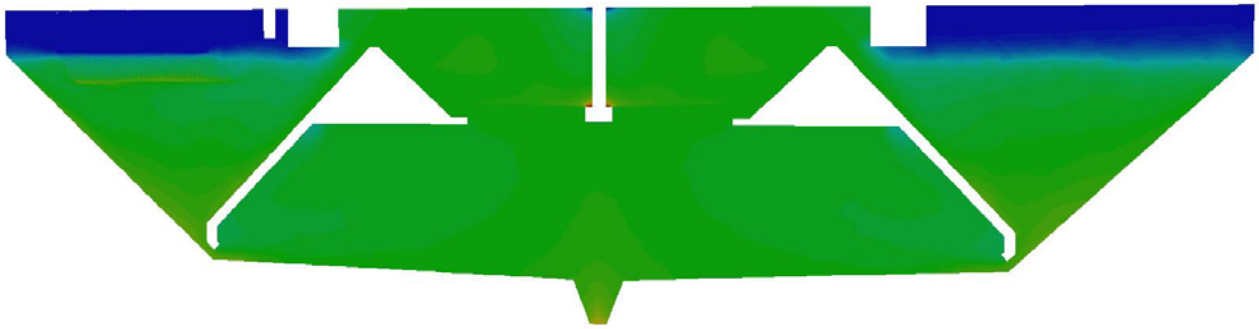
Optimization of a flocculation-sedimentation treatment plant with lamellas (FLUENT)

TECHNISCHE UNIVERSITÄT DARMSTADT

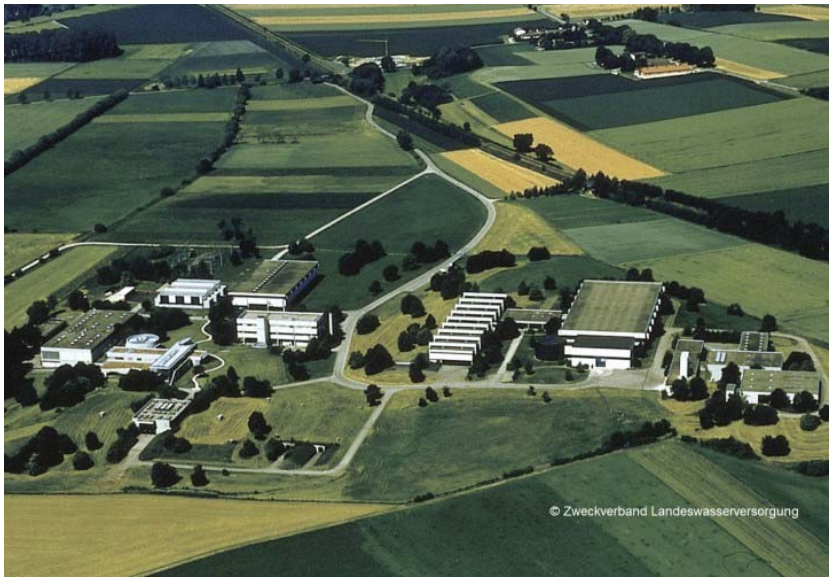
Zweckverband Landeswasser-versorgung

Dipl.-Ing. Marian Brenda
Dresden-Rossendorf

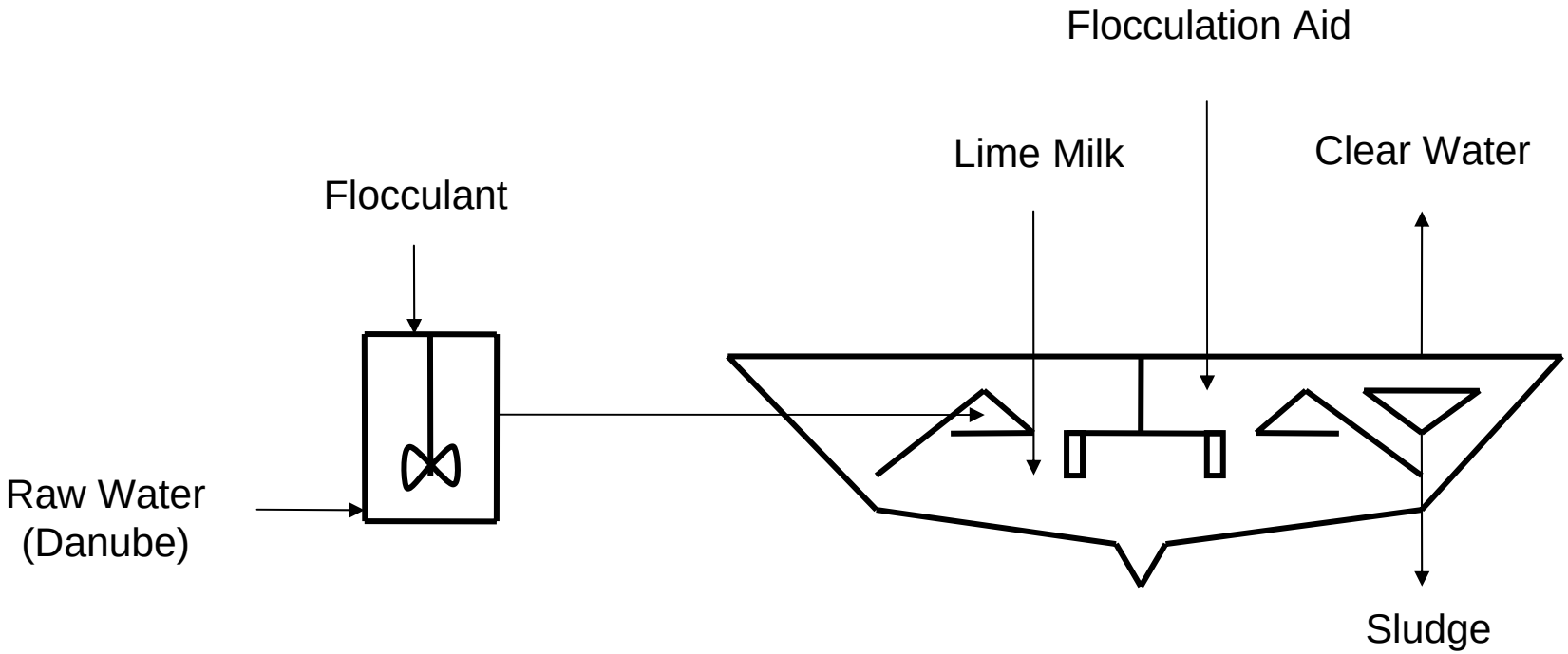


Backround Information

- The Zweckverband Landeswasserversorgung provides drinking water for the north-east of Baden-Württemberg and parts of Stuttgart
- Water delivery 90 Mio m^3/a
- Within the water treatment plant of Langenau raw water from the river Danube is purified



