COLLEGE OF ENGINEERING
UNIVERSITY of WASHINGTON

Numerical Modeling of Hydrokinetic Turbines and their Environmental Effects

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IMPSO - Sept.23.2010

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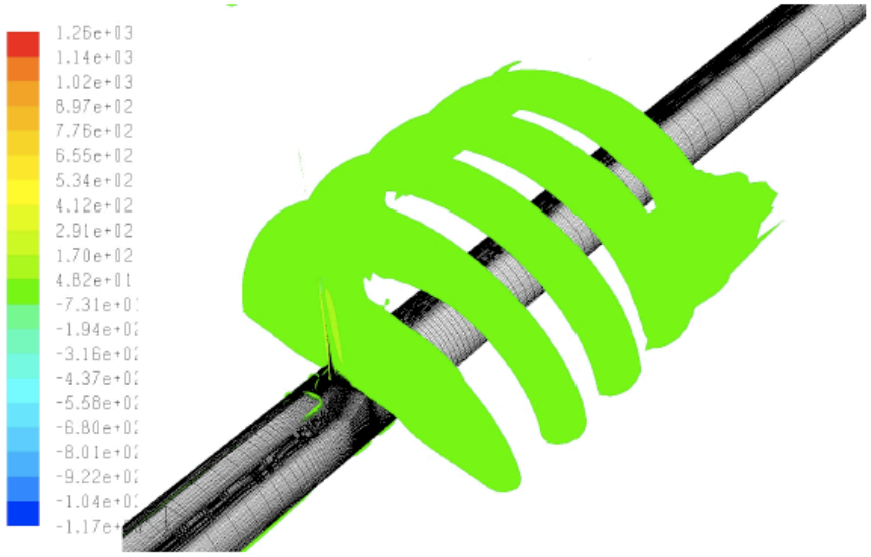
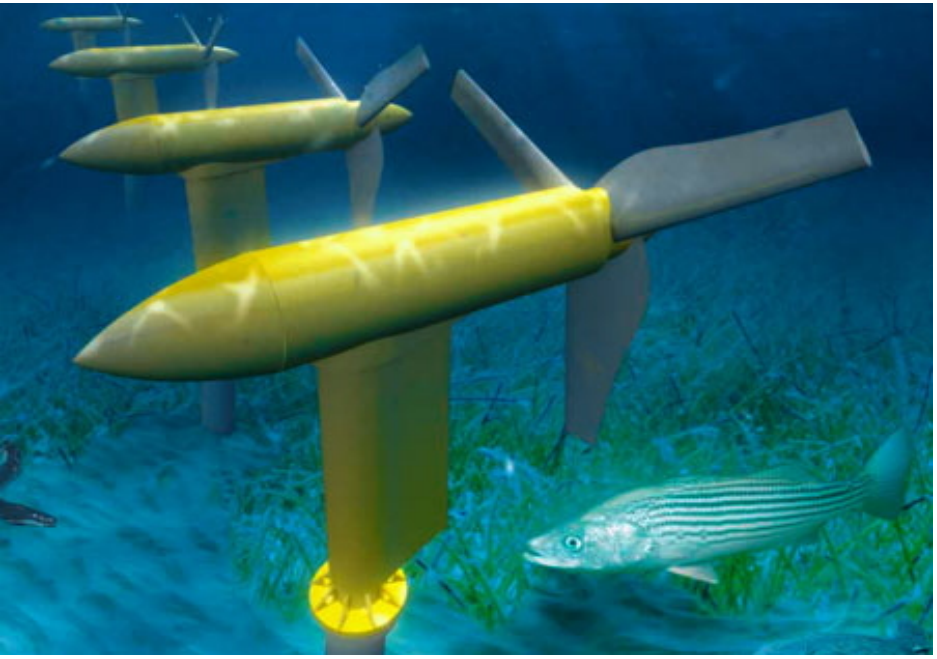
Motivation

Methodology development for numerical modeling of tidal turbines :

- Optimized distance in a turbine farm
- Simulating the flow around blades
- Modeling the turbulent wake
- Blade design





Understanding and minimizing the potential environmental impacts of tidal turbines:

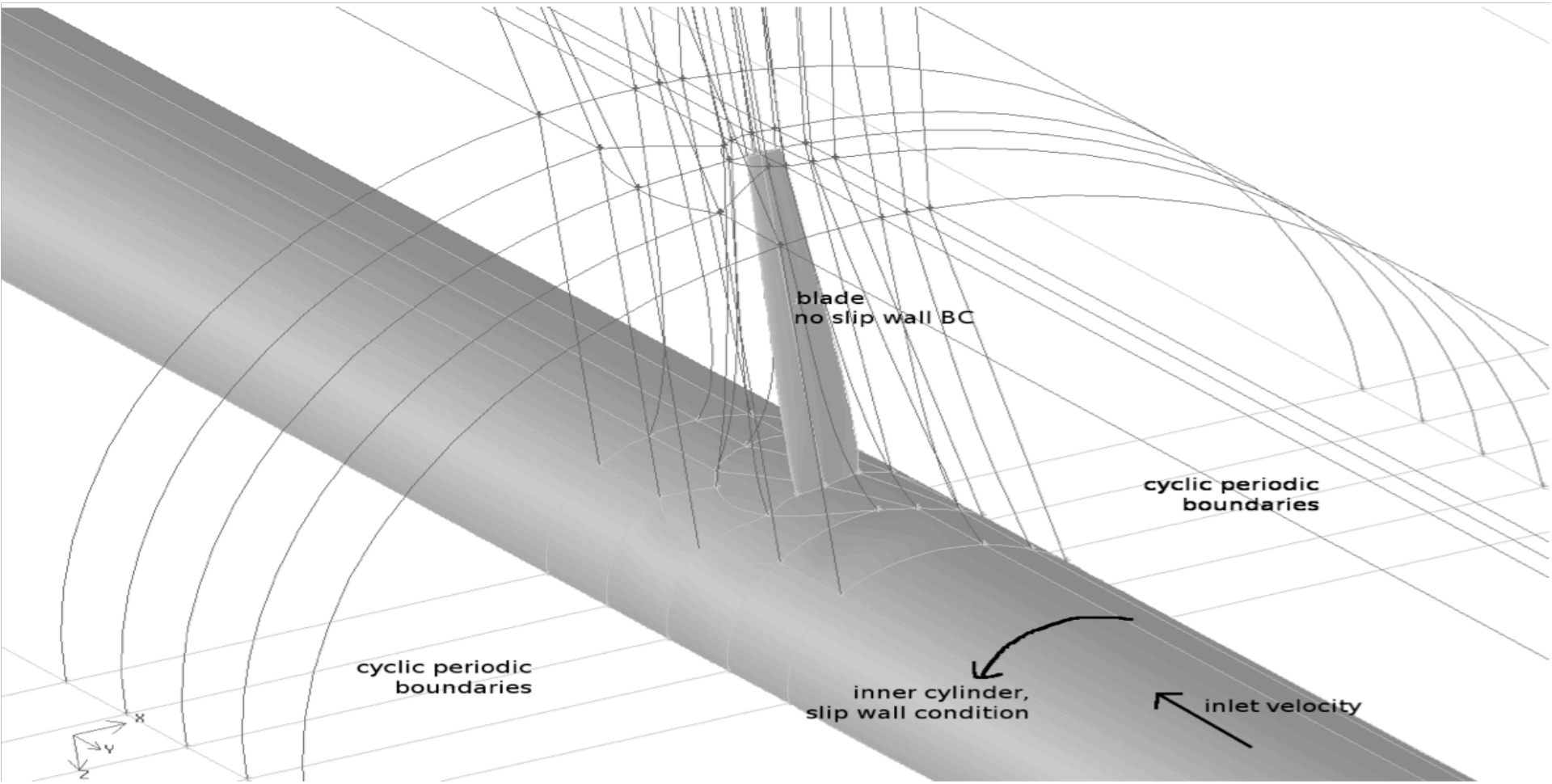
- Sediment transport
- Effects on marine species

