



Far / near-field transition Case studies

Gerhard Jirka, Tobias Bleninger

*Institute for Hydromechanics
University Karlsruhe
Germany*

plant related regional impacts

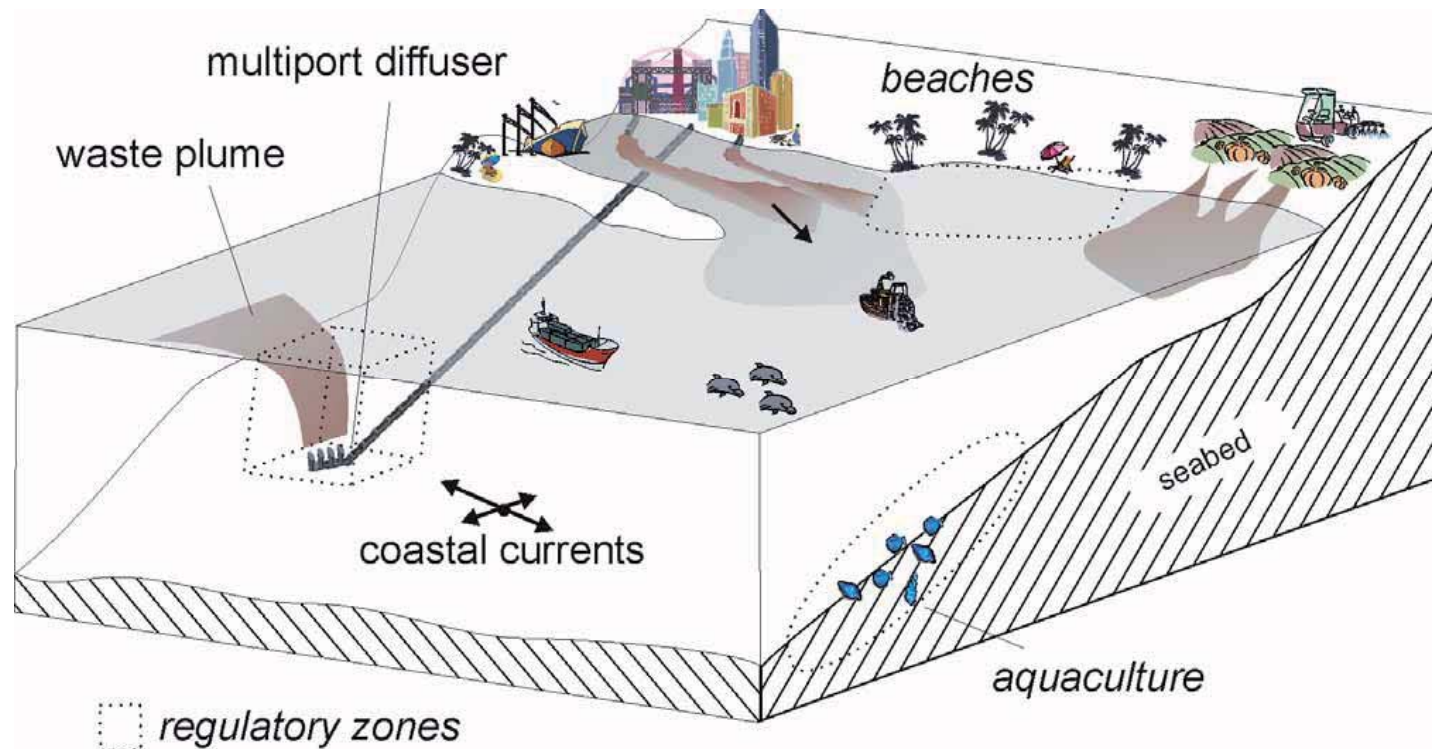
-> salinity/temperature and additive concentration distributions
influenced by discharge siting and induced mixing (near-field)