Flow diagram of the flocculation-sedimentation

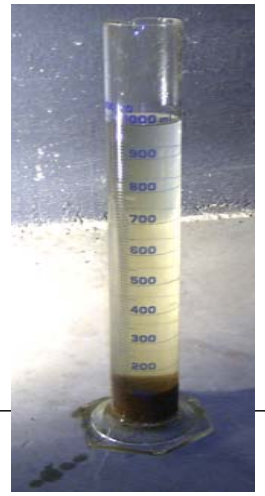


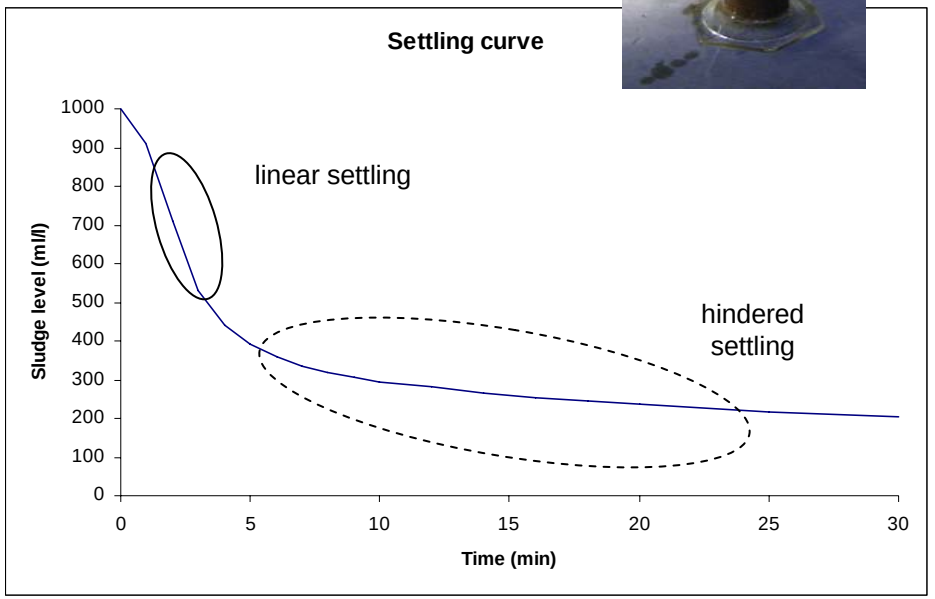
Overview

- Capacity 400 to 800 l/s
- Diameter Accelator: 36 m
- Height Accelator: 9,5 m

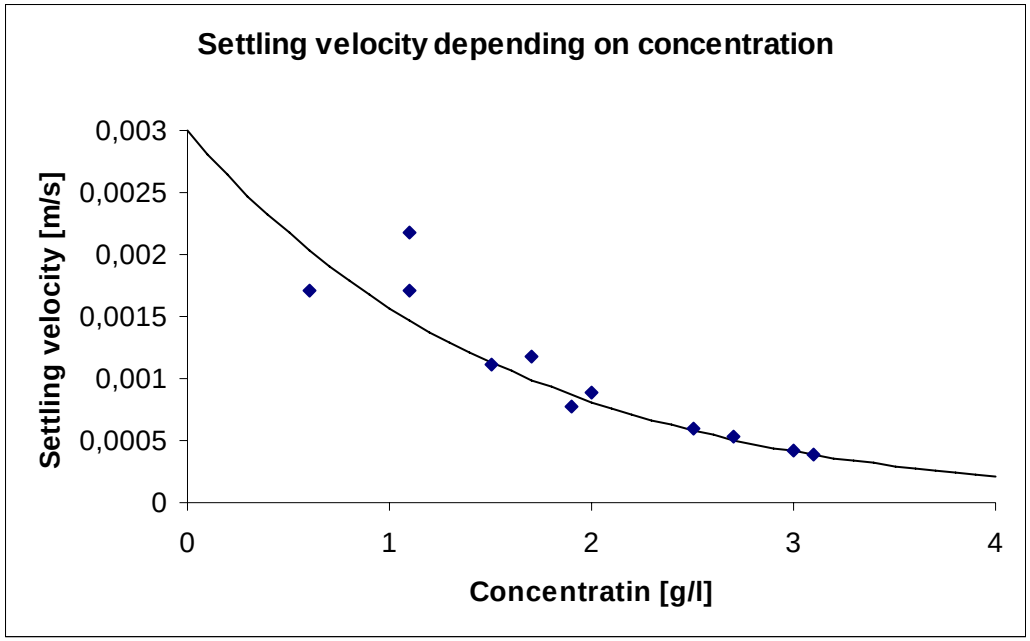
Measuring the settling velocity

- During the settling test the sludge level is measured over the time
- Within the first minutes linear settling takes place
- Thereafter hindered settling takes place
- Within the phase of linear settling the concentration and settling velocity is constant → settling velocity for a certain concentration
- Relatively easy to measure (standard test DIN 38 414)
- Height of the sludge level after 30 Minutes is called sludge volume (important parameter in waste water treatment plants)



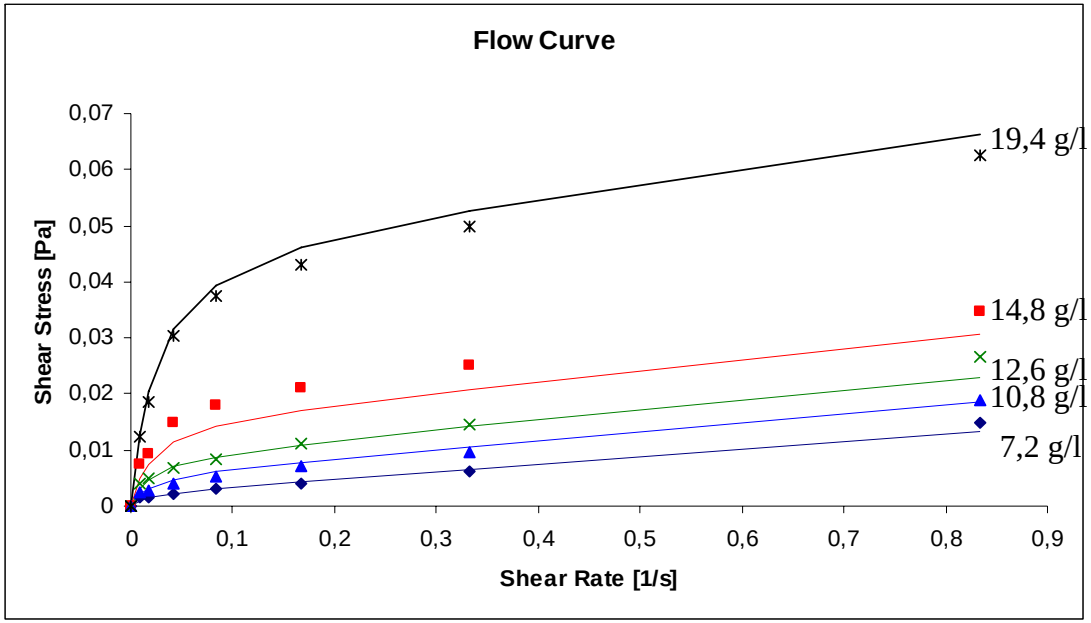


Settling velocity depending on concentration



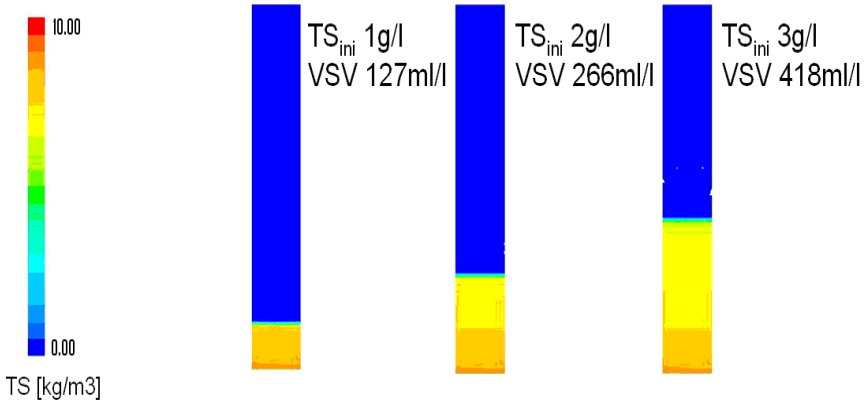
Rheology

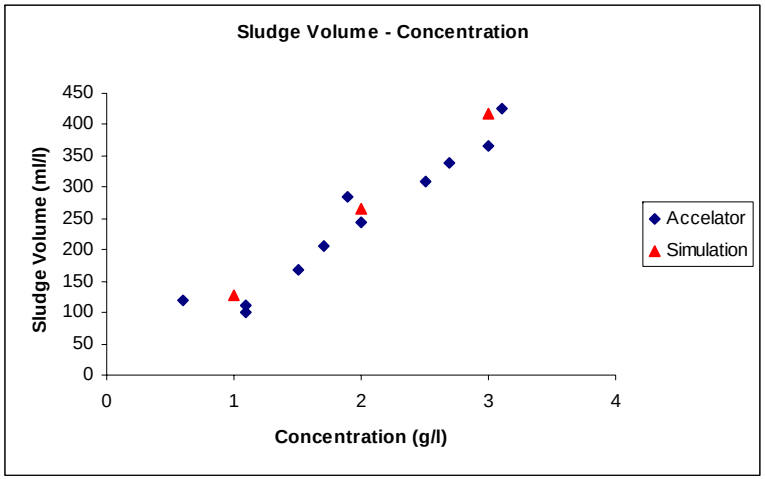
- Non Newton fluid
- Shear thinning
- Viscosity depending on concentration