Outline

- Benchmarking numerical models:
  - NREL Phase VI wind turbine
  - Single Reference Frame (SRF)
  - Virtual Blade Model (VBM)
  - Actuator Disk Model (ADM)

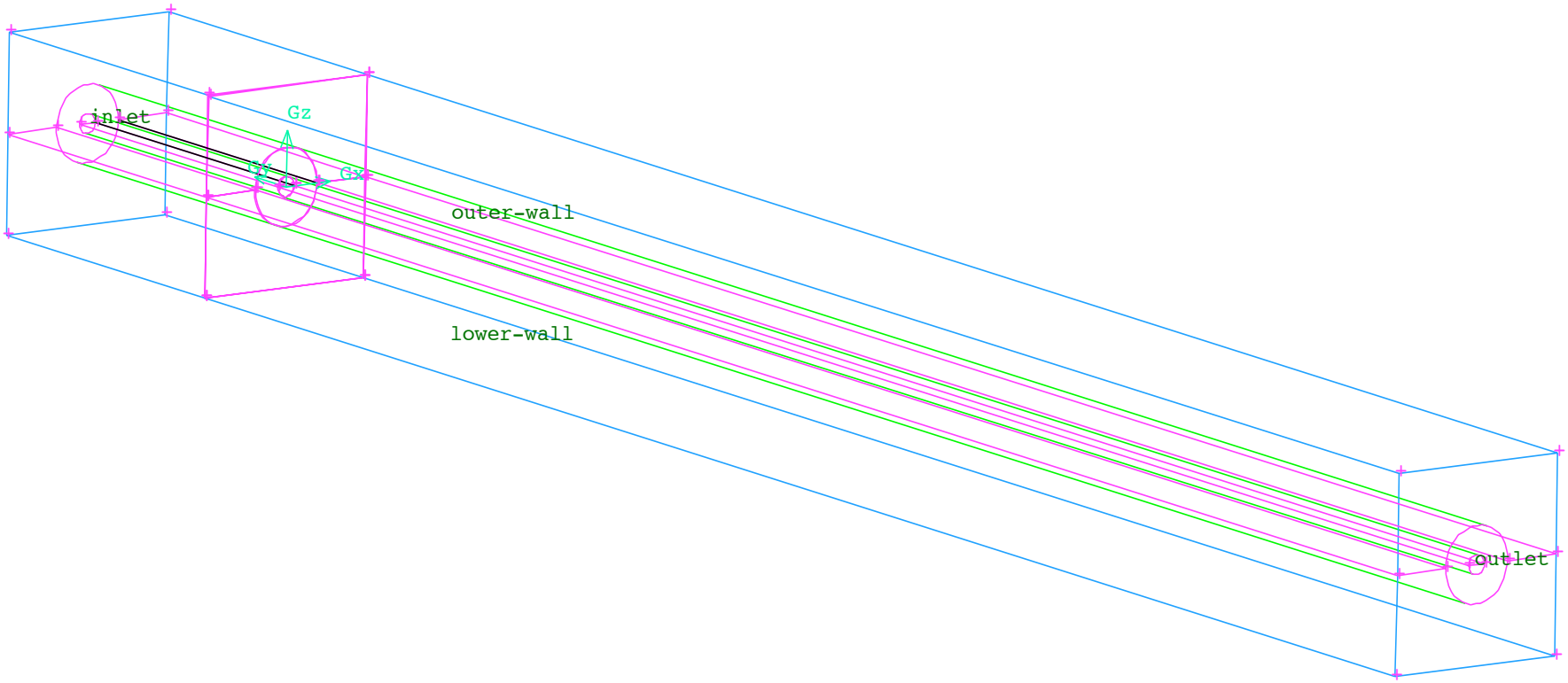
- Considering potential environmental effects:
  - Turbine effect on suspended particles sedimentation process.

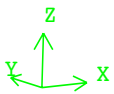
Numerical Models



Single Reference Frame (SRF)

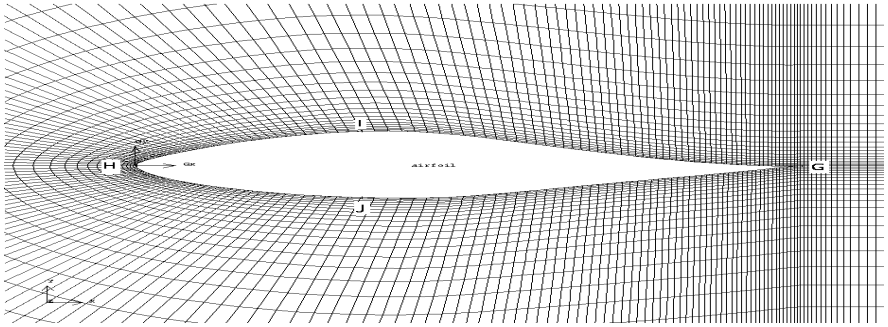
Numerical Models





Virtual Blade Model (VBM)
Actuator Disk Model (ADM)

Validation of SRF Methodology Against Experimental Data from AMES Wind Tunnel (NREL Phase VI turbine).



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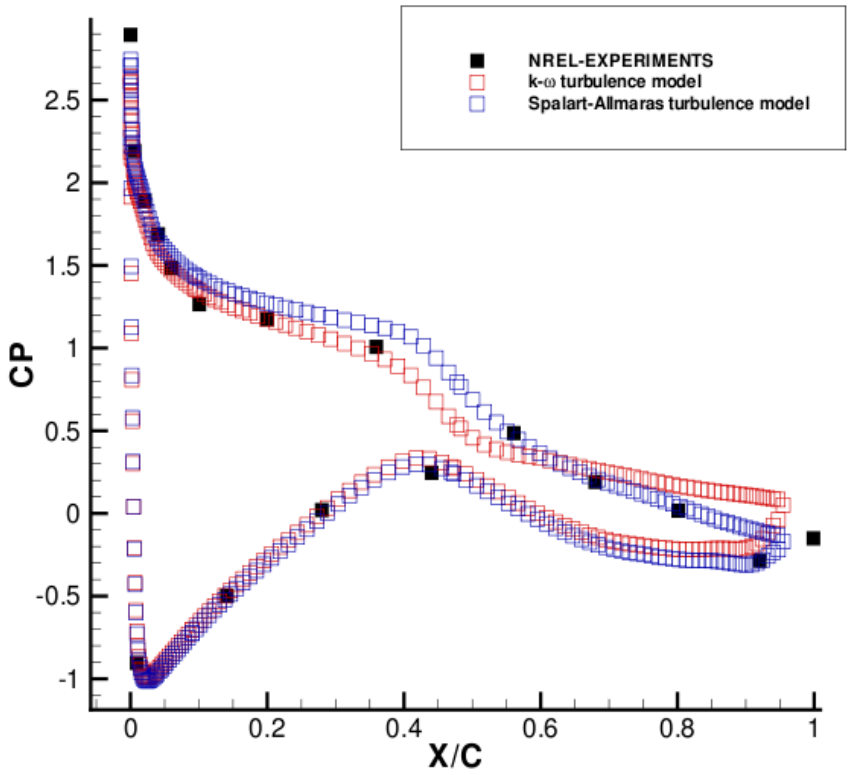