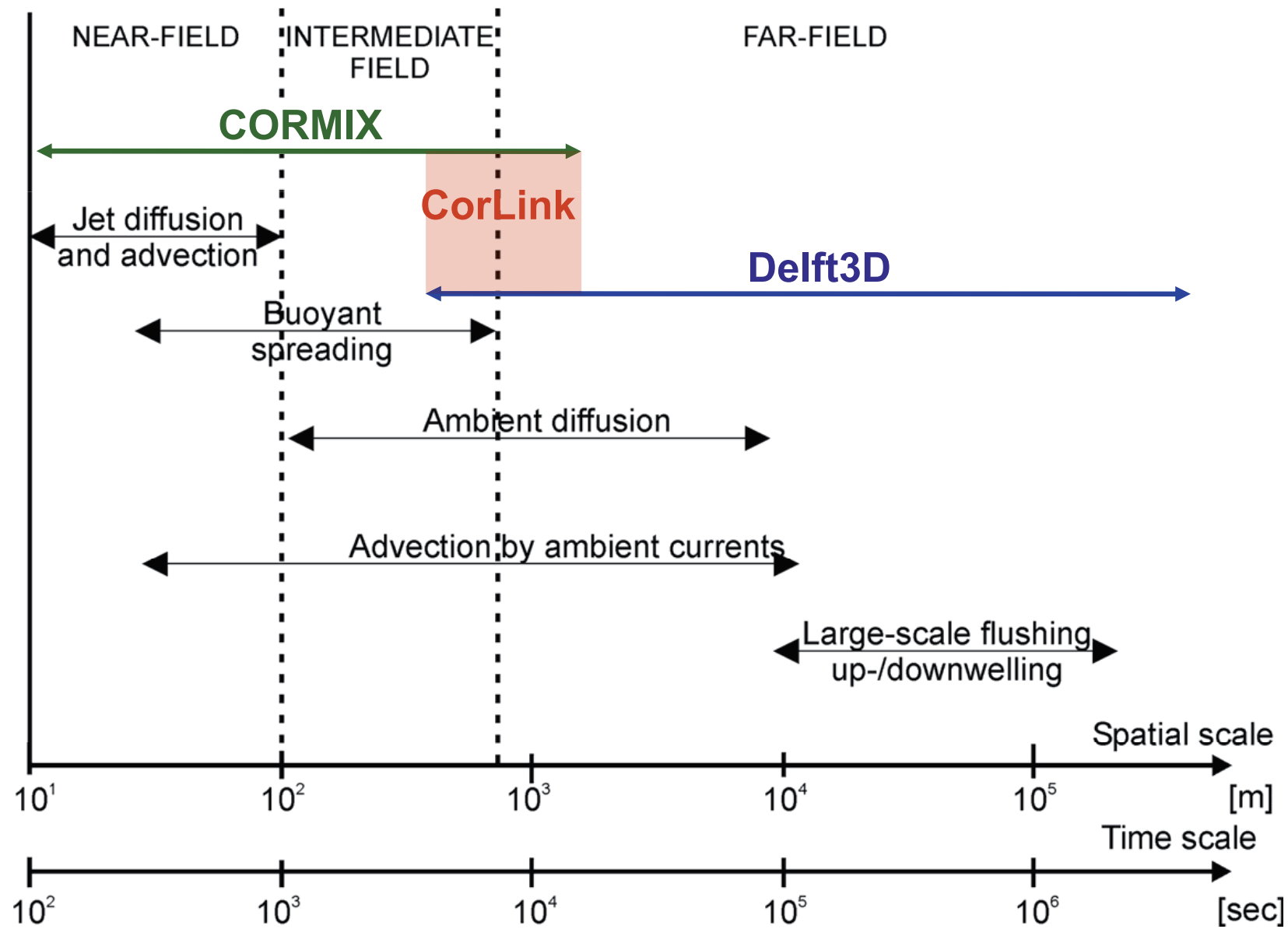
water body related impacts

-> additive loads, accumulation

influenced by water body characteristics, and ambient mixing (far-field)