Validation of sludge modell

- The settling test was simulated with FLUENT
- The results were compared with the measurements
- Simulation and measurements fit quite well according to sludge volume





The sludge model

TECHNISCHE UNIVERSITÄT DARMSTADT

- Sludge is modeled with a „user defined scalar“ (uds) and contains of following components:

Convection	Settling velocity depends on concentration
Diffusion	Turbulent diffusion depends on density gradients („full buoyancy effect“)
Viscosity	Viscosity depends on concentration and shear rate
Density	Density depends on concentration

The sludge model

TECHNISCHE UNIVERSITÄT DARMSTADT

- Components which will be developed in further research projects:

Convection	Settling velocity, regarding low concentrations
Viscosity	Viscosity of low concentrated sludge, Yield stress, Time dependent viscosity
Parameter Identification	Mathematical Optimization of model parameters

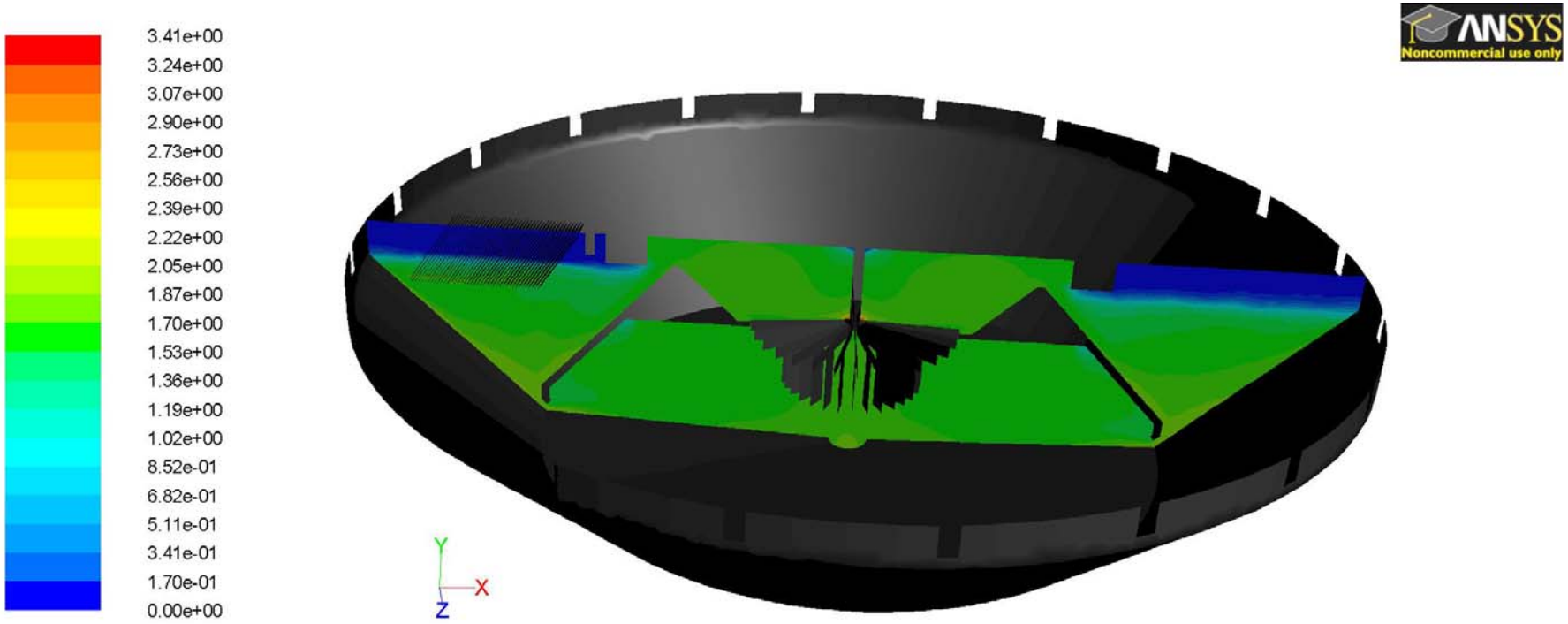
Multiphase or Singlephase?

TECHNISCHE UNIVERSITÄT DARMSTADT

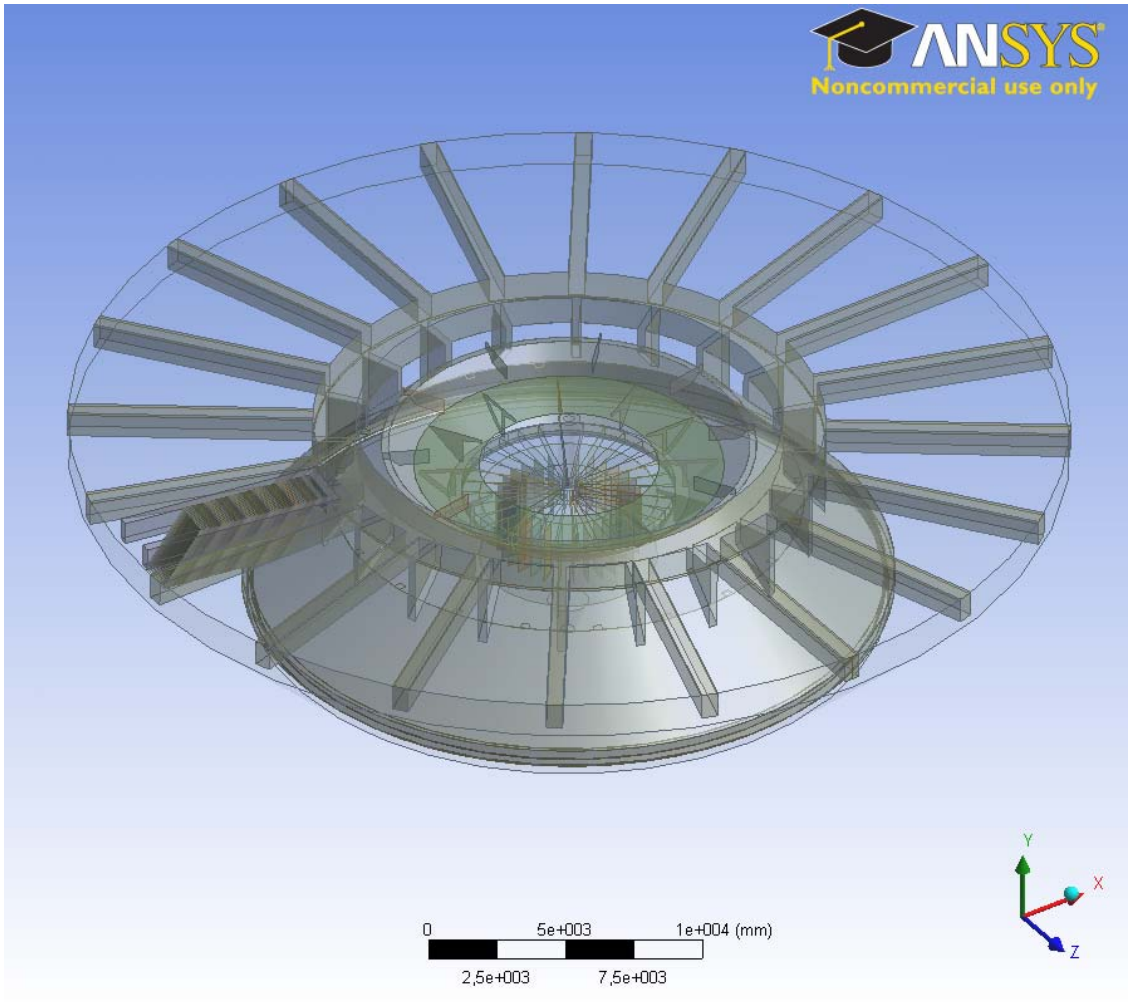
- Even though the sludge model is a singlephase approach it interacts intensively with the flow regime
- Advantage: no particle size of flocs required to determine the settling velocity
- Modelling of sludge with multiphase approachs also possible, but require complex models to describe the variation and distribution of particle sizes
- Singlephase approach requires less computational efforts
- To model the sedimentation process a relatively long flow time is required. Example for this case: 12 cores, 8 Mio cells, 3.600 seconds flow time, ~30.000 iterations à 20 seconds/iter → 1 week per calculation