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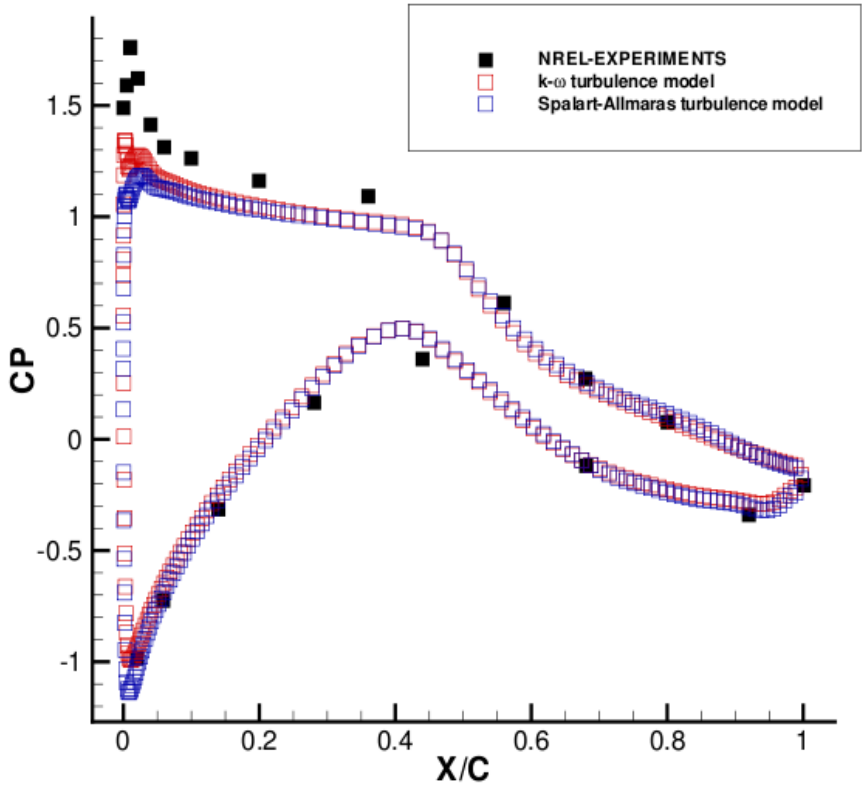
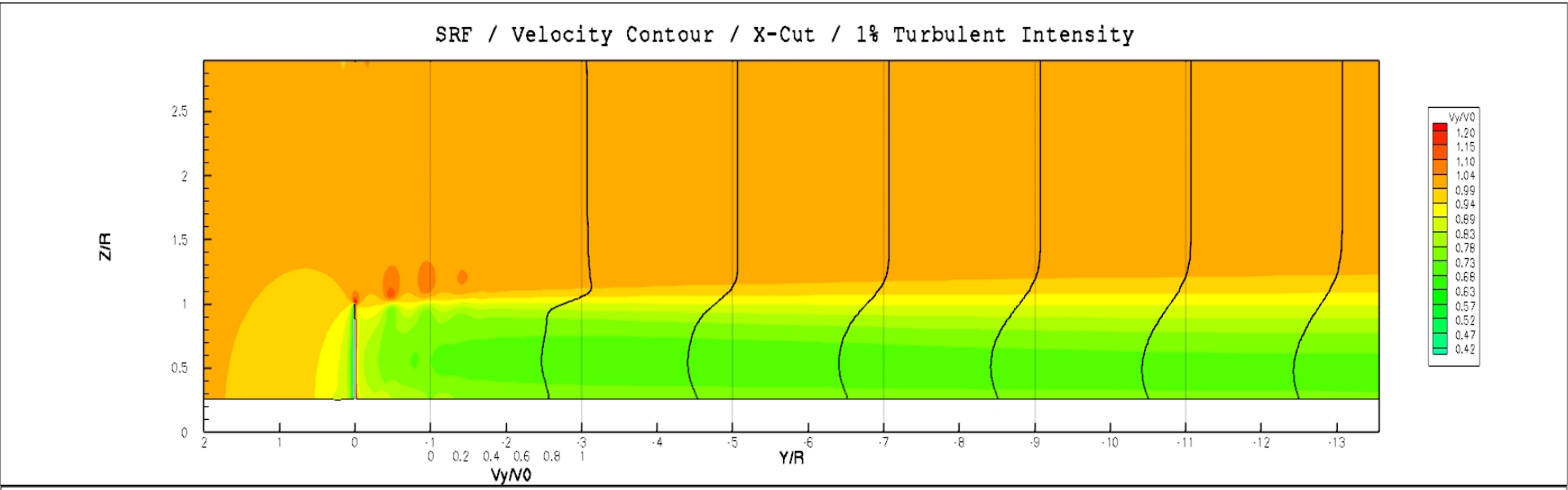
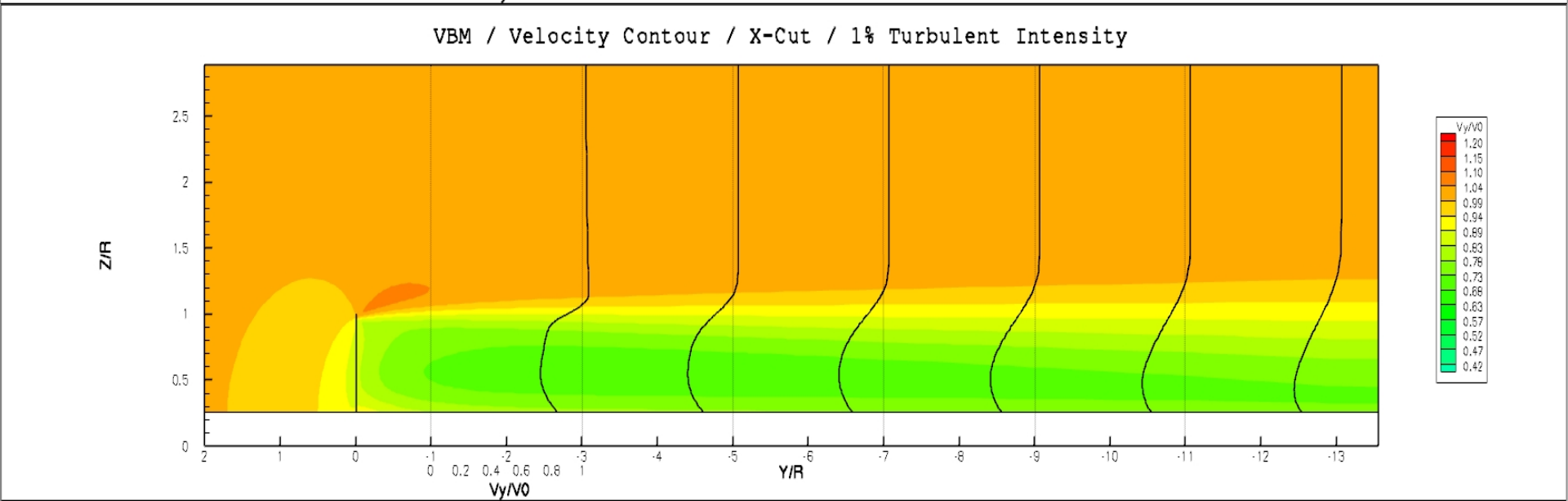


Validation of VBM with SRF Results





Application of Numerical Models to Quantify the Potential Environmental Effects

- Apply VBM to model particle settling in the tidal turbine wake.

- Apply SRF to look at potential effects of blade tip vortices and pressure fluctuations due to turbine turbulent wake on marine species (Will not be discussed in this talk).