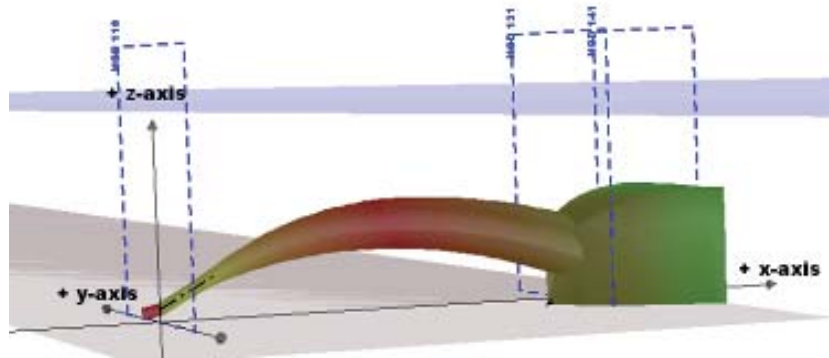
large scale and process differences





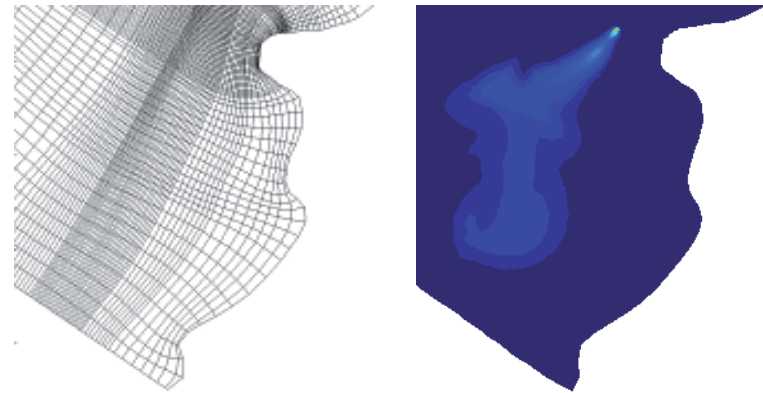
(Fischer et. al, 1979; Jirka & Lee, 1994;)

NF model: **CORMIX**



- Predicts jet trajectory and dilution characteristics of the initial mixing zone
- Variety of outfall configurations for simplified ambient conditions and topography
- **CorTime**: time series calculation considering variable parameters (e.g. flow rate, density,...)
- DCORMIX: module for dense currents
 - Allows sloping bottoms
 - under improvement (MEDRC project)
- Limitations:
 - steady-state
 - strong schematization
 - no far-field dynamics

FF model: **Delft3D-FLOW**



- Simulation of multi-dimensional hydrodynamic flows and transport processes
- Solves the unsteady shallow water equations
- curvilinear, boundary fitted grid
- s-coordinates for vertical discretization
- Limitations:
 - No consideration of NF processes or outfall geometry
 - Calibration necessary for adjustment of initial and boundary conditions
 - Spatial and temporal resolution limited by computing power and storage capacity

Coupling algorithm

Pre-Processing



CorTime



Post-Processing



Model linking



Delft3DFLOW

Preparation of field measurements as time series input for the near-field model

Time series near-field modeling with CORMIX

Analysis of the results of CORMIX

Preparation of near-field results as time series input for the far-field model

Hydrodynamic modeling based on field data and the results of the near-field model