4 Variations of lamella clarifier: different slope and distance between lamellas (5 or 10cm)

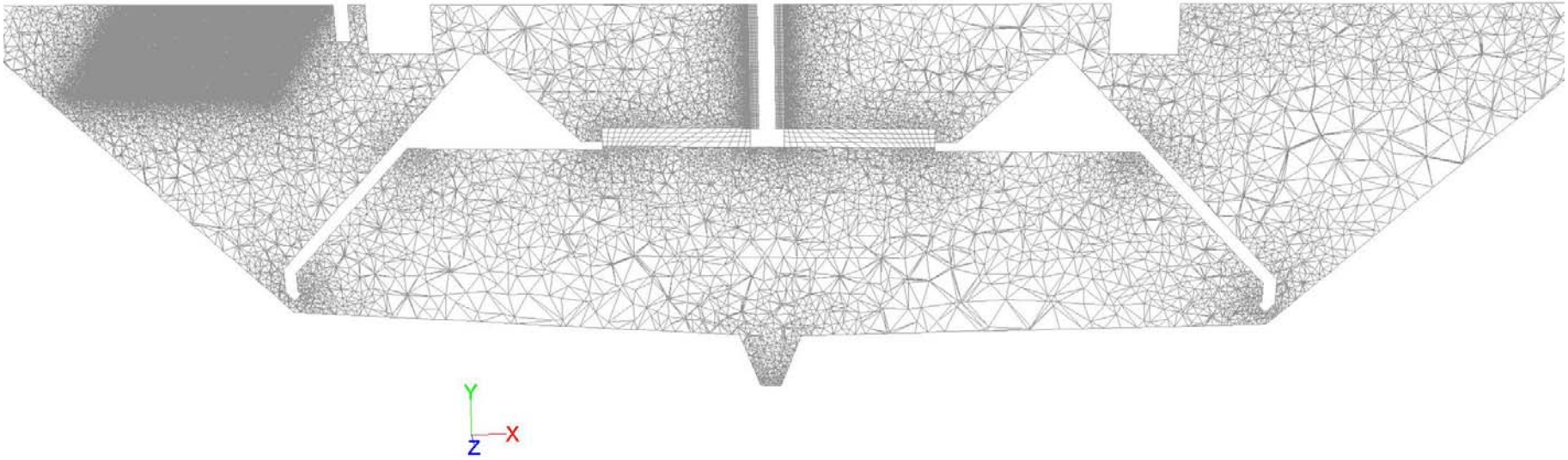
TECHNISCHE UNIVERSITÄT DARMSTADT



Geometry


ANSYS
Noncommercial use only
0
5e+003
1e+004 (mm)
2,5e+003
7,5e+003
Y
X
Z

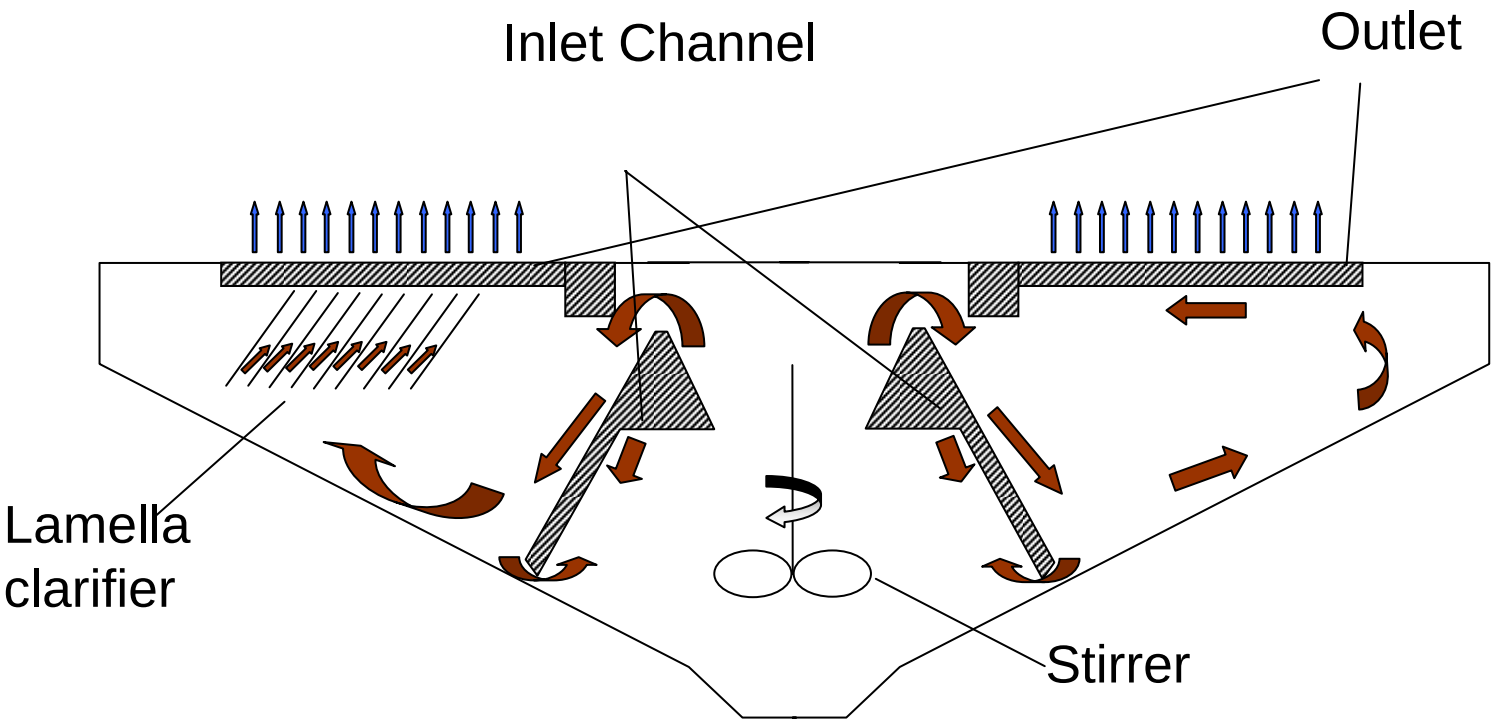
Grid: between 6 and 13 Mio cells



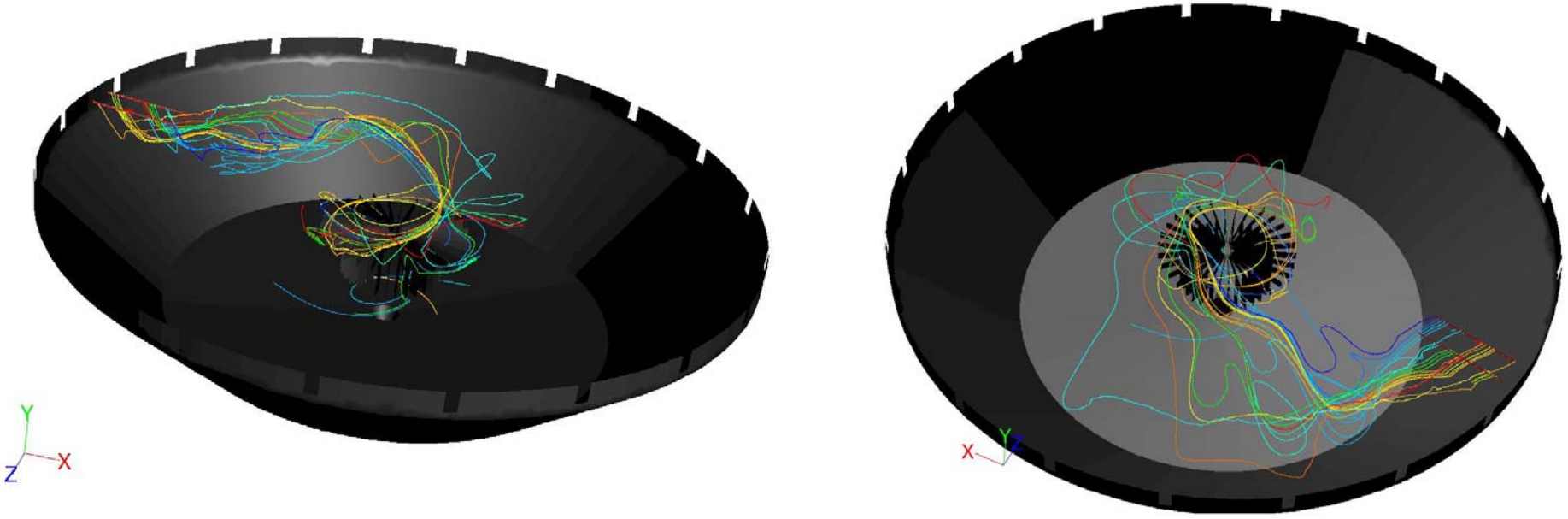
Mesh (Time=3.6005e+03)

Apr 28, 2011
ANSYS FLUENT 12.1 (3d, pbns, ske, transient)