Modeling Suspended Particle Sedimentation Process

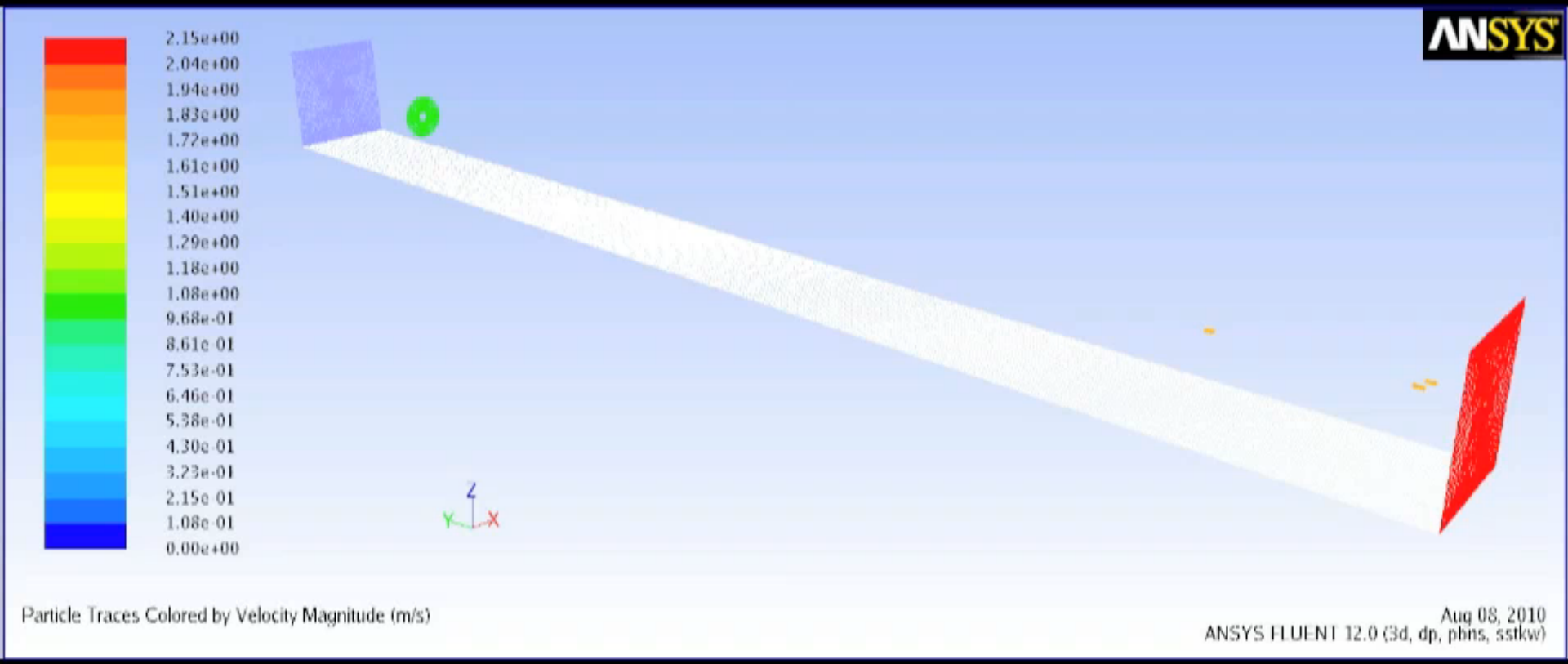
Video was captured by NNMREC during on of the field works.

Modeling Suspended Particle Sedimentation Process

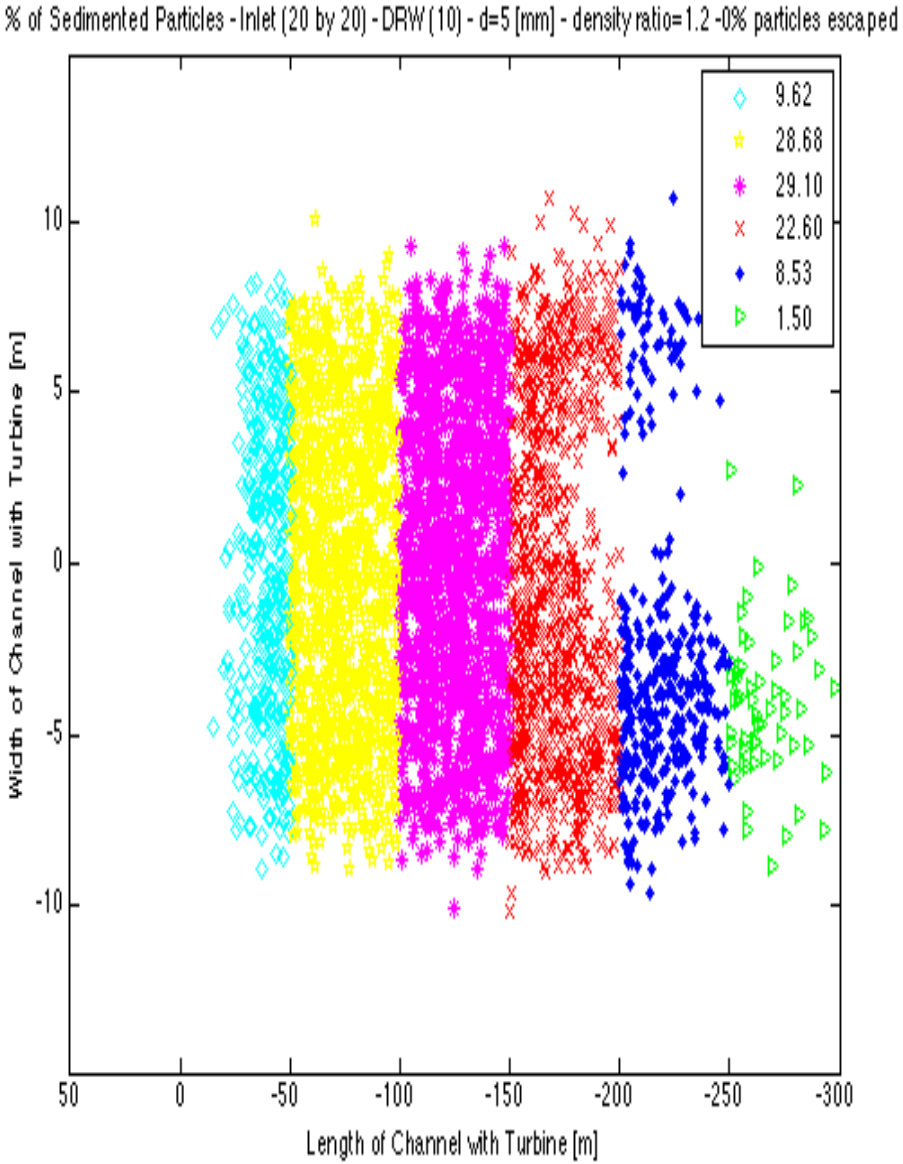
- VBM is used to study the particles sedimentation
- Particles are modeled as simple sphere
- Discrete Random Walk (DRW) model

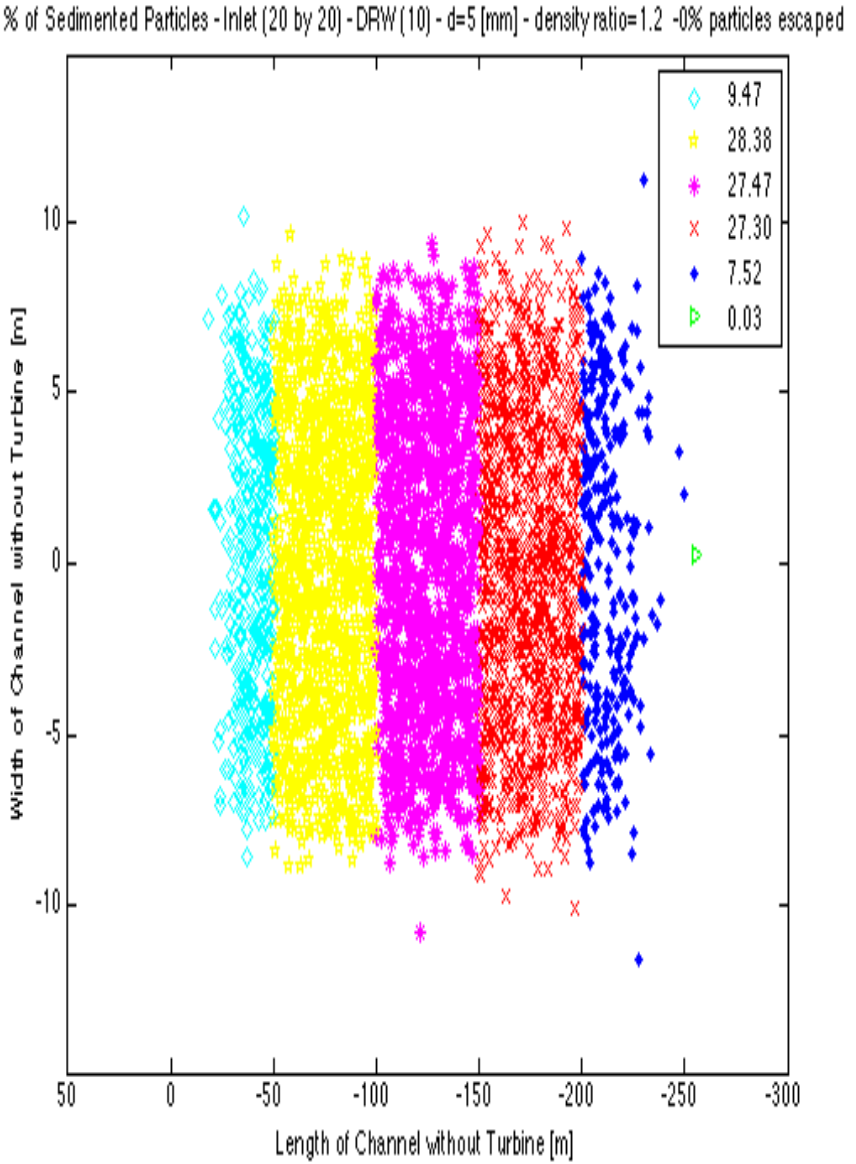
Place of injection grid	Injection grid size	Number of tries for DRW model	Total number of injected particles	Diameters of injected particles	Density ratio w.r.t water
Inlet of the channel	20 by 20	10	4000	100 [μm] 1 [mm] 5 [mm] 1 [cm]	1.2