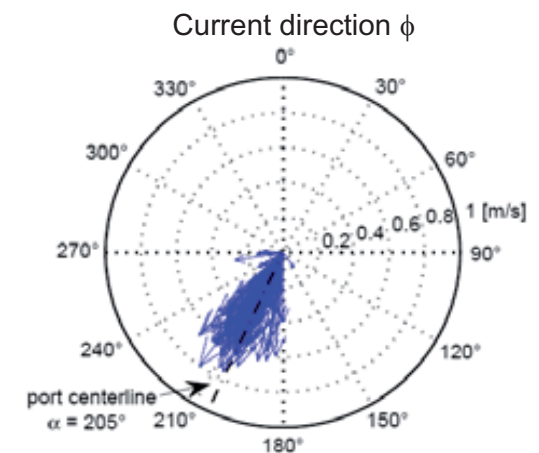
Input files are text files with specified structure (given by CORMIX and Delft3D)

Generation of data by the use MatLab[®]-routinen

Case study

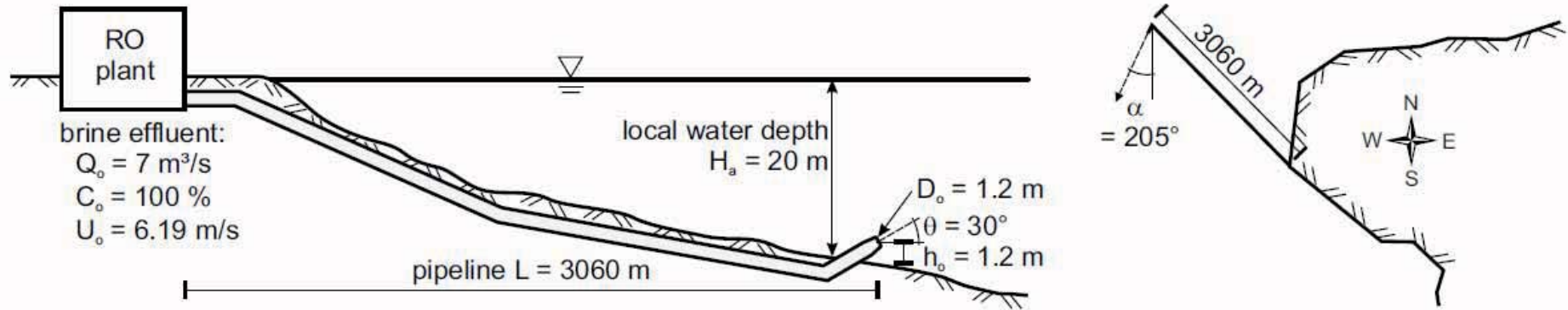
Brine discharge of a RO plant through a submerged single port

- Cartagena outfall (Columbia) following Bleninger (2006): field data, boundary conditions, numerical grid
- 1 week = 169 h = 169 time steps
- Ambient conditions:
 - Depth averaged velocity $U_a = 8 - 80$ cm/s
 - $T_a = 27.7^\circ\text{C}$, $Sal_a = 36.3$ ppt (‰) $\Rightarrow \rho_a = 1023.50$ kg/m³
 - Density profile: uniform or linear ($\Delta\rho > 0.1$ kg/m³)
- Discharge conditions:
 - $Q_o = 7$ m³/s
 - $T_o = 27.7^\circ\text{C}$, $Sal_o = 66.9$ ppt (‰) $\Rightarrow \rho_o = 1046.78$ kg/m³



Design modeling

- Outfall design (e.g. CORMIX)