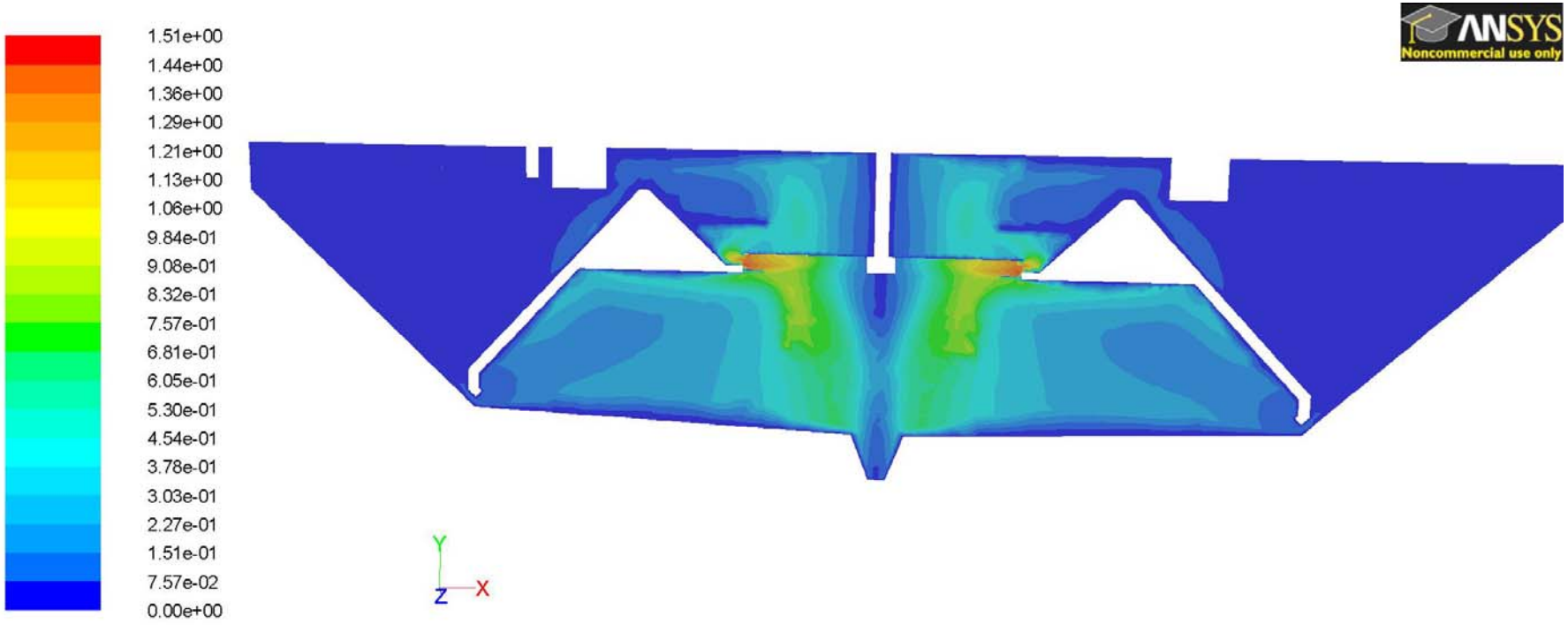
Scheme



Pathlines



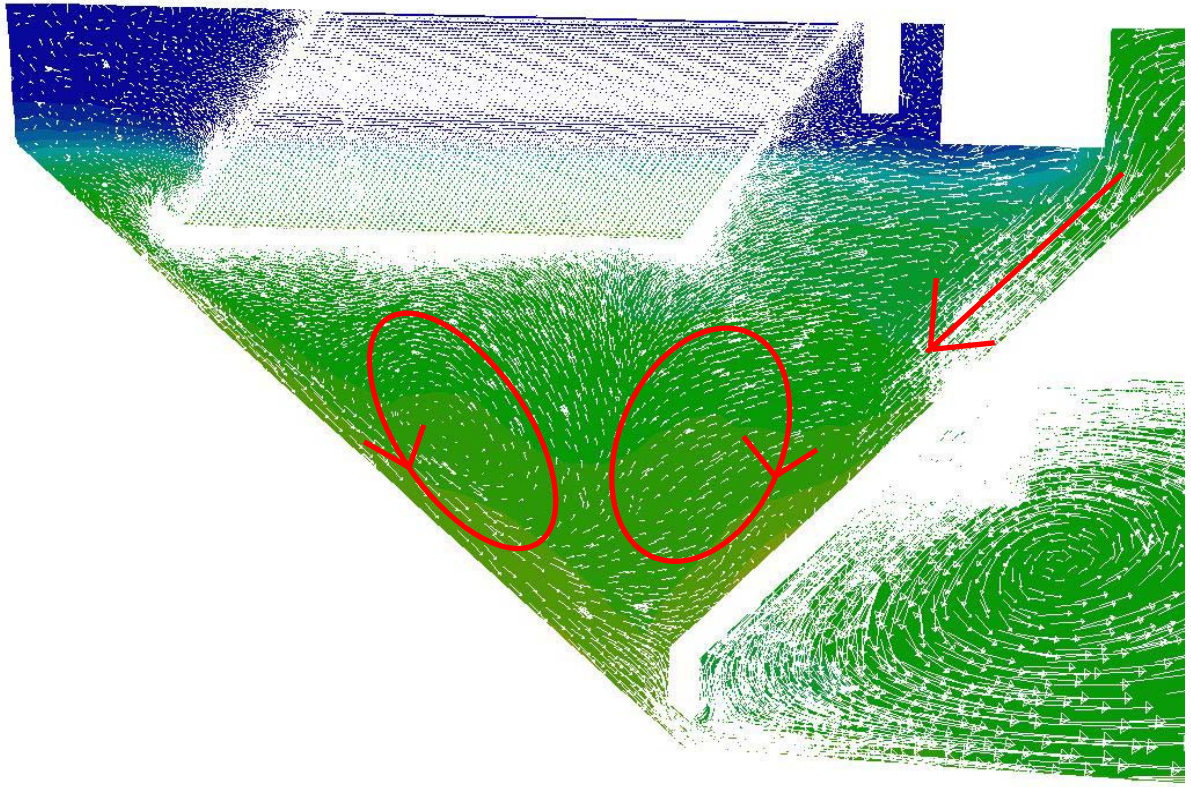
Velocity



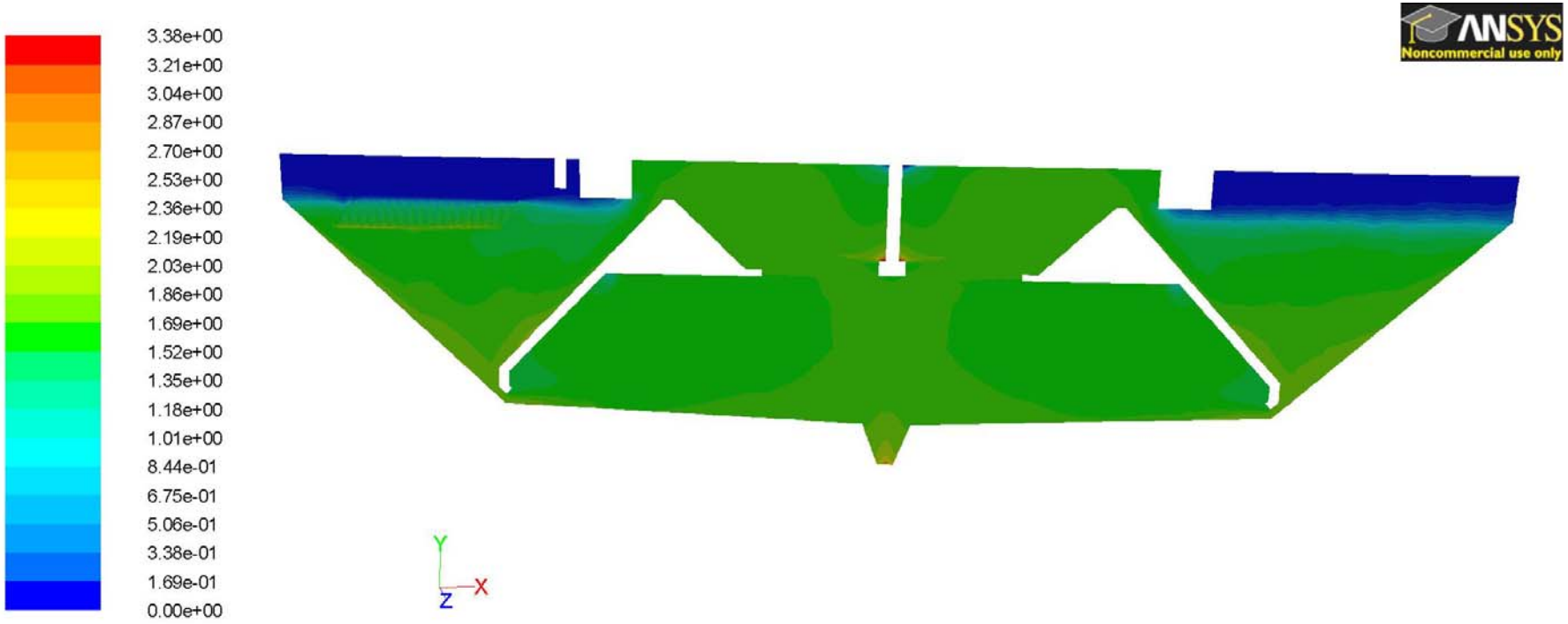
Contours of Velocity Magnitude (m/s) (Time=3.6005e+03)

Apr 28, 2011
ANSYS FLUENT 12.1 (3d, pbns, ske, transient)