Particles Motion Along the Tidal Channel (VBM)

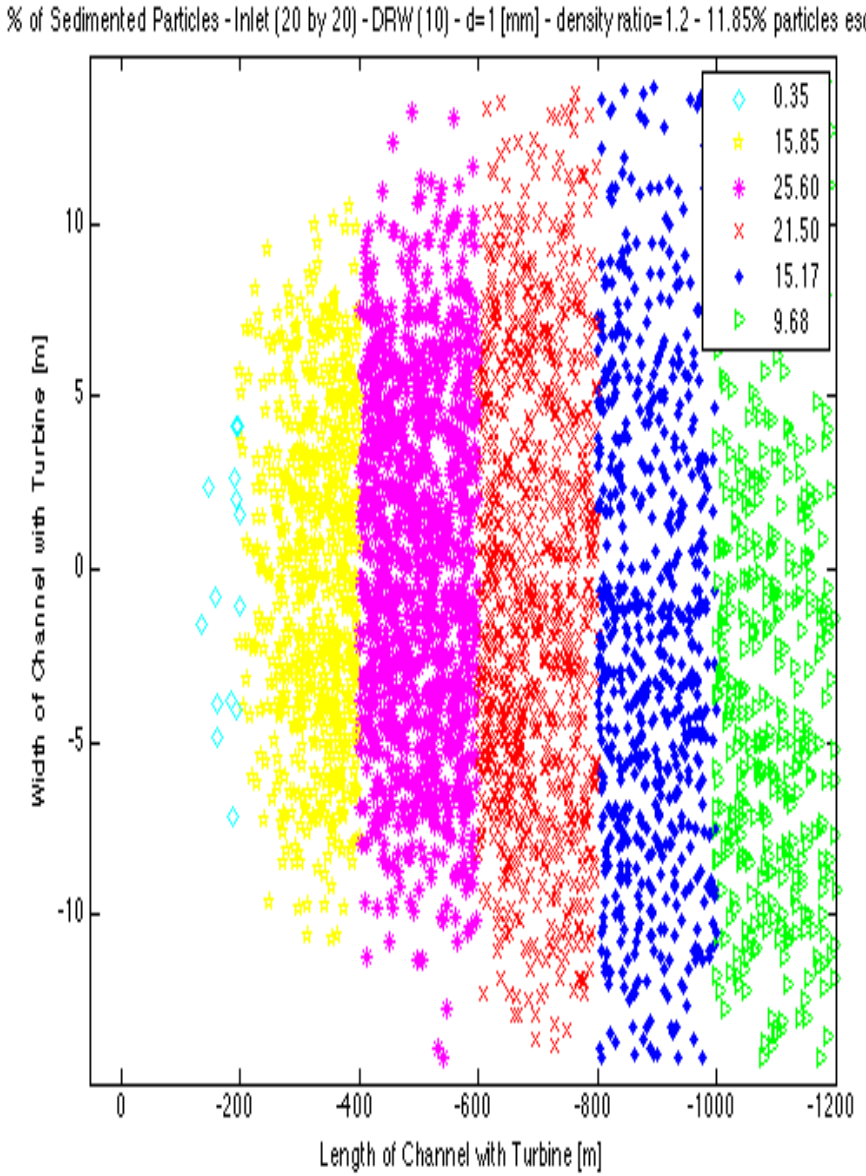


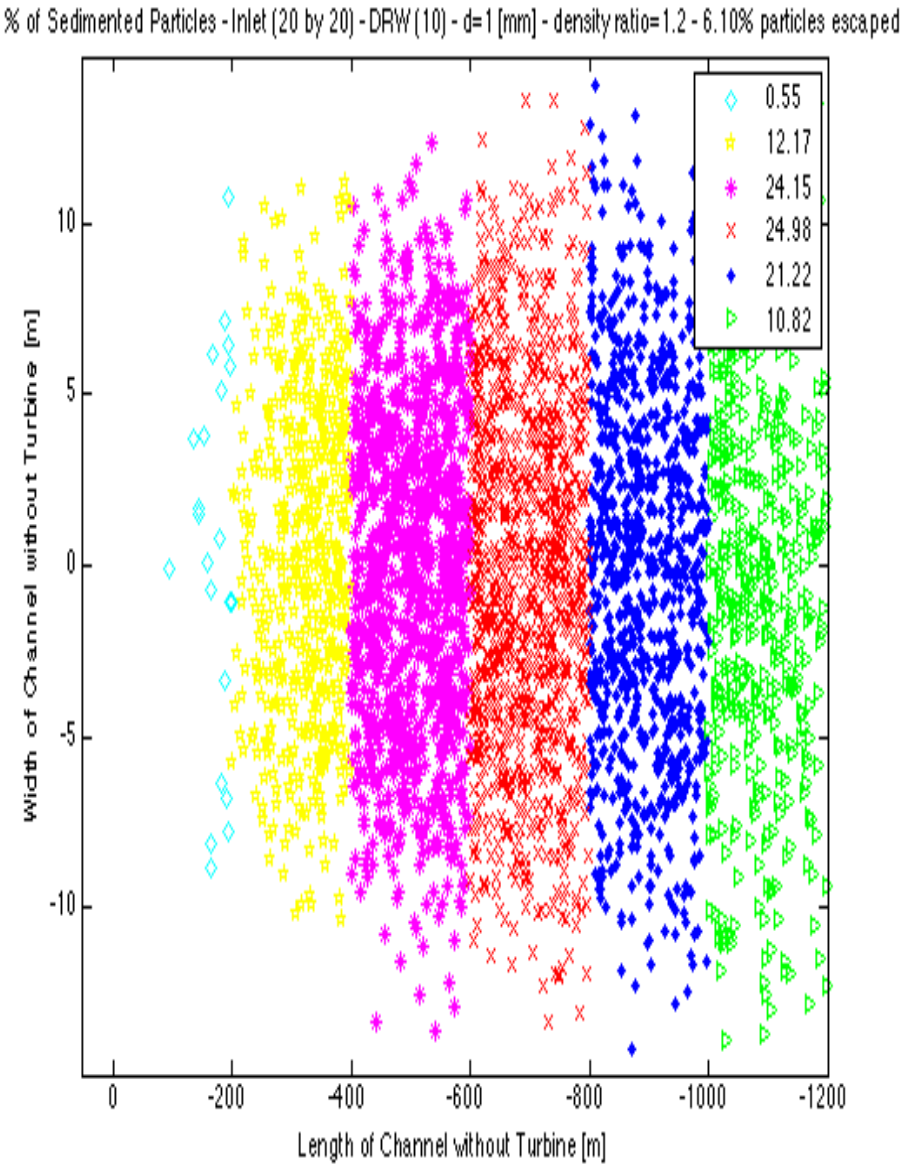
Top view of the Channel - Turbine at (0,0) - 5 [mm] - Left with Turbine - Right no Turbine