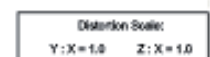
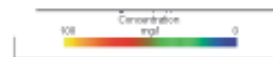
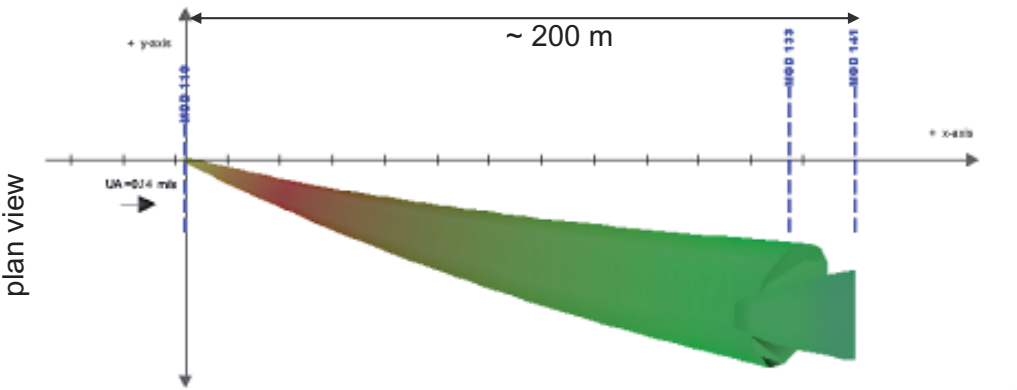
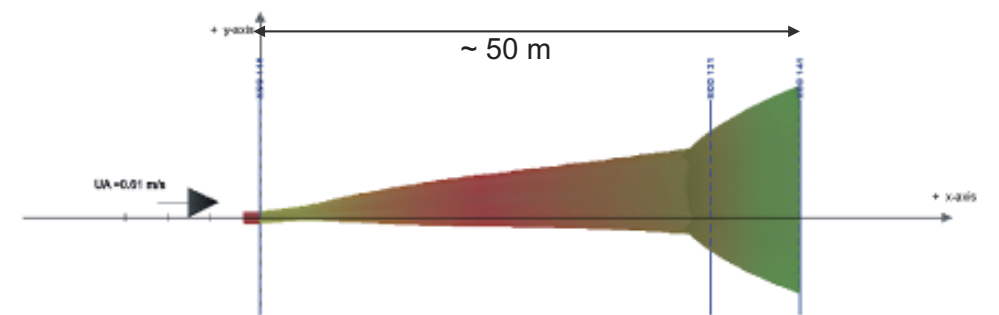
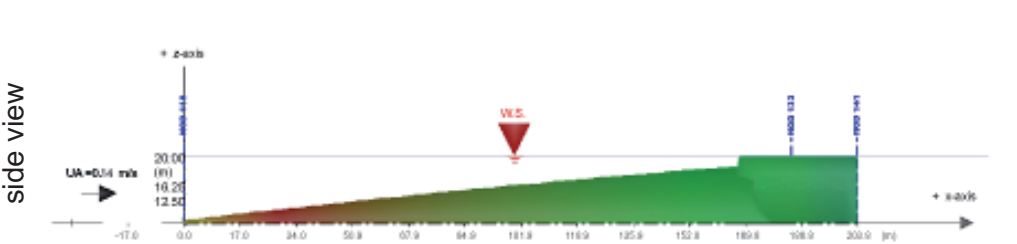
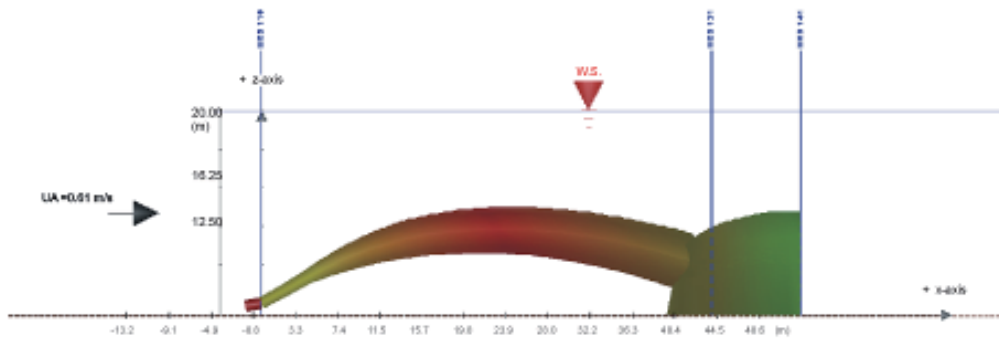
Two different flow classes:

