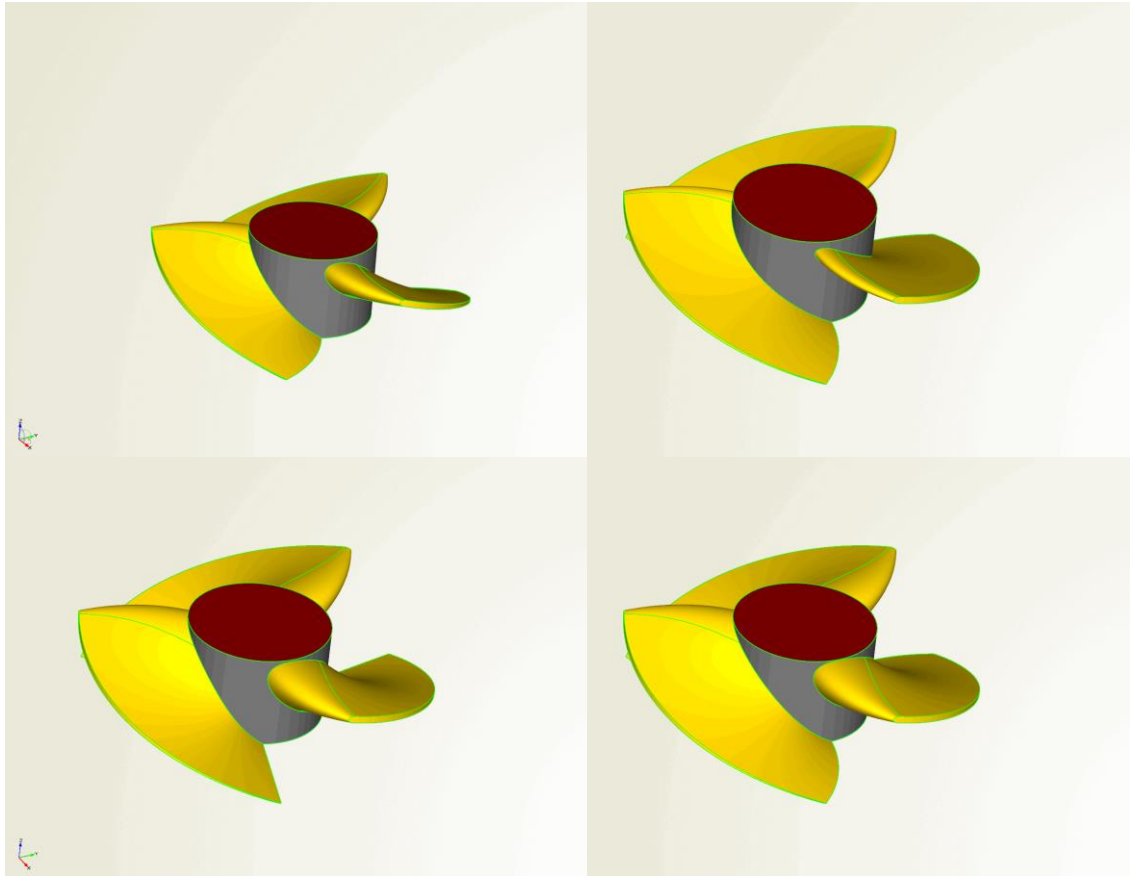
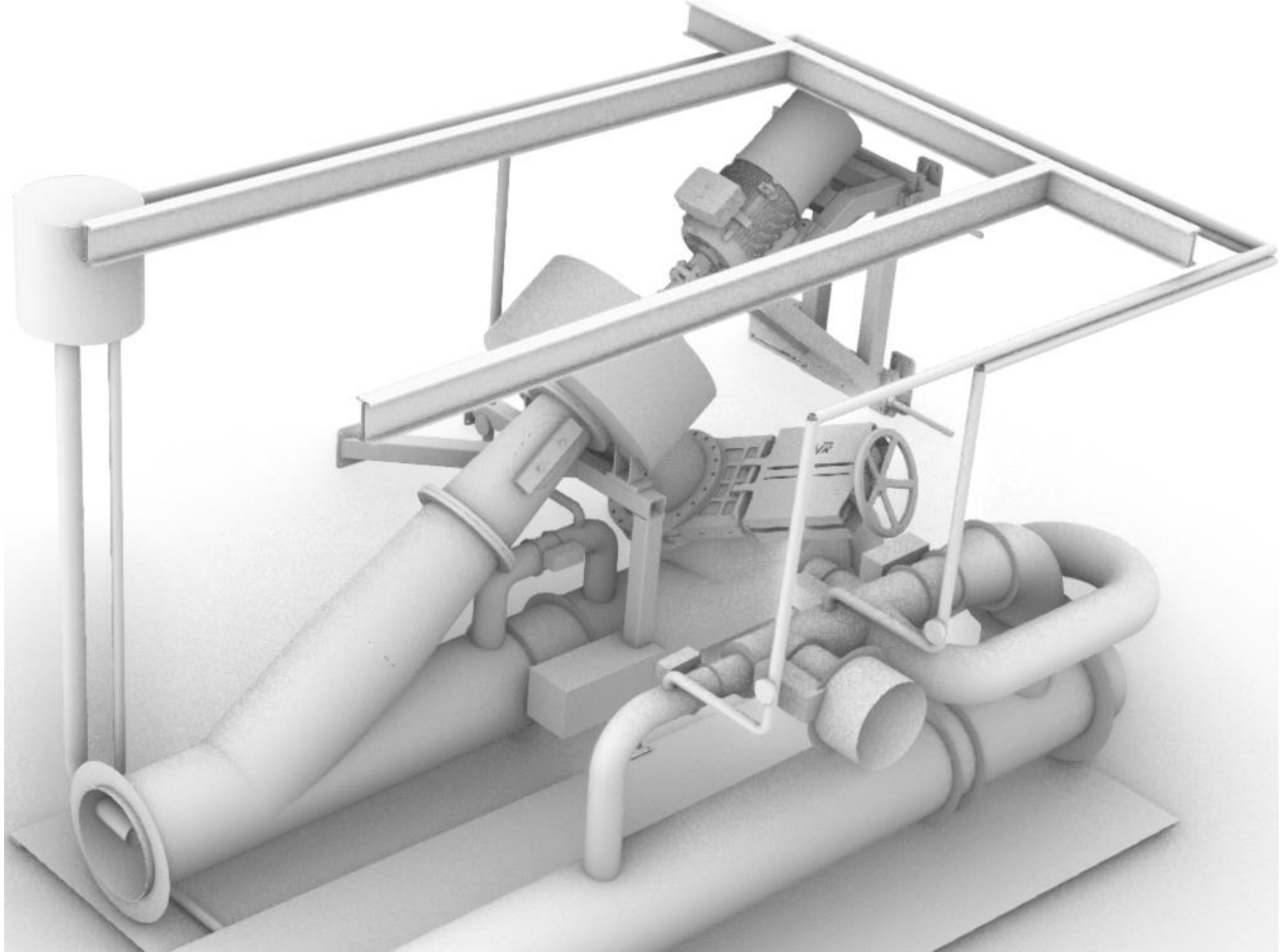
Inovative design of SHPP – „tailor-made“ solution

„FIT IN PLACE“ design
- maximal use existing structures
- provide the concept
- fixed meridional profile
- maximize the benefit of VS



Prototype – mechanical design



Inovative design of SHPP – „tailor-made“ solution

RUNNER BLADE DESIGN

- respects the specific hydraulic profile
→ power in the design point
→ efficiency in BEP
→ maximize benefits of VS operation
→ wide regulation range