Top view of the Channel - Turbine at (0,0) - 1 [mm] - Left with Turbine - Right no Turbine

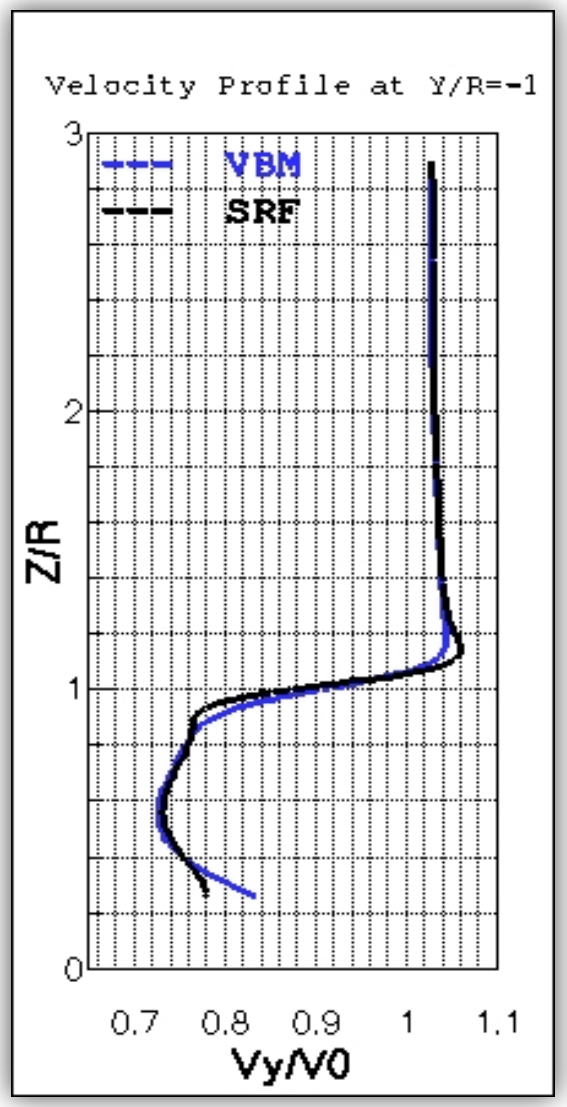


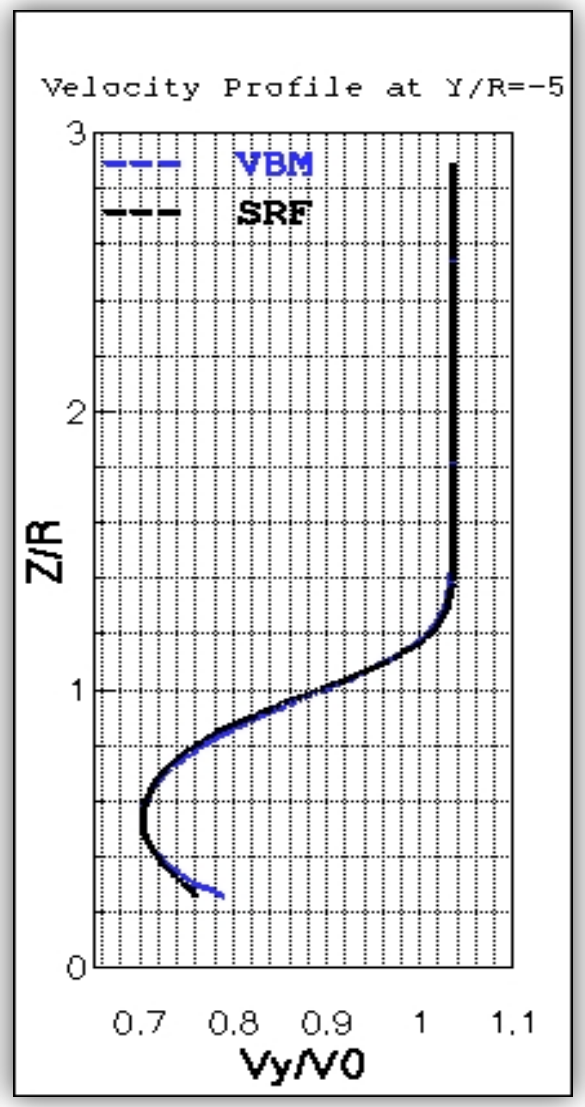


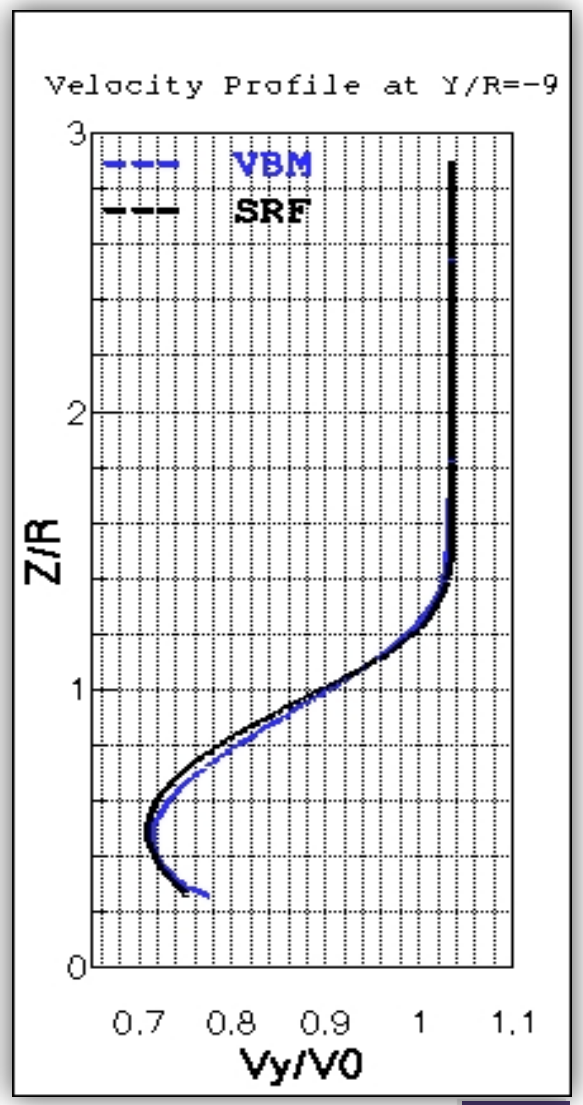
Summary and Future Work

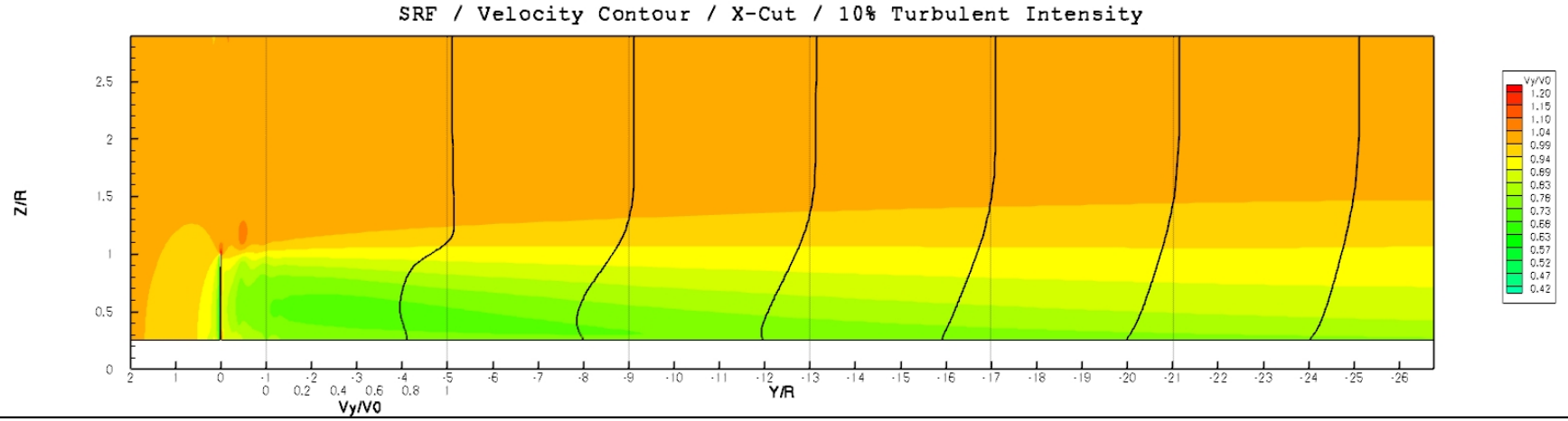
- Hierarchy of models to simulate the turbulent wake of a well characterized wind turbine (NREL Phase VI) has been developed and validated.
- Validated models has been modified to simulate a hydrokinetic turbine with realistic boundary conditions.
- Preliminary effects of turbine wake on particles settling has been studied and improvement for modeling has been investigated.