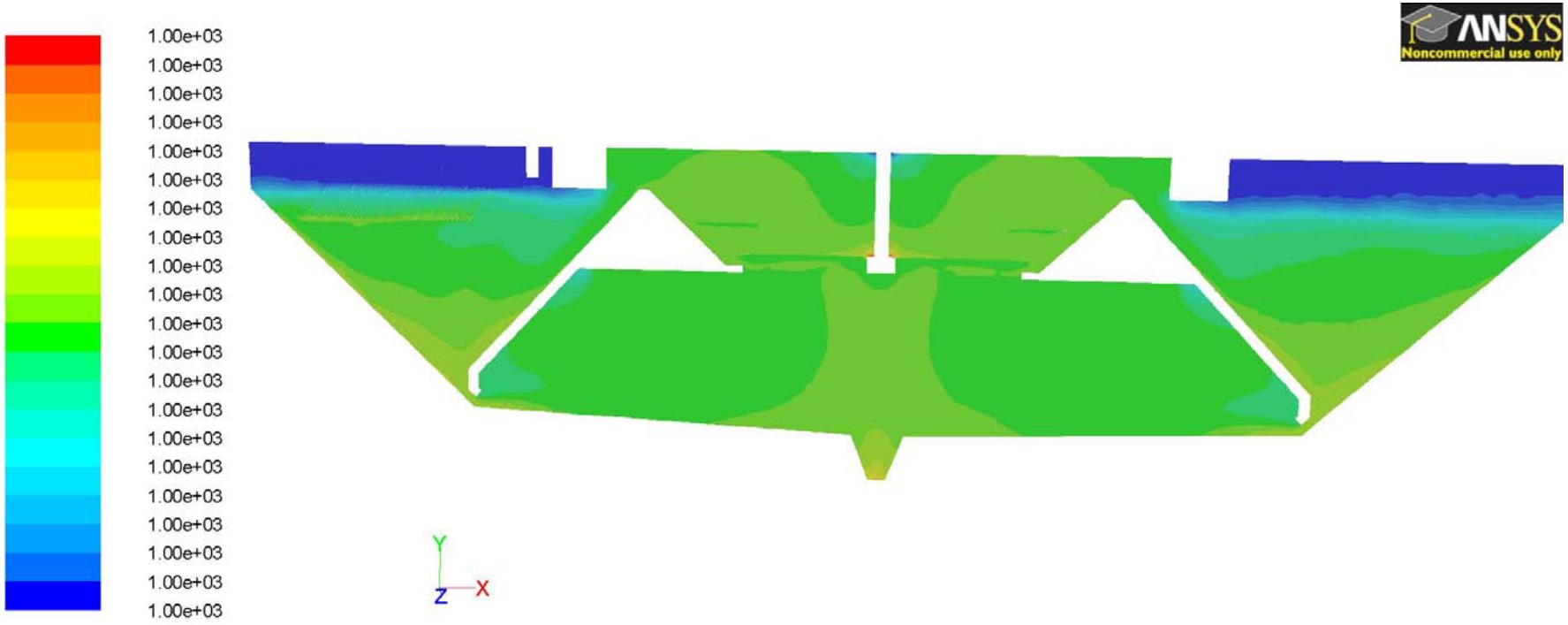
Flow regime



Sludge concentration



Density

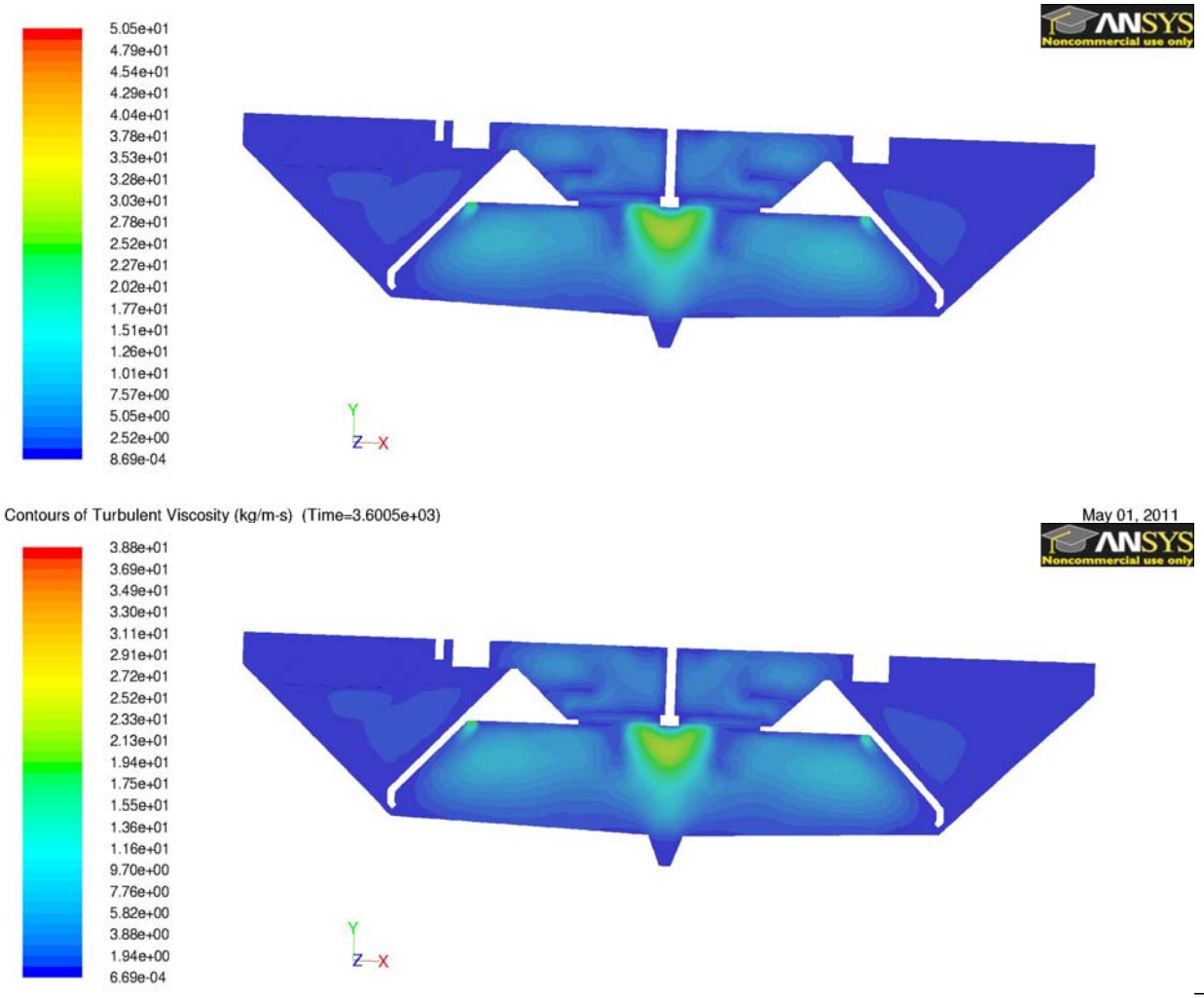


Contours of Density (kg/m3) (Time=3.6005e+03)