most parts ready for manufacturing

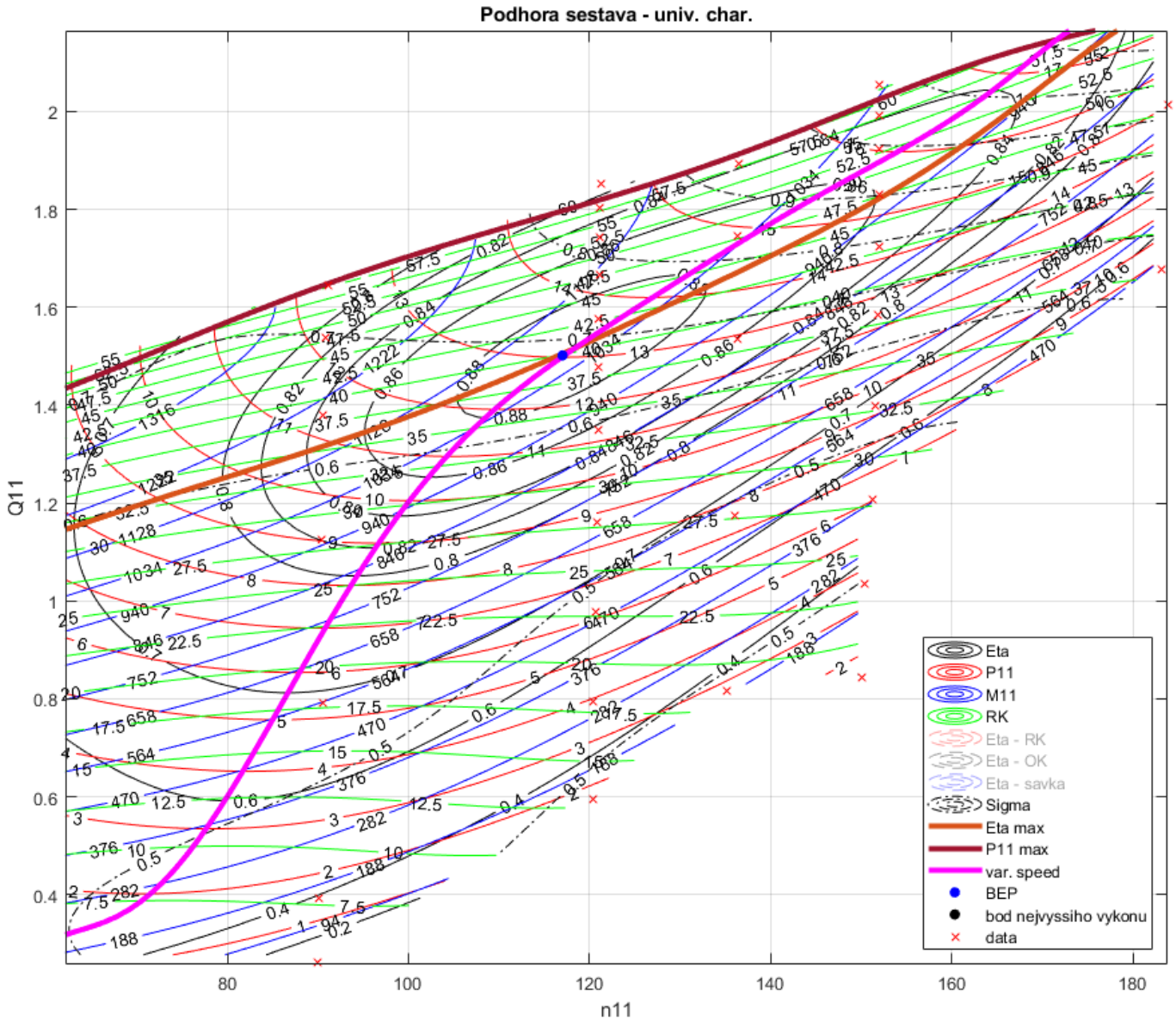
data for control system

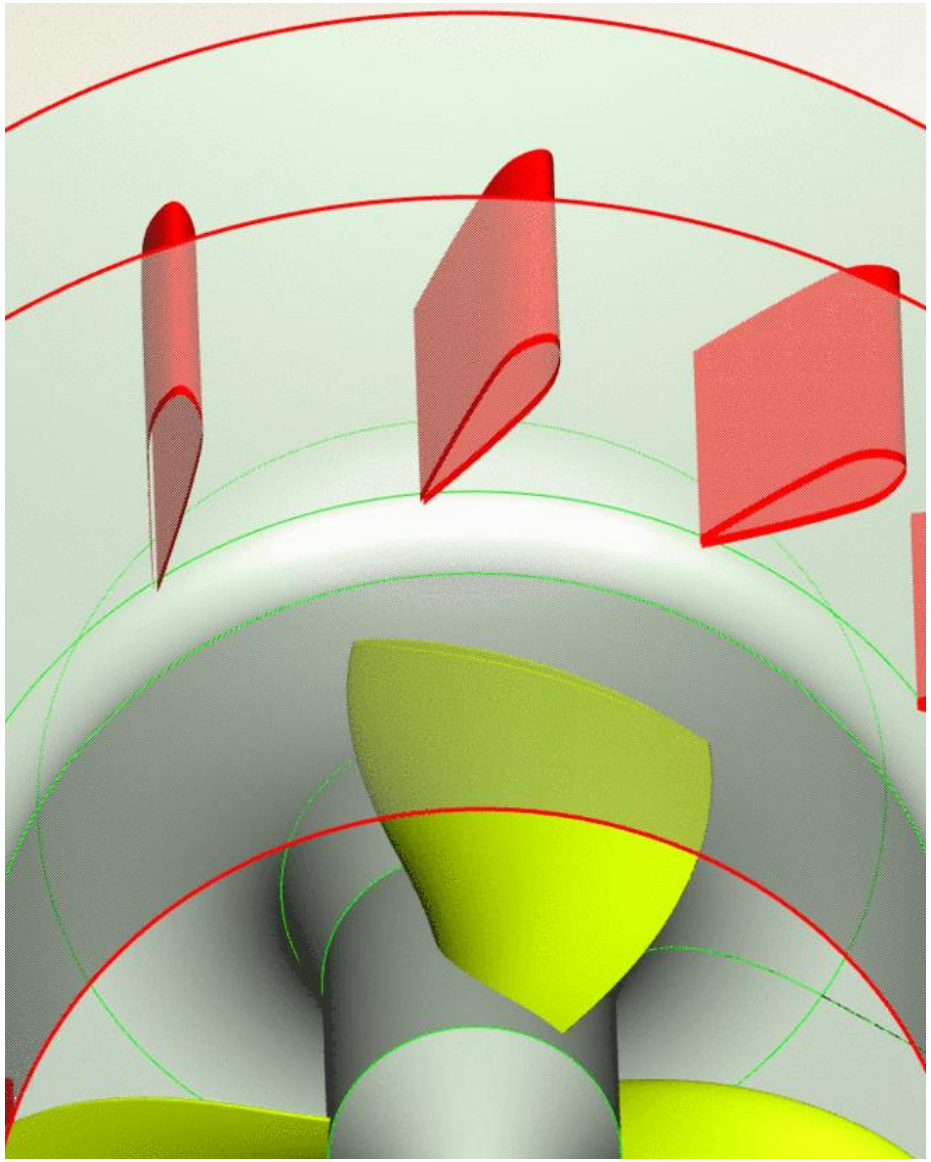
CONCEPT

- 3D model of existing structures
- 3D scan?
- hydraulic profile design
- design tuned for the specific site

VERIFICATION

- CFD calculations on fine mesh
→ operation range and efficiency
→ cavitation and unstabilities
→ structural analysis


Podhora sestava - univ. char.
Q11
n11
Eta
P11
M11
RK
Eta - RK
Eta - OK
Eta - savka
Sigma
Eta max
P11 max
var. speed
BEP
bod nejvyssiho vykonu
data



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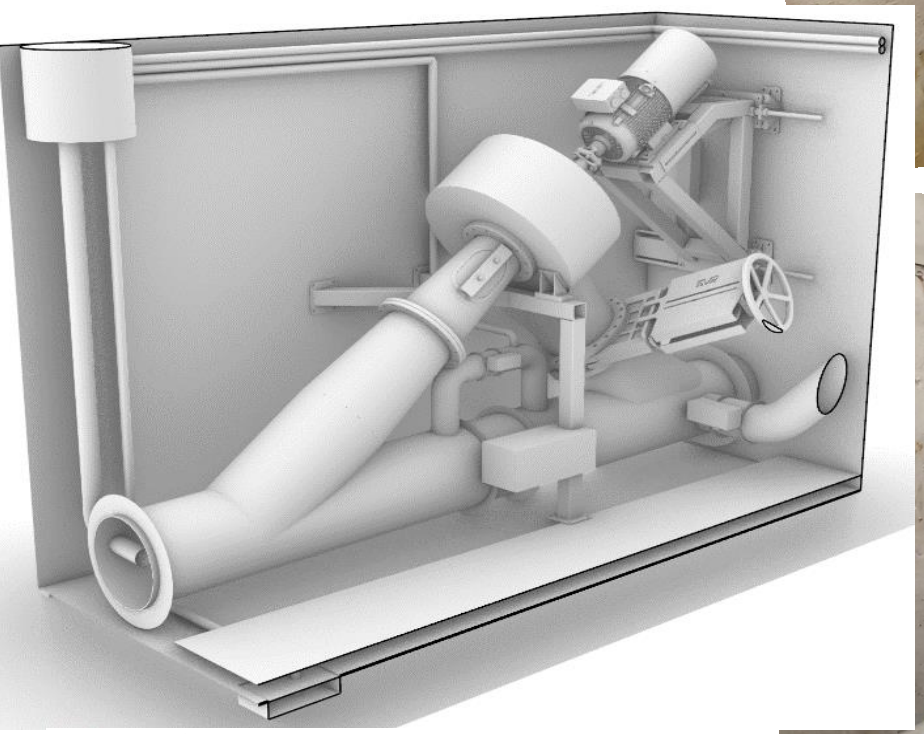