- Modeling the hub of the turbine with ideas from simpler models.
- Modeling array of devices in a farm of turbine with goal of array optimization.

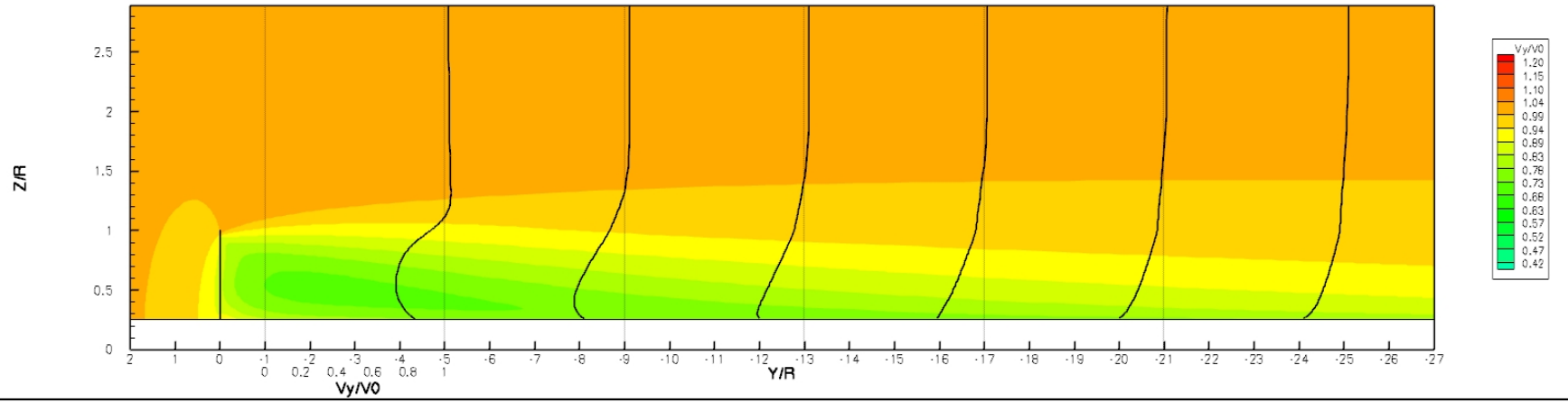
Validation of VBM with SRF Results








SRF / Velocity Contour / X-Cut / 10% Turbulent Intensity
Z/R
Y/R
Vy/V0
Vy/V0
1.20
1.15
1.10
1.04
0.99
0.94
0.89
0.83
0.78
0.73
0.68
0.63
0.57
0.52
0.47
0.42


VBM / Velocity Contour / X-Cut / 10% Turbulent Intensity
Z/R
Y/R
Vy/V0
Vy/V0
1.20
1.15
1.10
1.04
0.99
0.94
0.89
0.83
0.78
0.73
0.68
0.63
0.57
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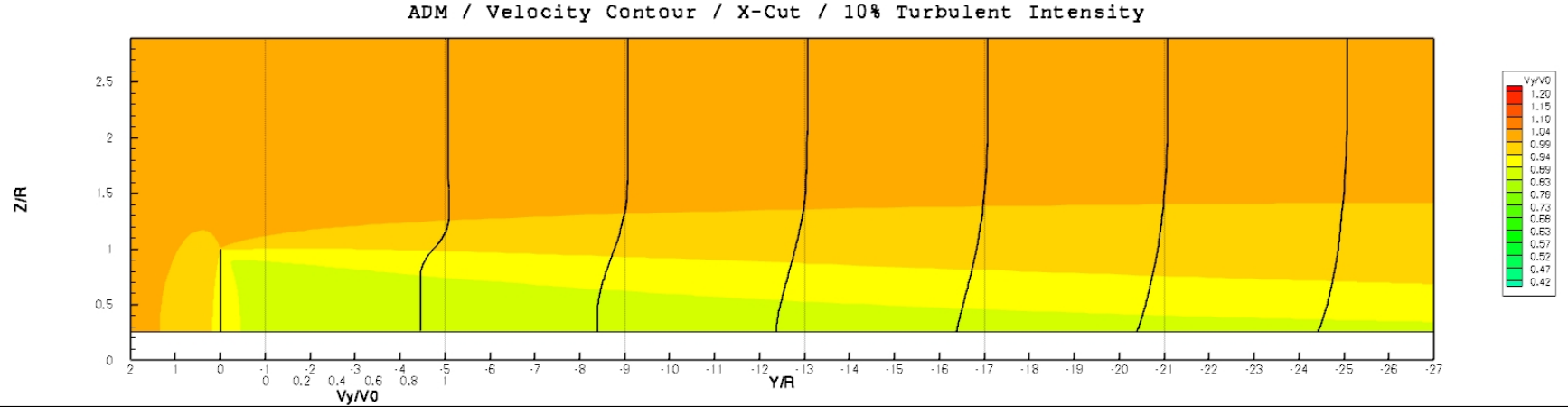
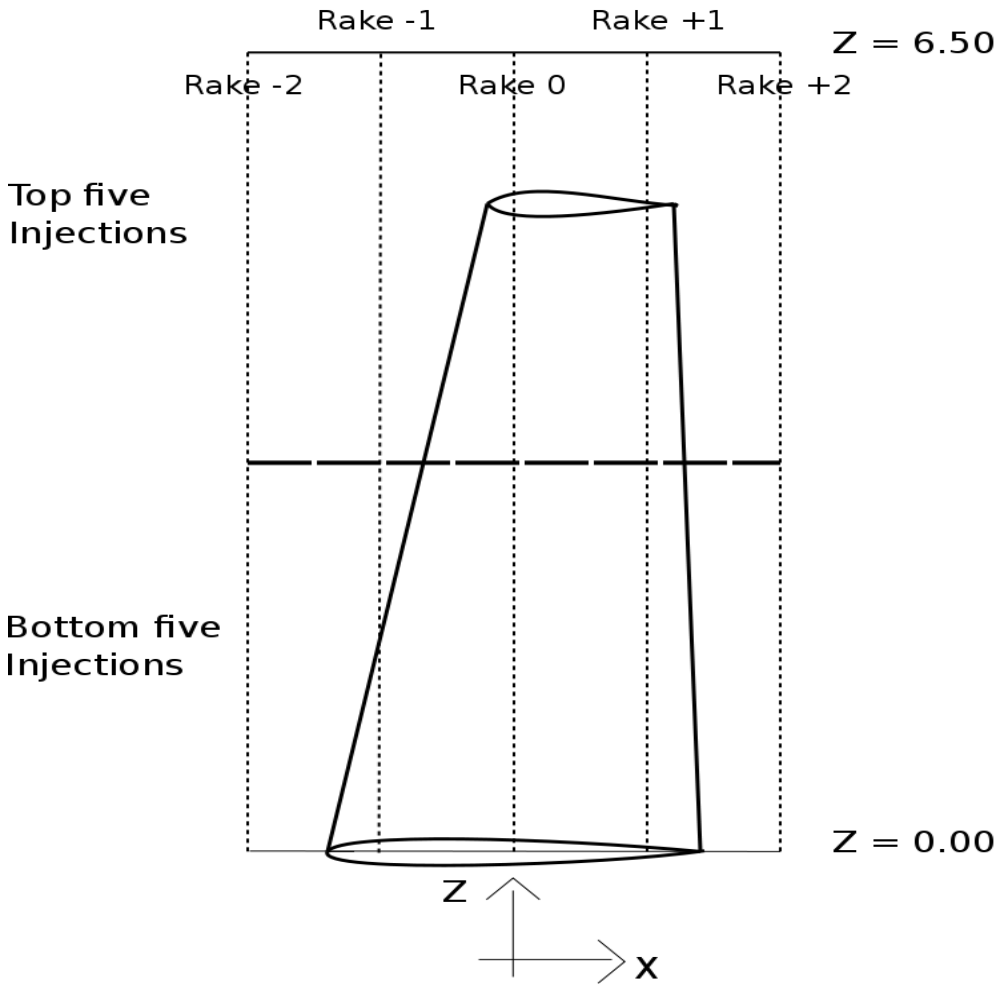
0.42