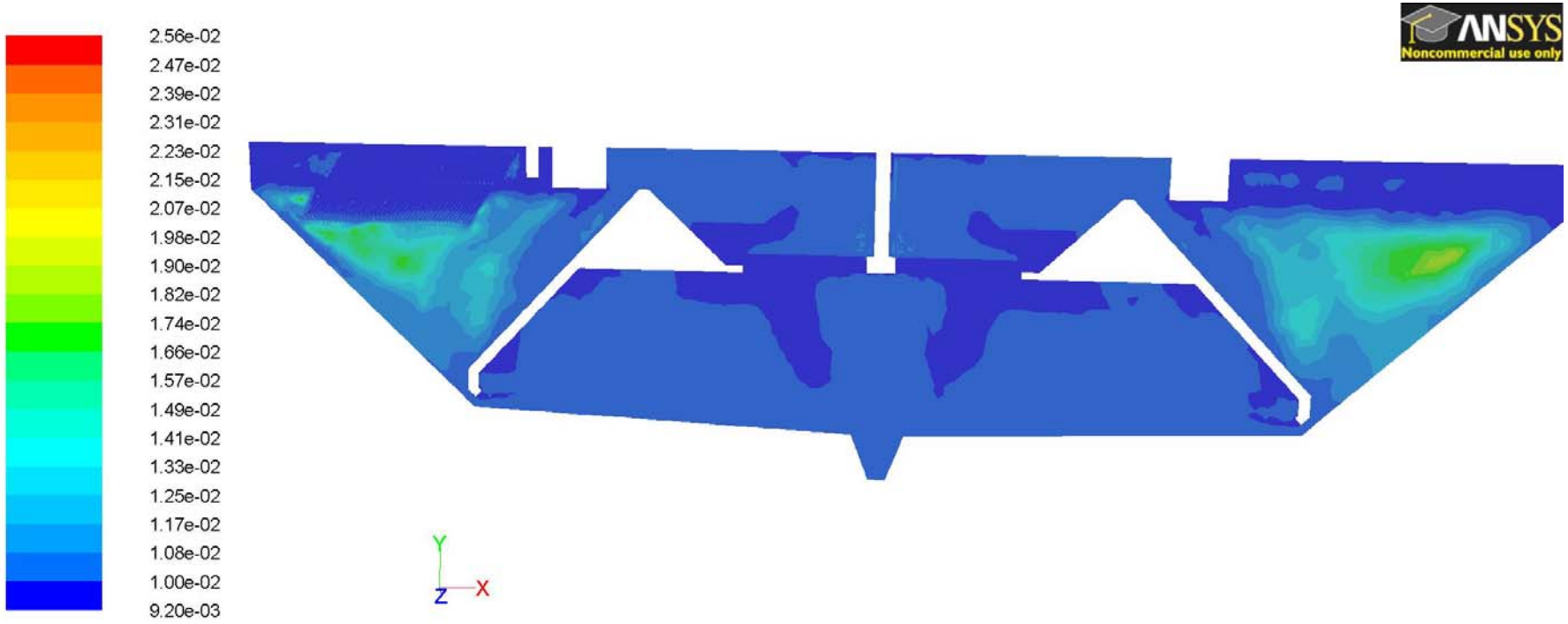
Apr 28, 2011
ANSYS FLUENT 12.1 (3d, pbns, ske, transient)

Coupling turbulent viscosity - diffusion coefficient (Schmidt Number 1.3)