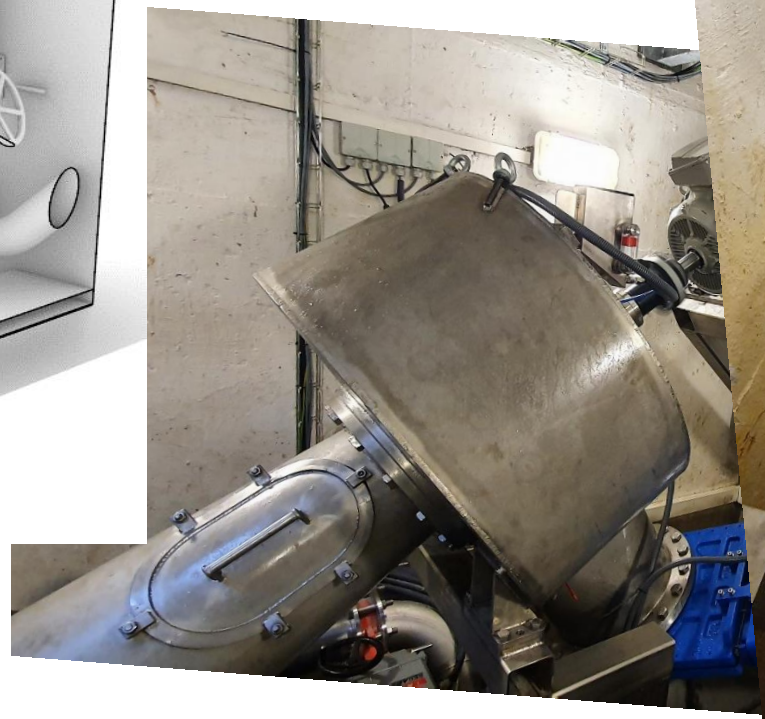

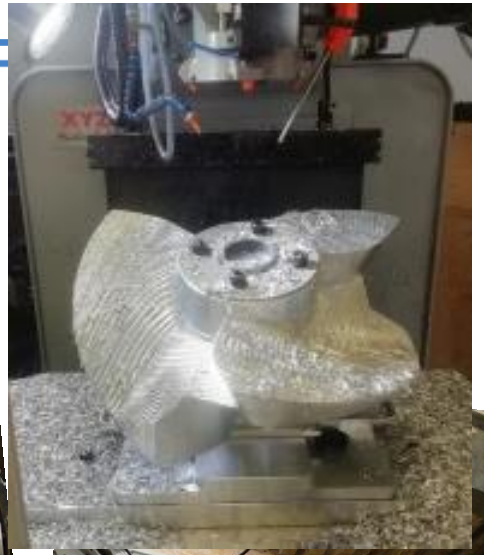

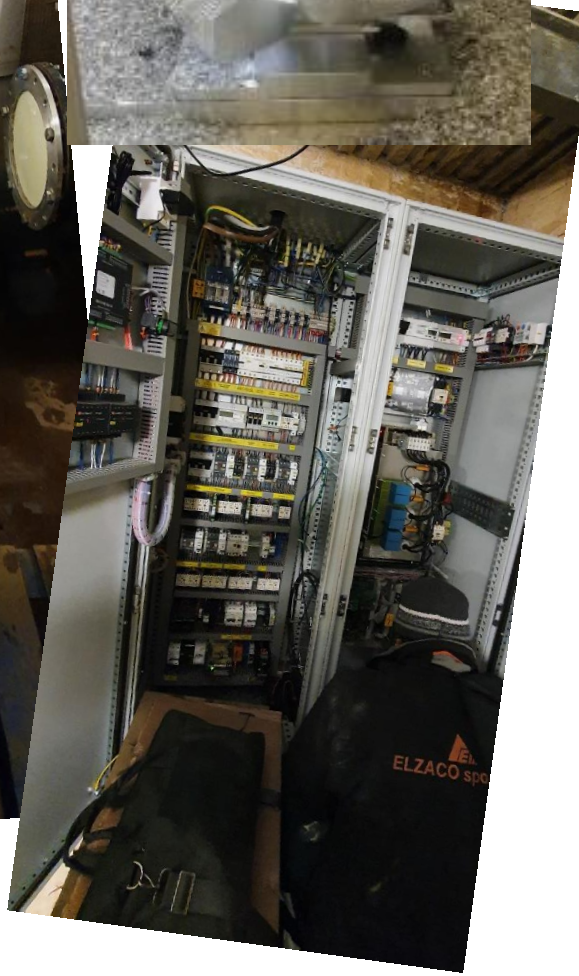

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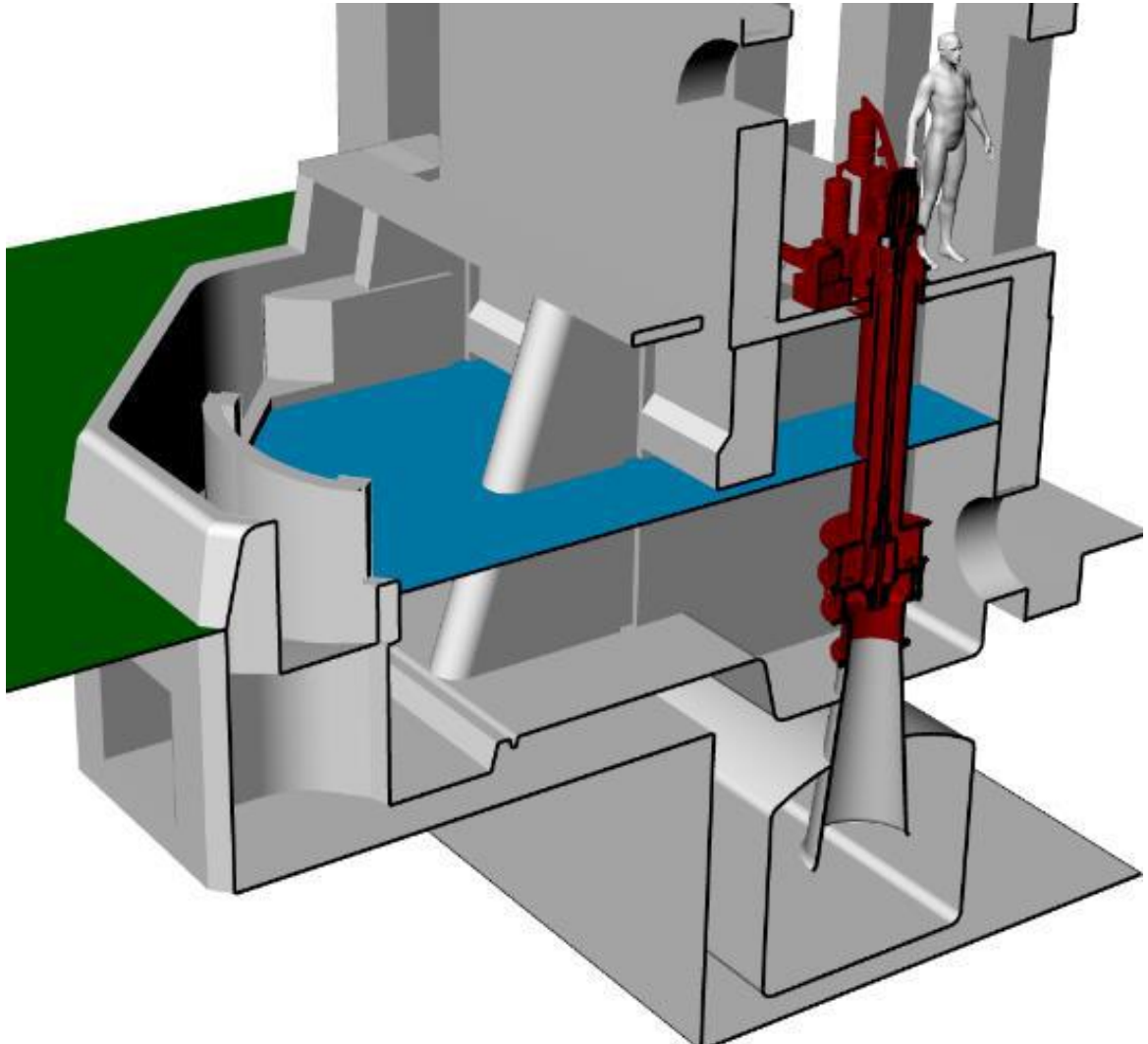
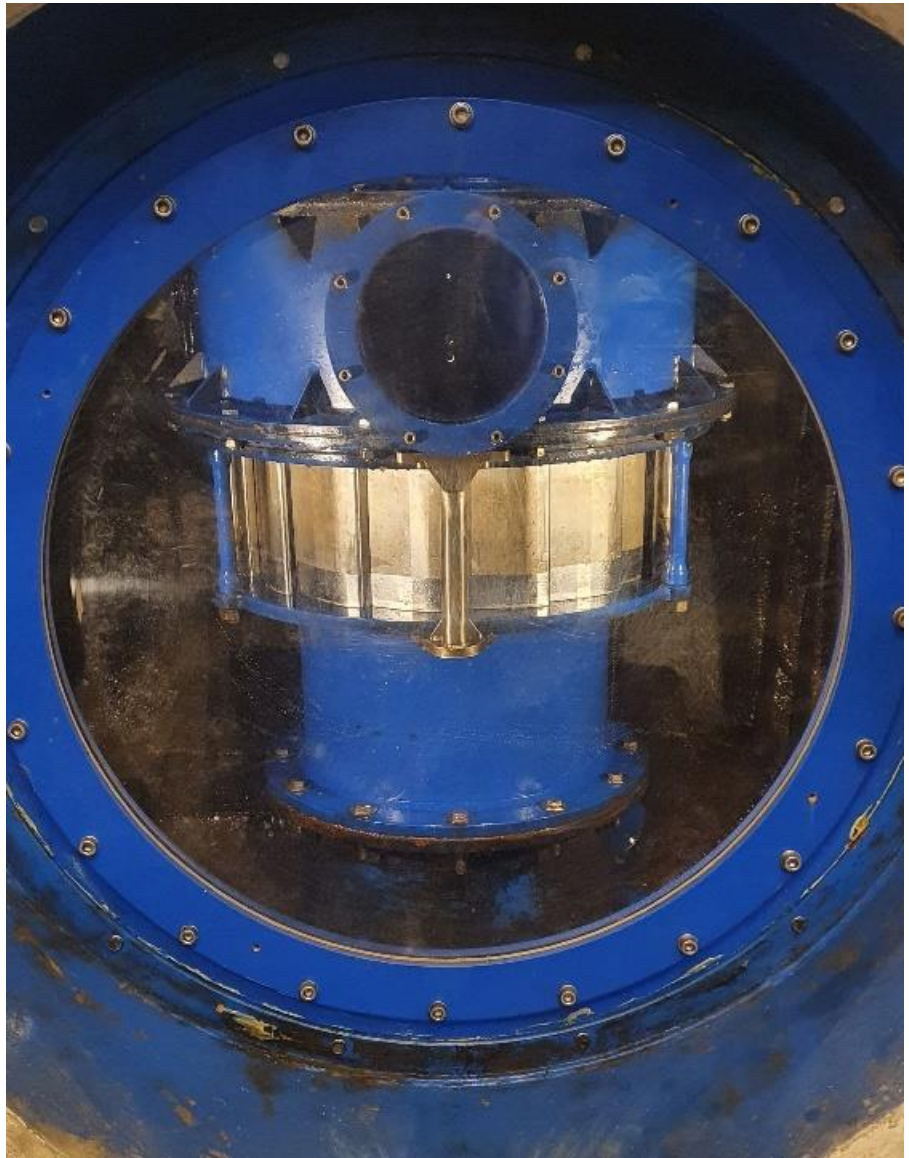
Low head turbine replacement





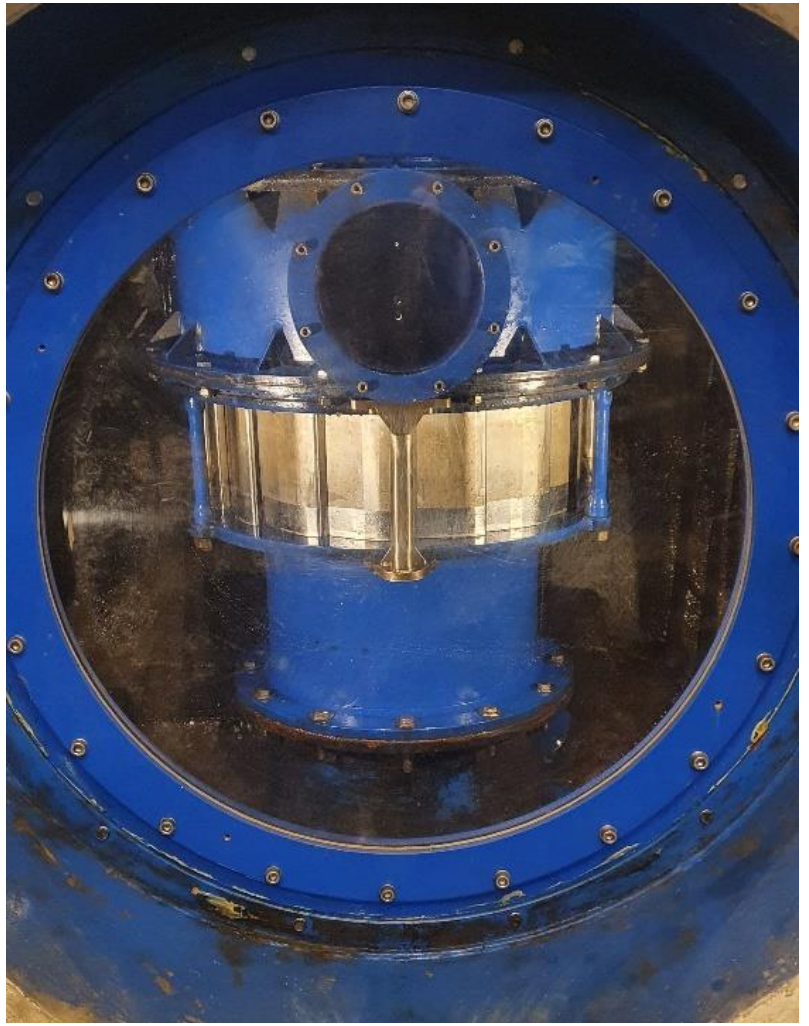
Inovative design of SHPP – „tailor-made“ solution

- simplifies mechanical design
- keeping a wide operating range
- reduction of construction works
- shortening the realization