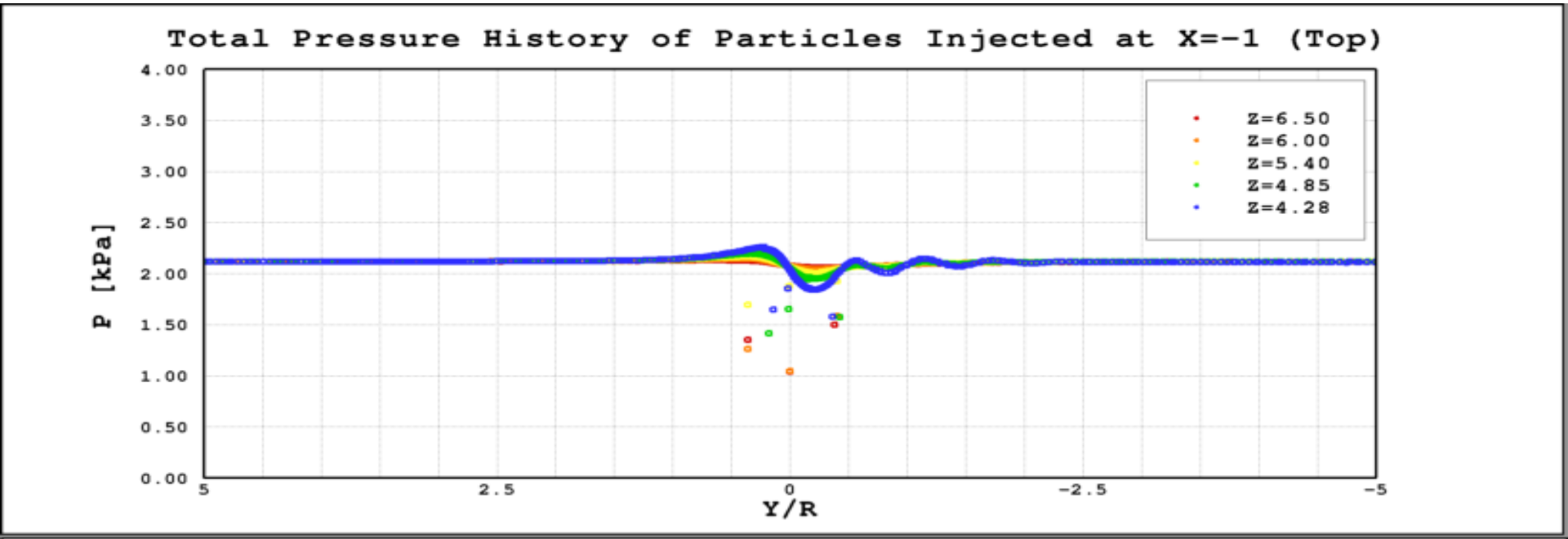

ADM / Velocity Contour / X-Cut / 10% Turbulent Intensity
Z/R
Y/R
Vy/V0
Vy/V0
1.20
1.15
1.10
1.04
0.99
0.94
0.89
0.83
0.78
0.73
0.68
0.63
0.57
0.52
0.47
0.42

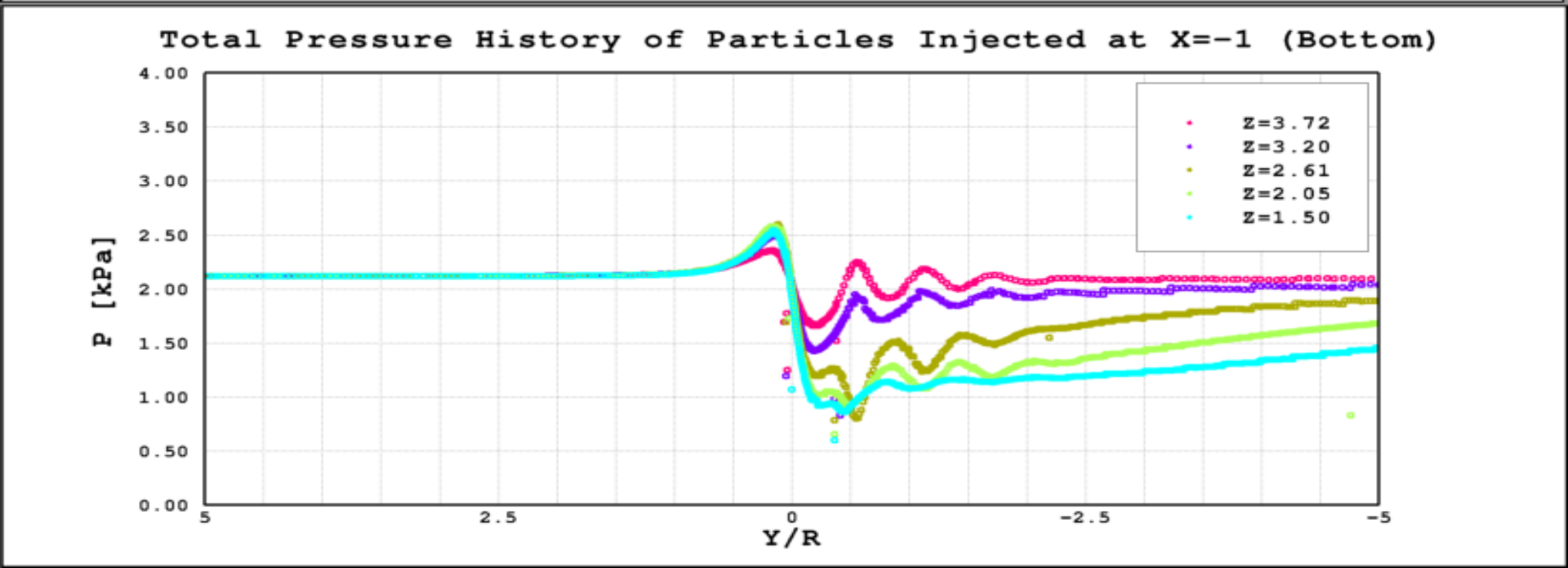
Turbine interaction with juveniles fishes.



Injection plane	Inlet
Grid	10 x 1 [evenly located particles on each rake]
Diameter	5 [mm]
Density ratio w.r.t water	0.95

Results for pressure fluctuation through turbines





Results for pressure fluctuation through turbines