TECHNISCHE UNIVERSITÄT DARMSTADT



Molecular viscosity

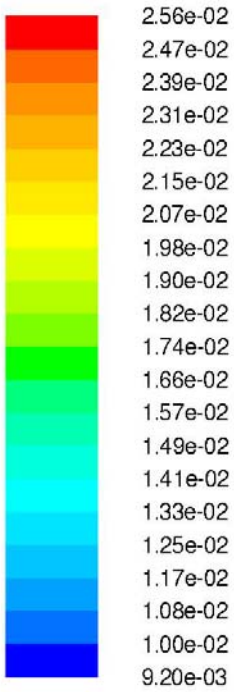


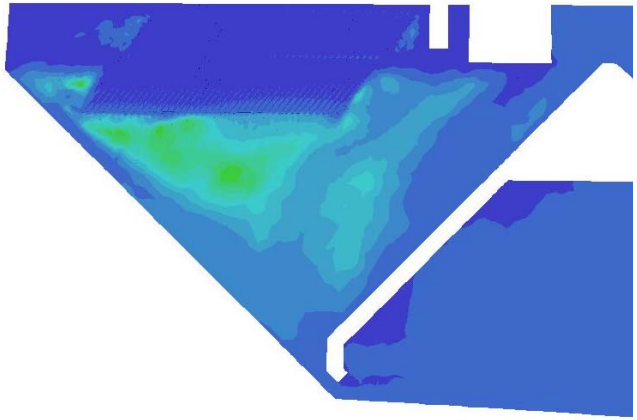
Contours of Molecular Viscosity (kg/m-s) (Time=3.6005e+03)

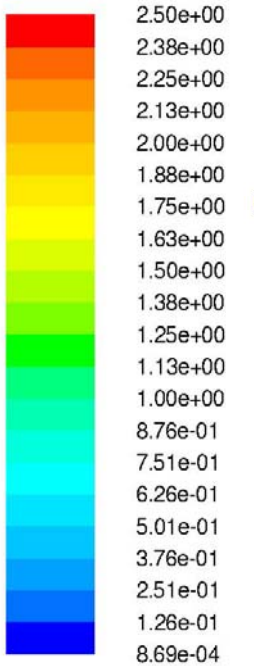
Apr 28, 2011
ANSYS FLUENT 12.1 (3d, pbns, ske, transient)

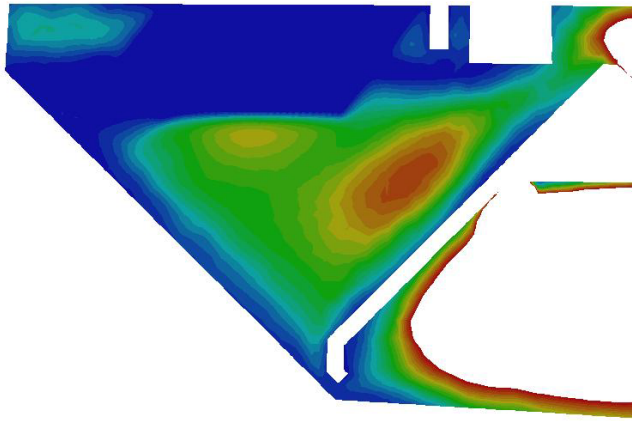
Molecular viscosity vs. turbulent viscosity in the sedimentation zone

TECHNISCHE UNIVERSITÄT DARMSTADT

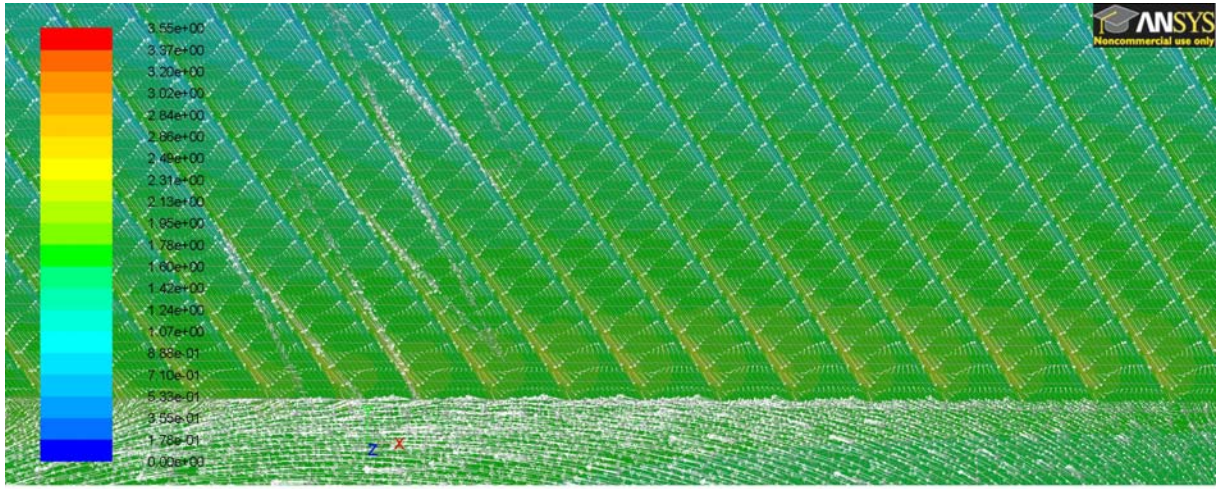




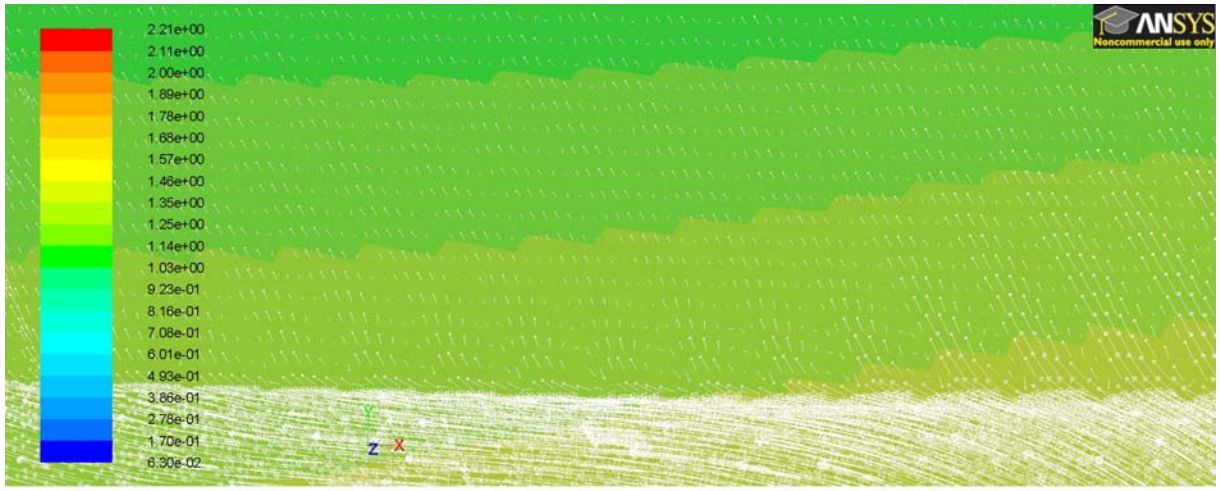




Grid effects



13 cell rows between lamellas: backflow of highly concentrated sludge



7 cell rows between lamellas: no backflow of highly concentrated sludge

Contours of Scalar-0 (Time=3.6013e+03)

Apr 28, 2011
ANSYS FLUENT 12.1 (3d, pbns, ske, transient)

Results

TECHNISCHE UNIVERSITÄT DARMSTADT

- Results can be seen only in comparison between the simulations. For validation on the real plant the lamella clarifier has to be built and measurements have to be taken to compare simulation with reality.
- Sludge concentration at the outlet of lamella clarifier are 2 (10cm distance) to 5 (5cm distance) orders of magnitude lower than without
- The slope has no significant effect on the flow regime or the outlet concentration
- The grid quality is very important for the results
- Further research is necessary to improve the sludge model and to verify it with the real plant

Thank you for your attention

TECHNISCHE UNIVERSITÄT DARMSTADT

Zweckverband Landeswasser-versorgung