→ reconstruction

→ atypical HPPs

→ small HPP



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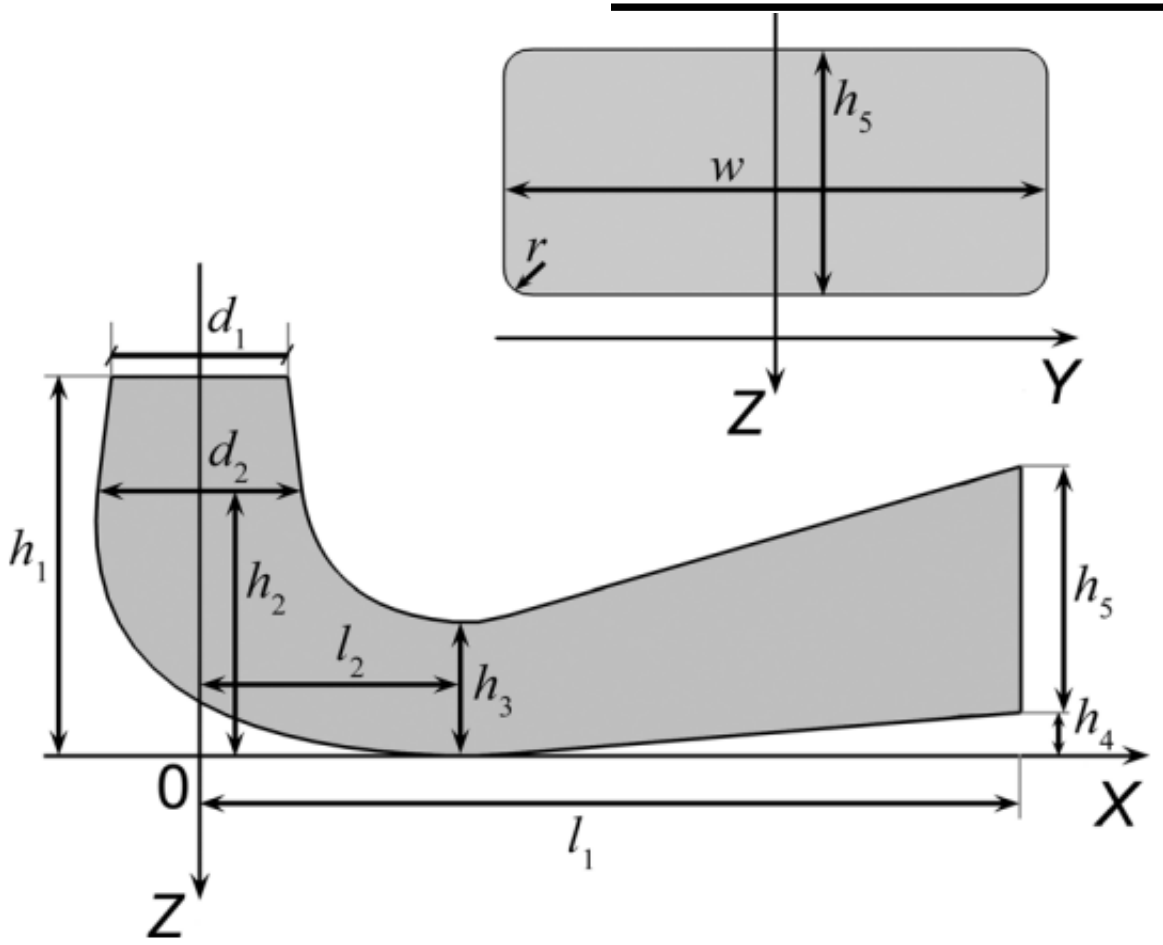
Elbow draft-tube optimization



author: Jiří Souček
Department of Hydraulic Structures

12 free parameters

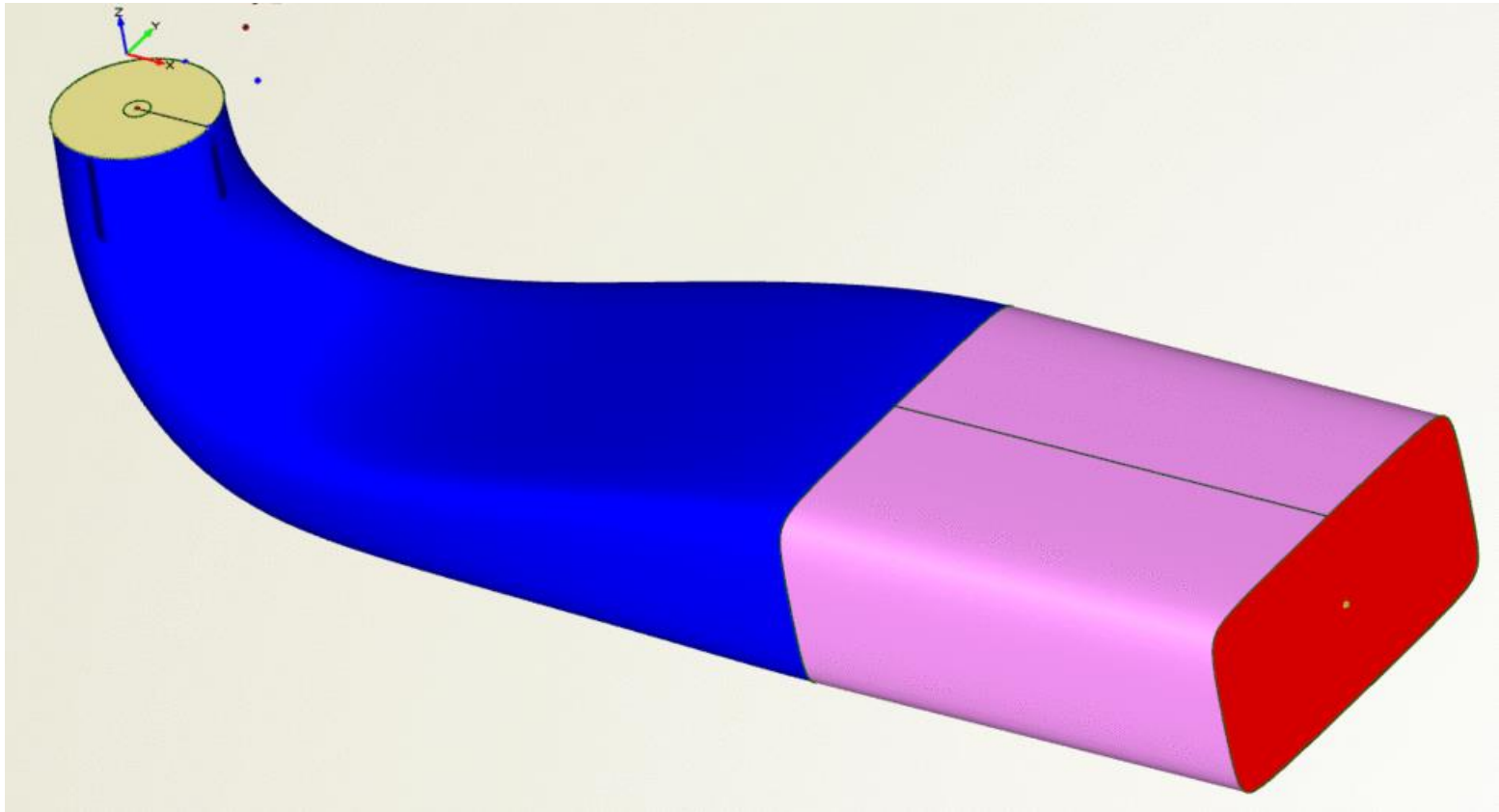
This research was supported by the Student Grant of Faculty of Civil Engineering SGS21/106/OHK1/2T/11 „Optimization of Selected Hydraulic Elements and Hydraulic Structures“, 2021 – 2022.

Elbow draft tube optimization

→ Compromise between improving efficiency and depth of the foundation

→ maximize the benefit of the variable speed operation

→ mitigate the negative effect of existing non-ideal structures



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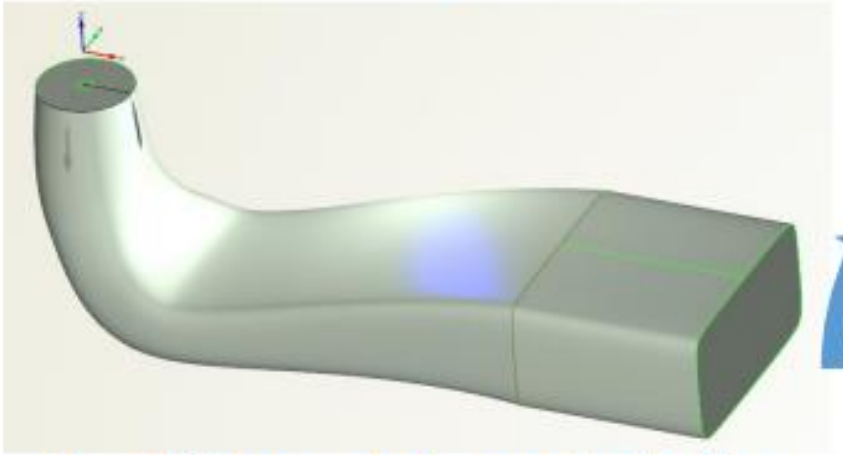
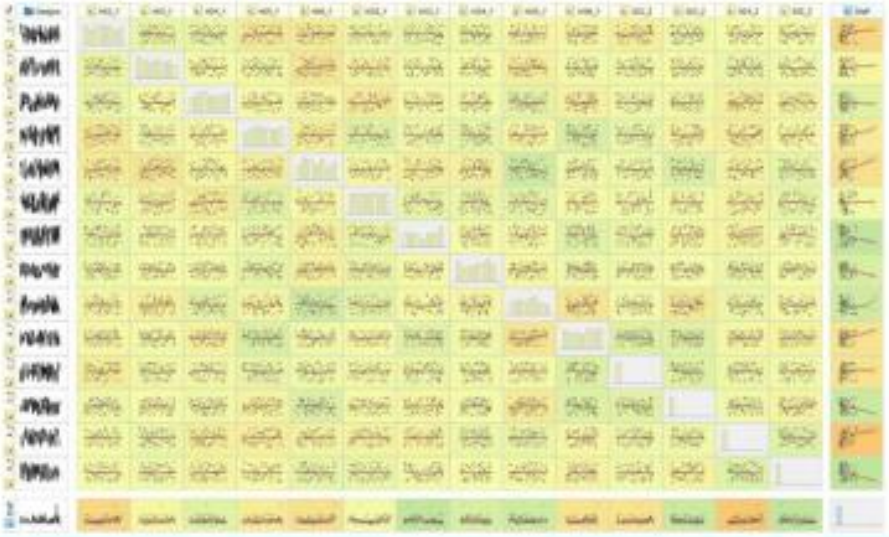
Parametric geometry



Sensitivity analysis + optimization



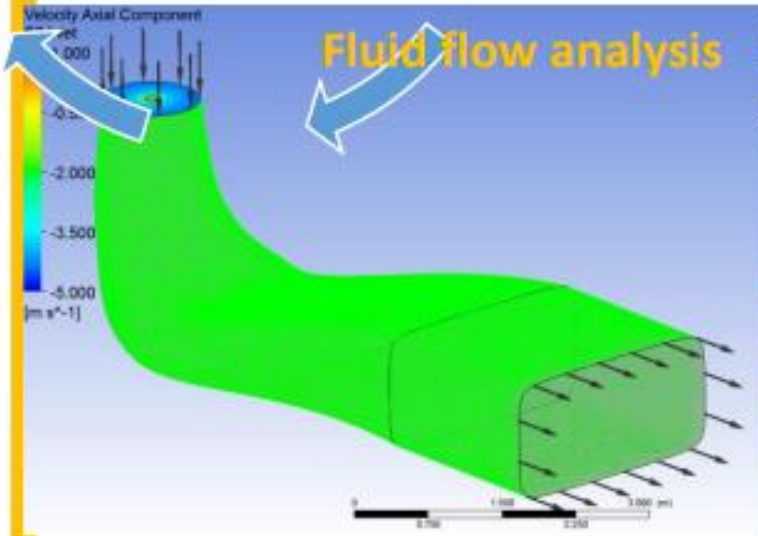
WORKFLOW

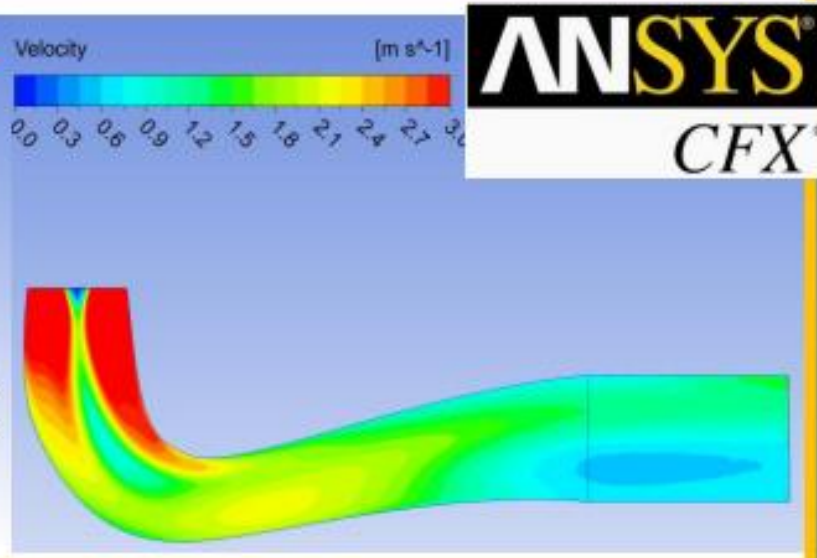
ANSYS

ANSYS ICEM CFD

Meshing

Fluid flow analysis





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Elbow draft tube optimization

→ Compromise between improving efficiency and depth of the foundation

→ maximize the benefit of the variable speed operation

→ mitigate the negative effect of existing non-ideal structures

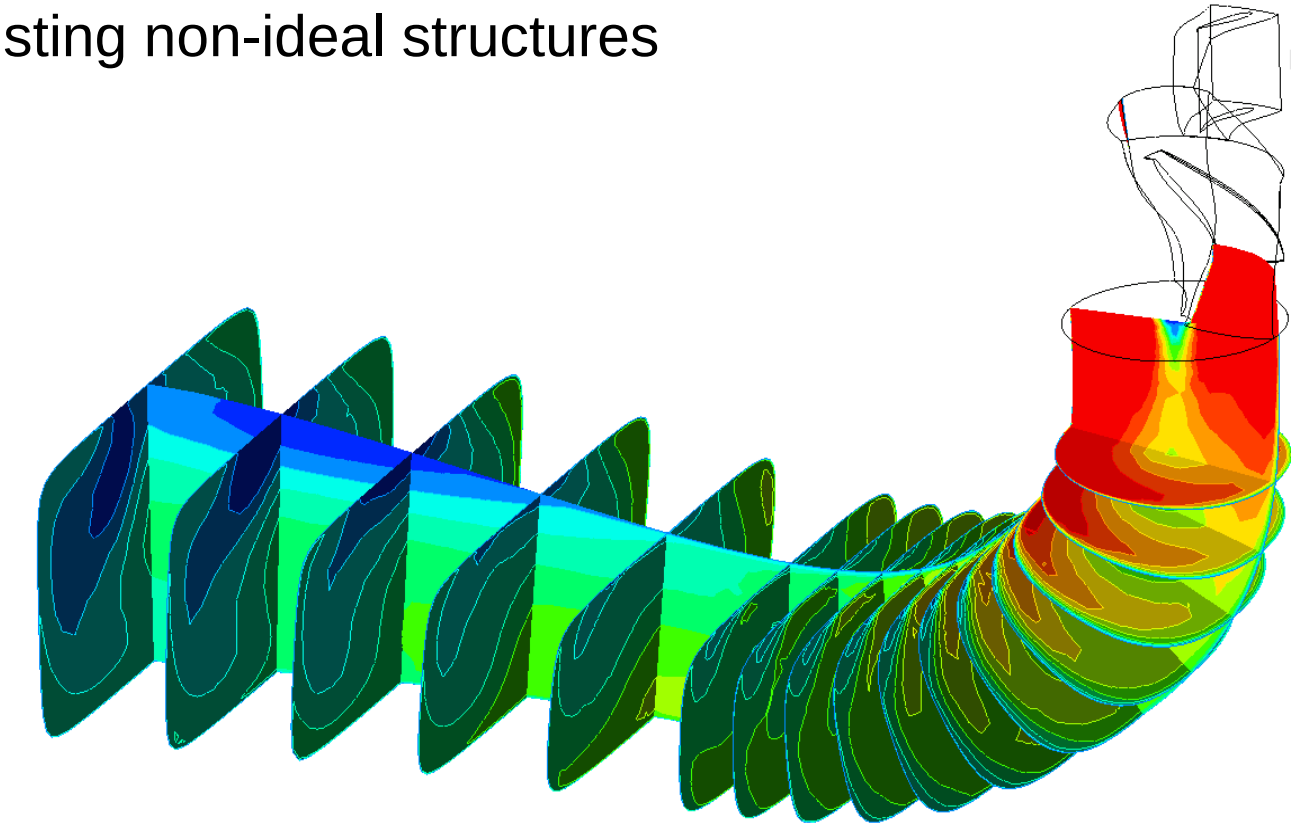
Tricky part

optimization for steady flow

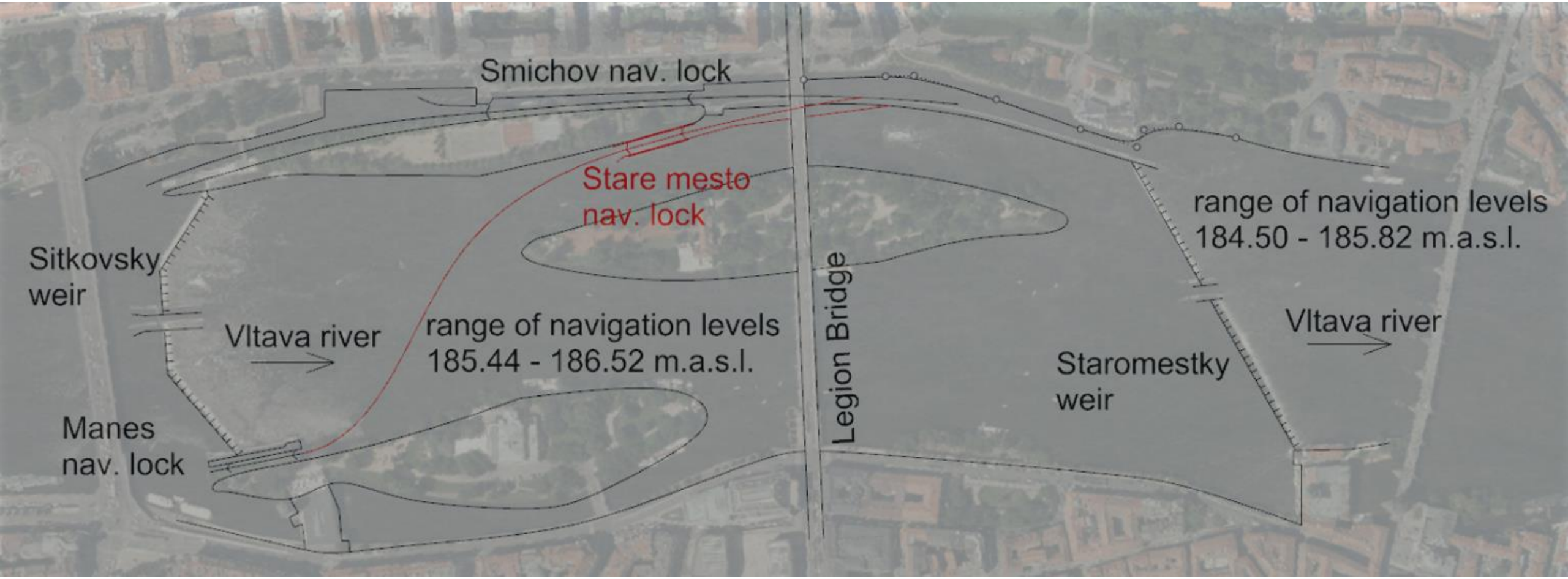
x

the real flow

- complex unsteady flow
- cavitation – rotating vortex
- vibration, instabilities



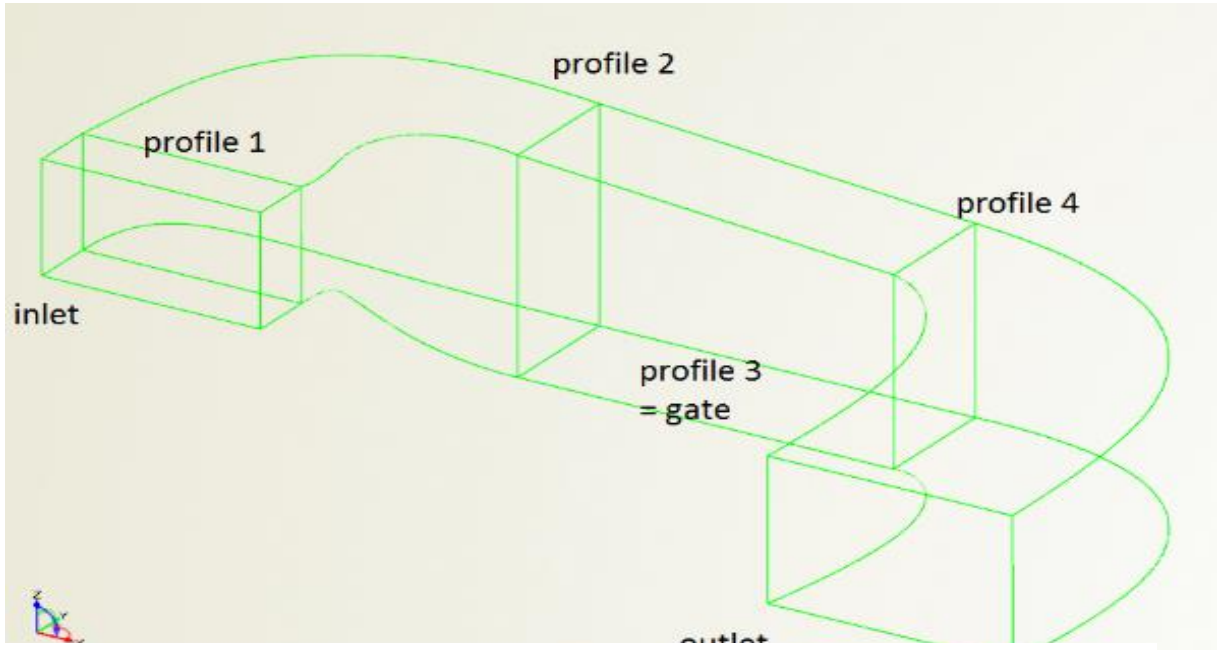
Navigation lock culvert



Shape restriction

- fairly limited by existing project
- shape resctricted by gates

AQUATIS



This research was supported by the Czech Technological Agency as a part of the project TJ04000187 „Shape optimization of Hydraulic Structures Using Parametric models and CFD“, 2020 – 2022.

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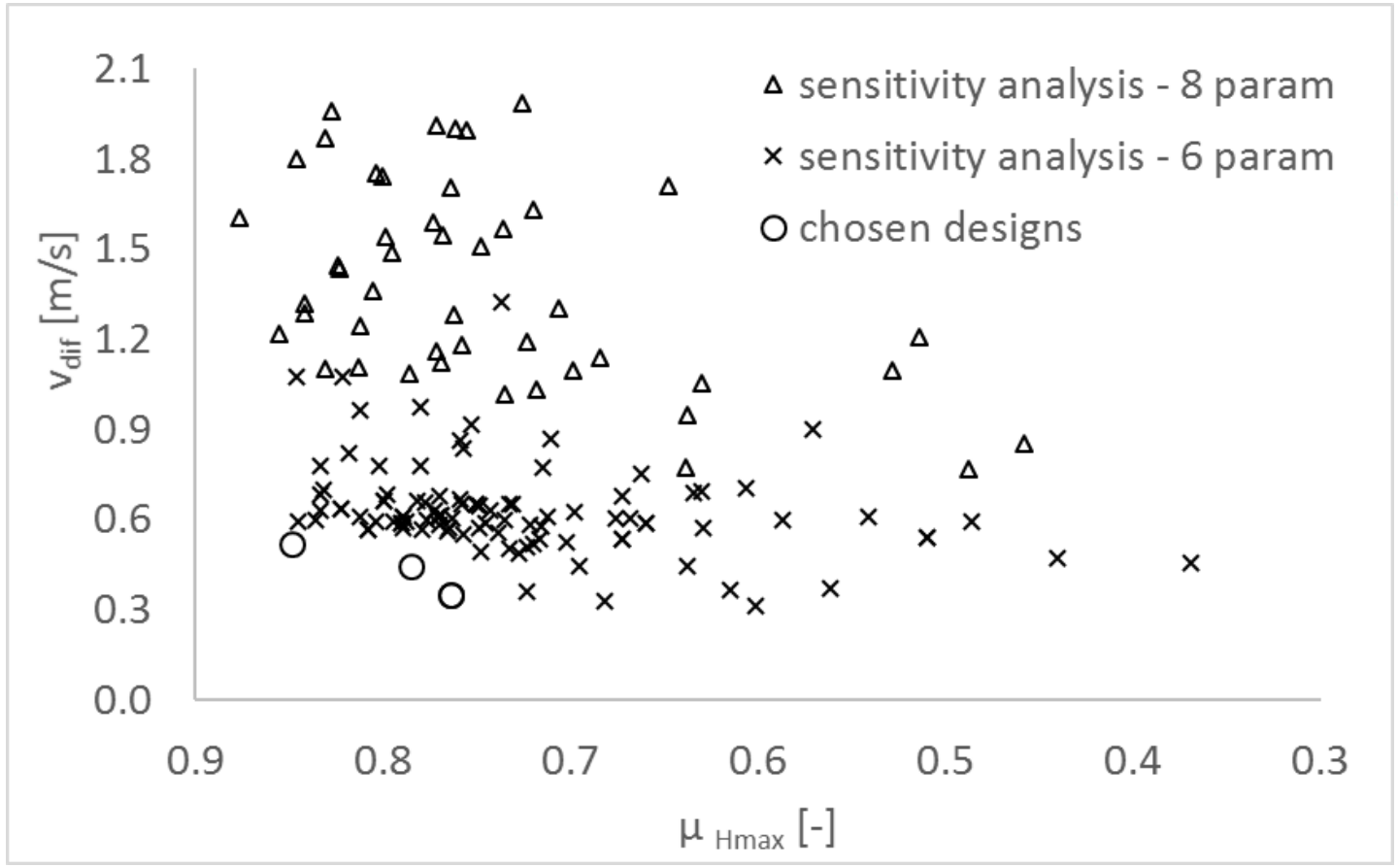
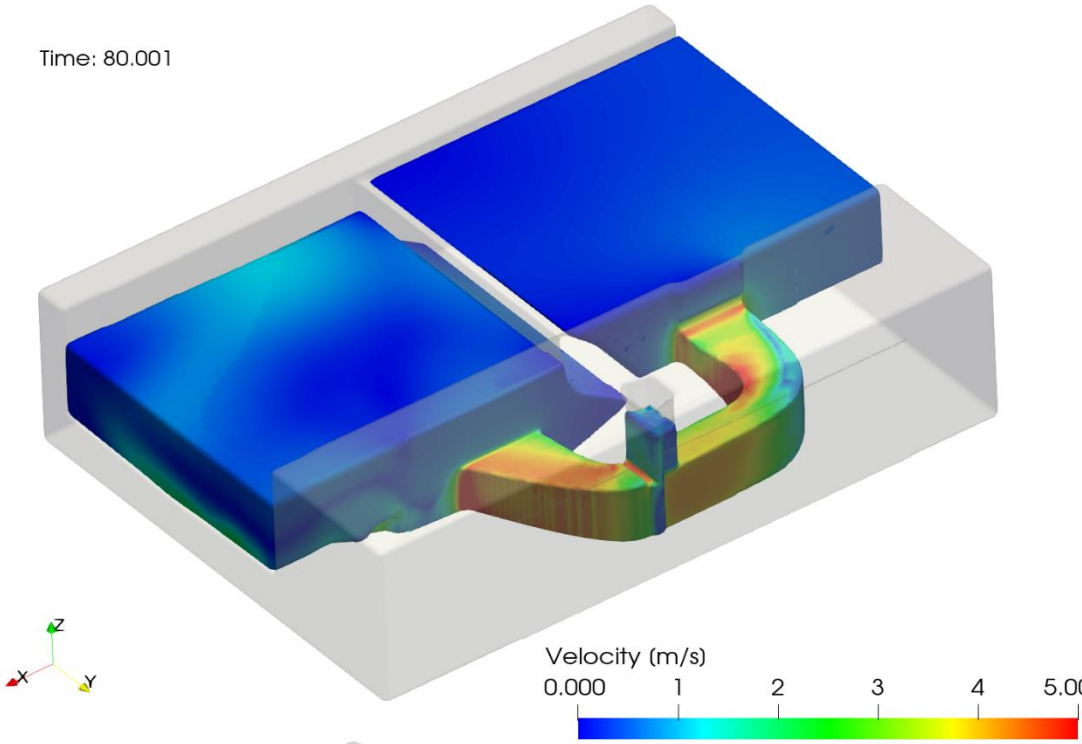
Optimization goals

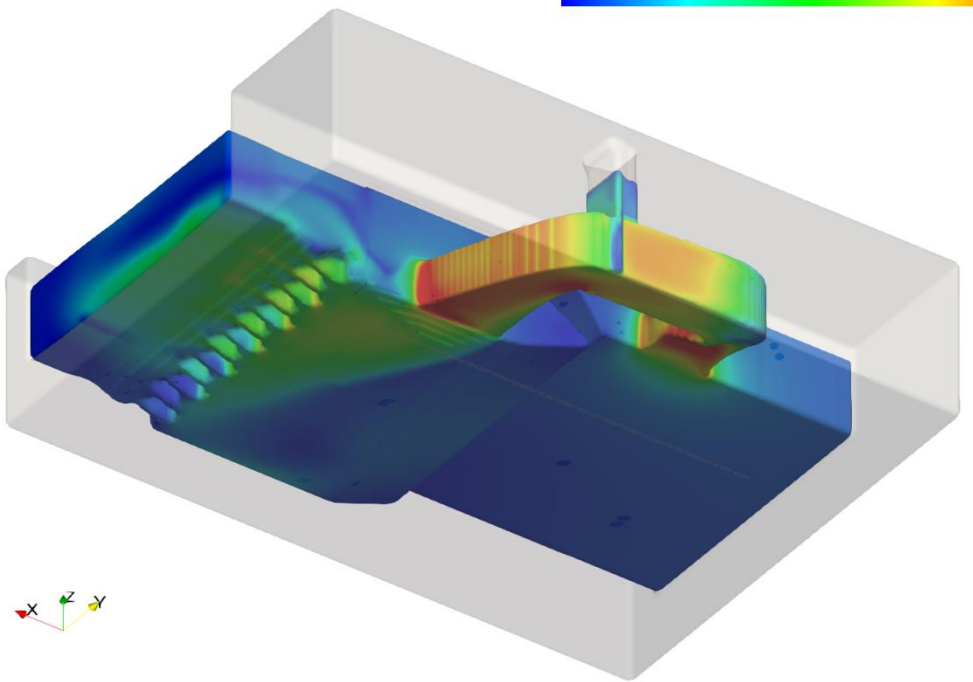
- ensure safety of the vessel
- shorten the filling time

Tricky questions

- free surface flow
- fully unsteady







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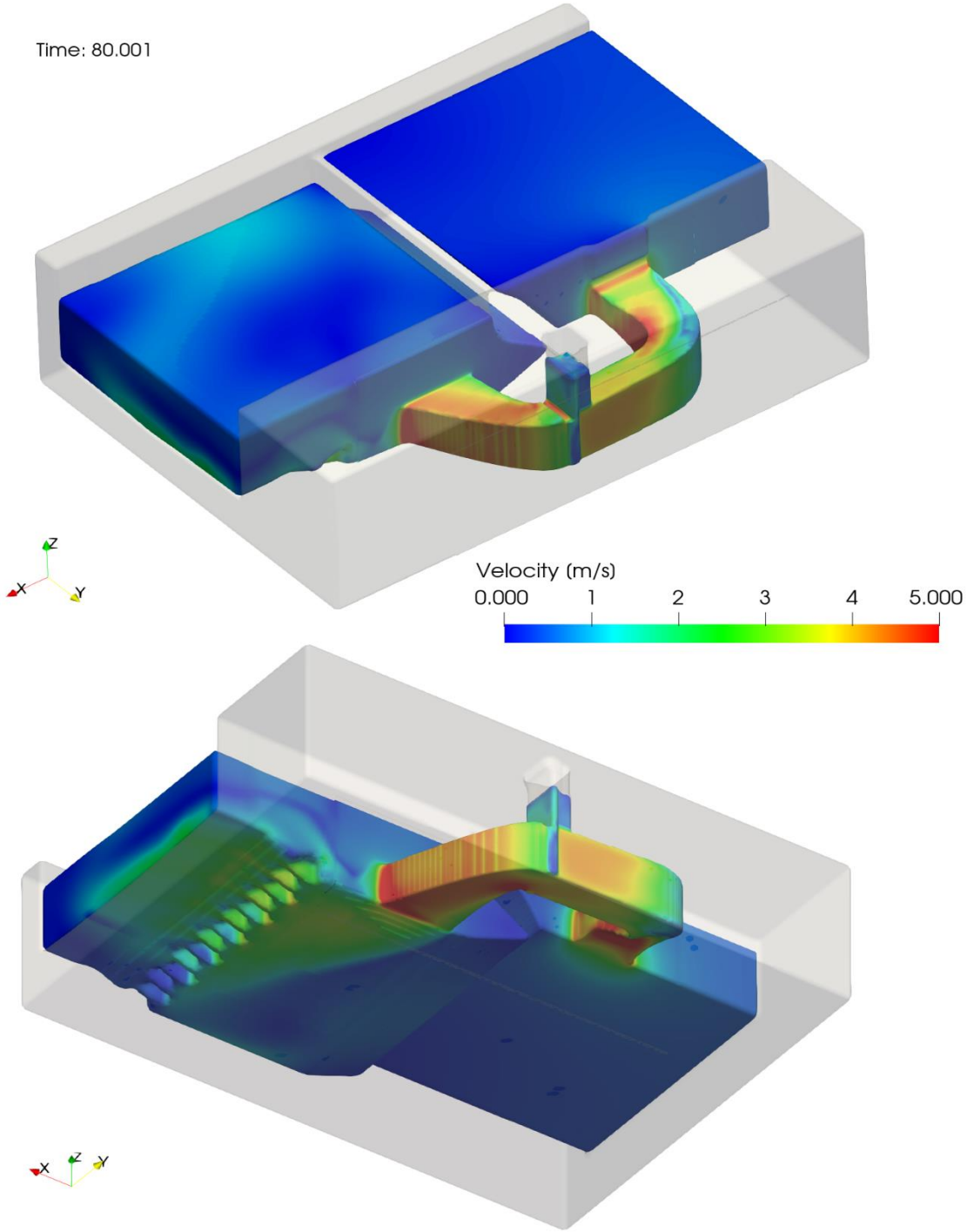
Tricky questions

- two phase flow
- fully unsteady

How to evaluate the benefit of optimization ??

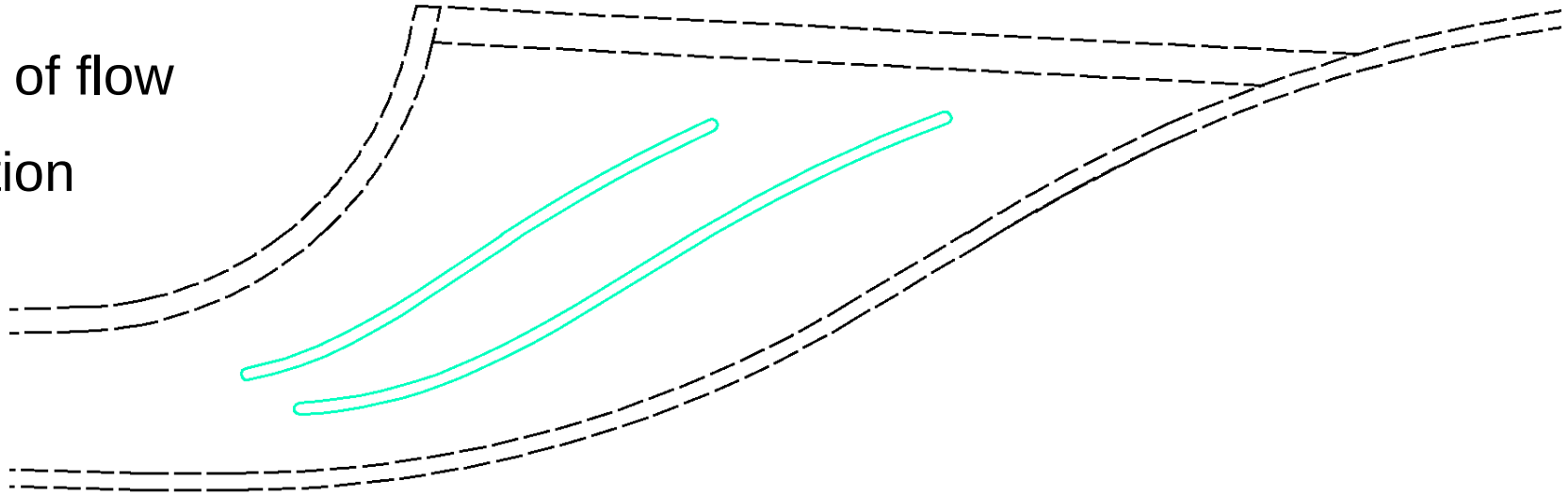


HPPs inlets and outlets

→ Decrease losses

→ Improve uniformity of flow

→ Enable the realisation



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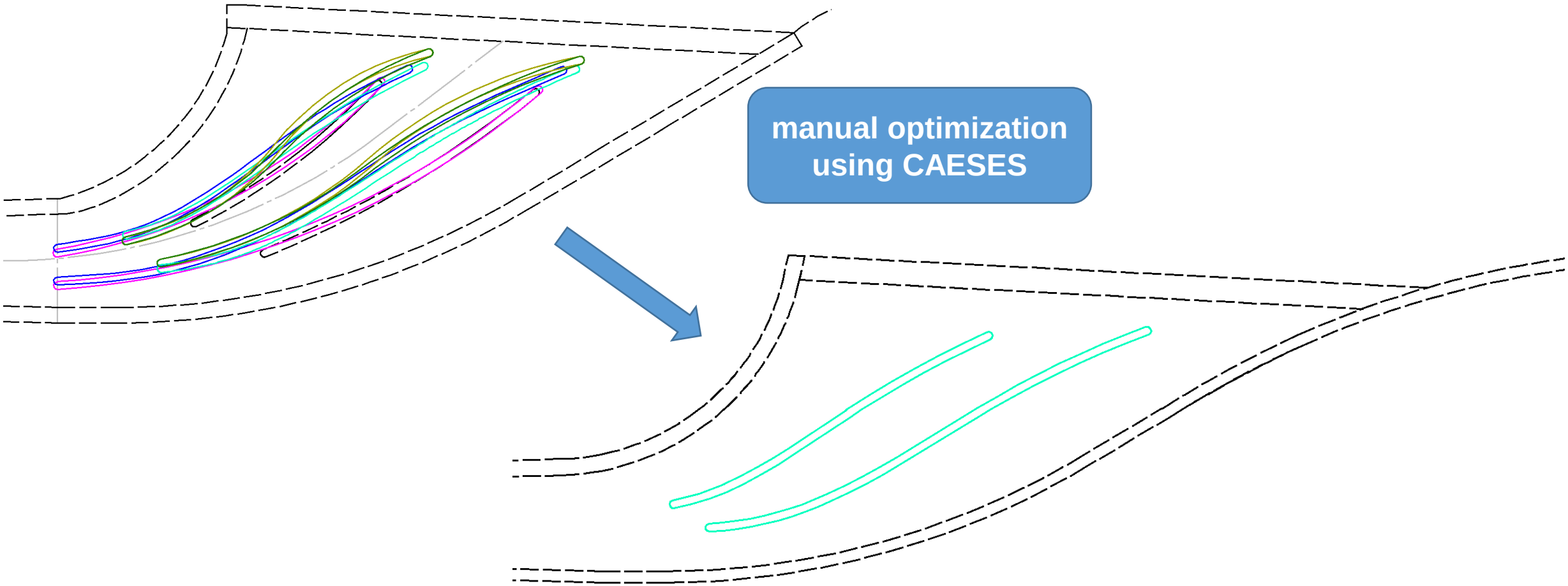
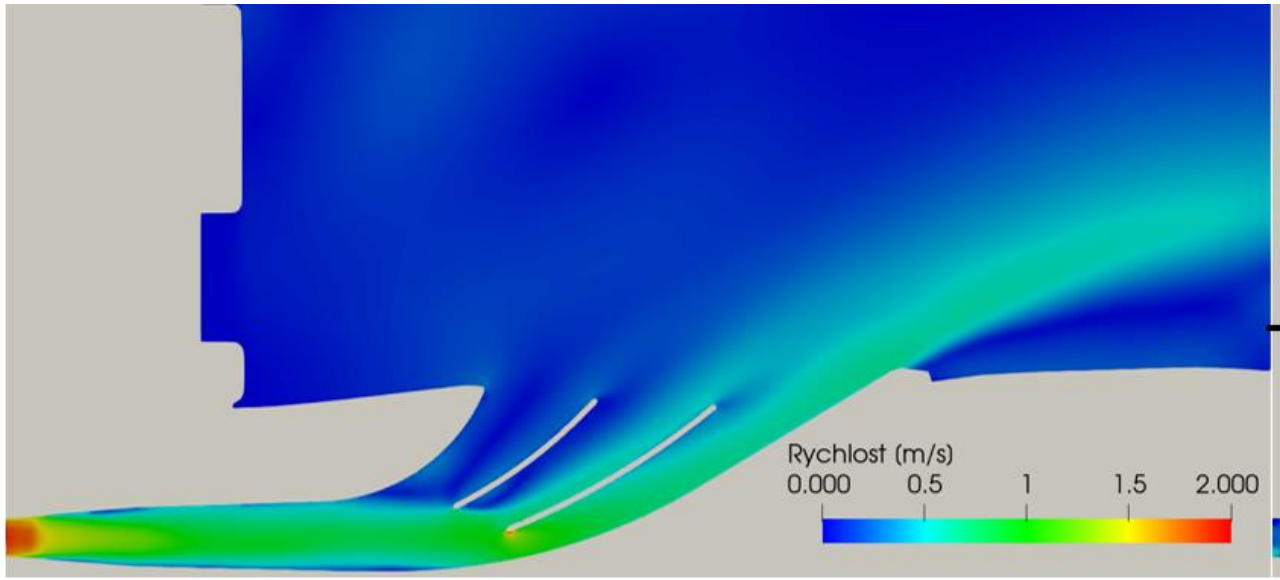
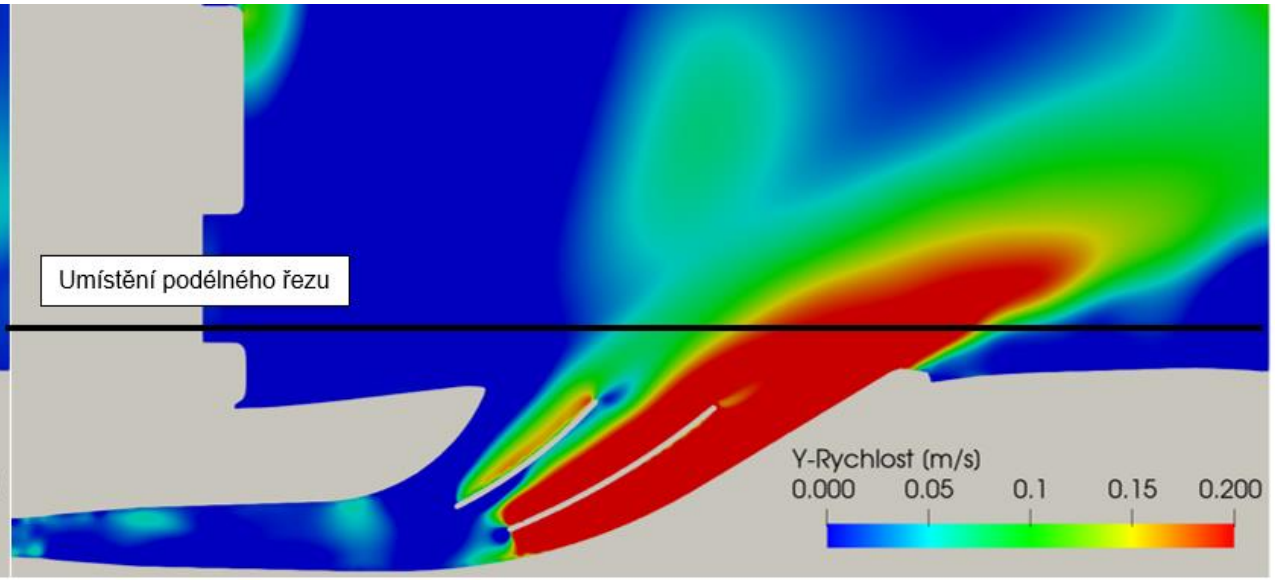
HPP outlet canal interfering with existing navigation canal







Y-Rychlost (m/s)
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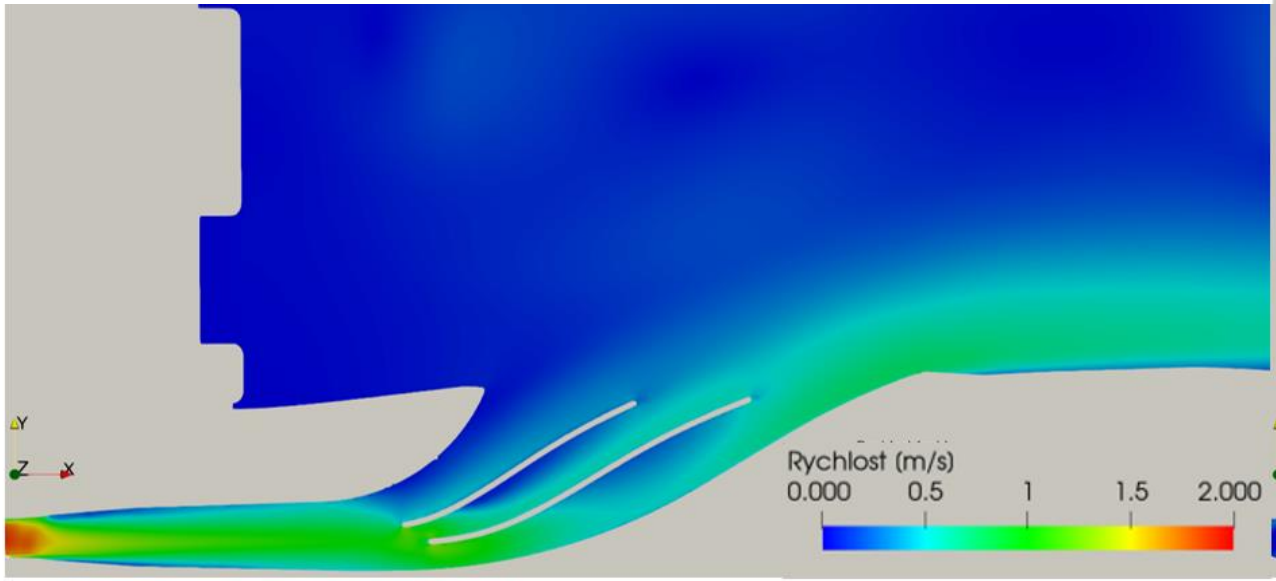
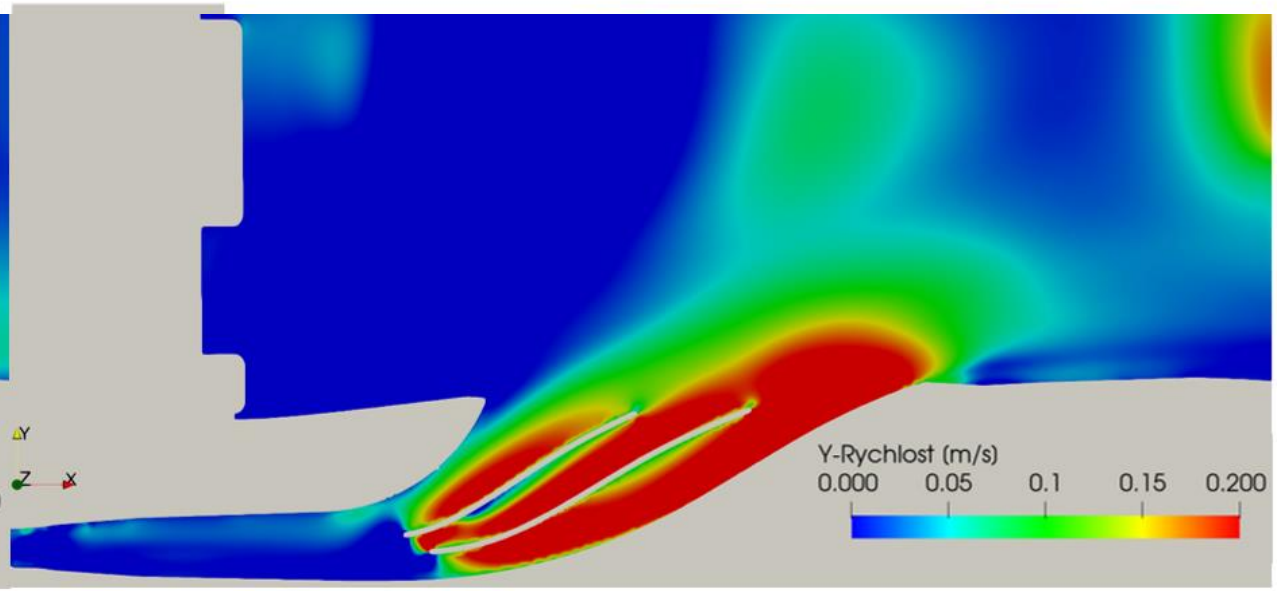
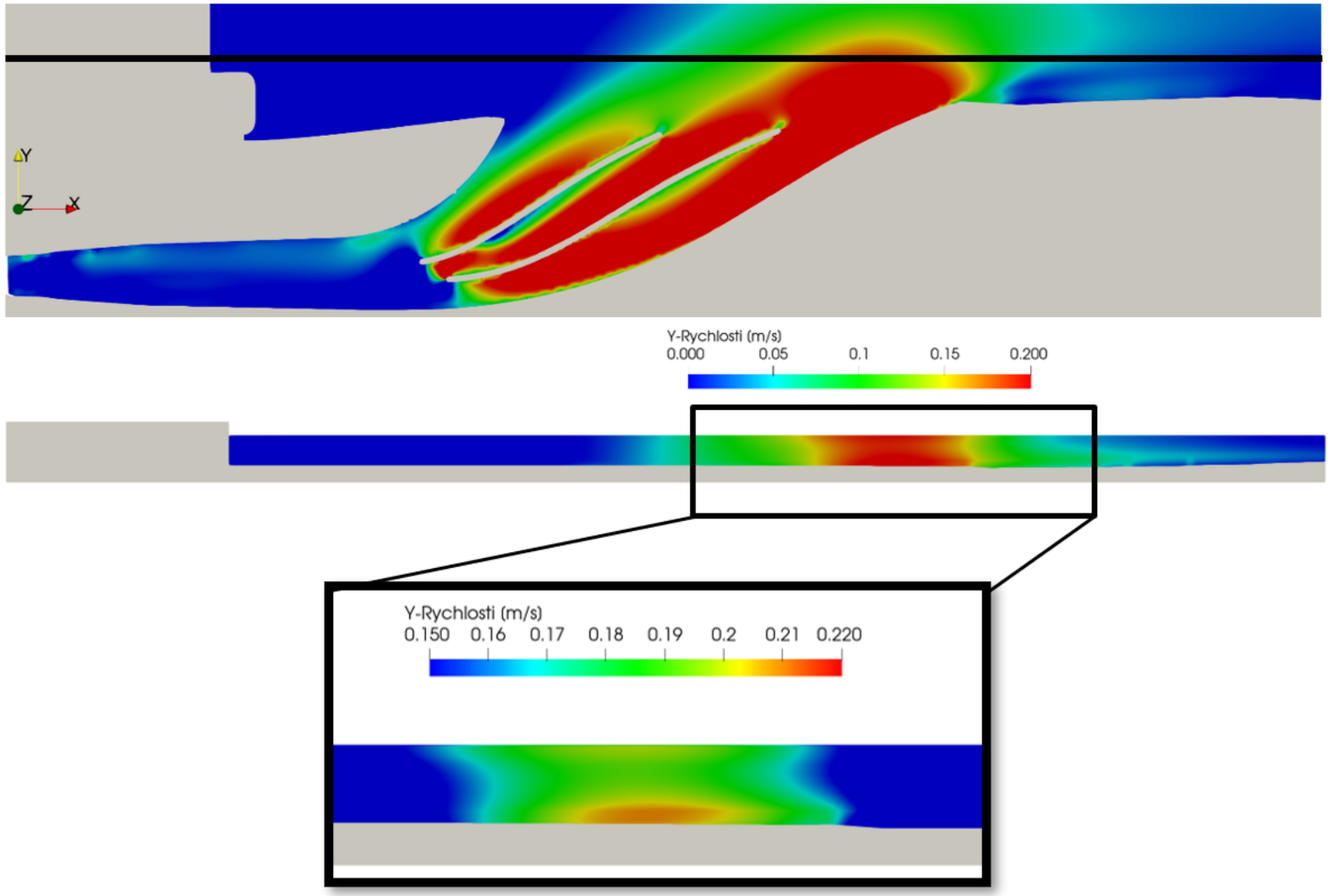




Tricky questions

- free surface flow
- large domain
- low velocities



Optimization for hydraulic structures

- **significantly improves structure properties**
- computational demanding
  - → many free surface applications
  - → large domains
  - → low velocities

- the benefit of optimization is often hard to evaluate
- project and realization limitations