Time step I

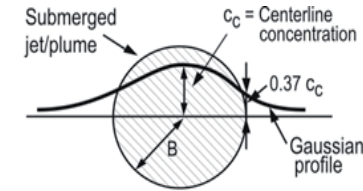
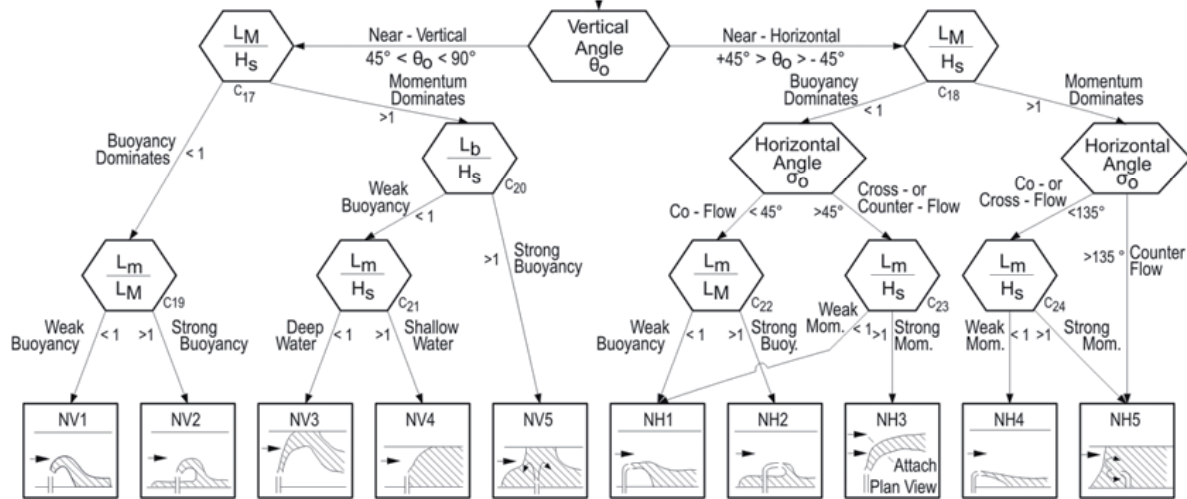
Time step II

Time: CorTimeInput.txt; TSTEP = 87
Time of Run: Fri Oct 12 14:56:23 2007
Cormix1 Simulation
Flow Class: NH4

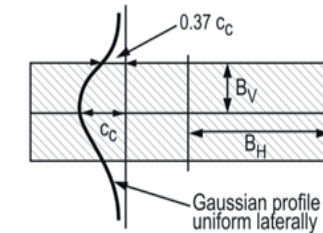
Time: CorTimeInput.txt; TSTEP = 111
Time of Run: Fri Oct 12 14:56:58 2007
Cormix1 Simulation
Flow Class: NH5



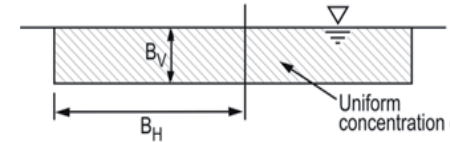
**FLOW CLASSIFICATION
NEGATIVELY BUOYANT JET
(OR DOWNWARD ORIENTED JET)
IN UNIFORM DENSITY LAYER (HEIGHT H_s)**



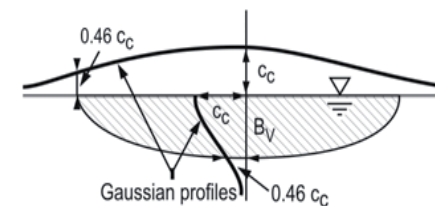
- a) Submerged round jet/plume cross-section
 B = Radius
 S = Centerline dilution = $\frac{c_0}{c_c}$



- b) Submerged plane jet/plume cross-section
 B_V = Normal width
 B_H = Lateral width
 S = Centerline dilution = $\frac{c_0}{c_c}$



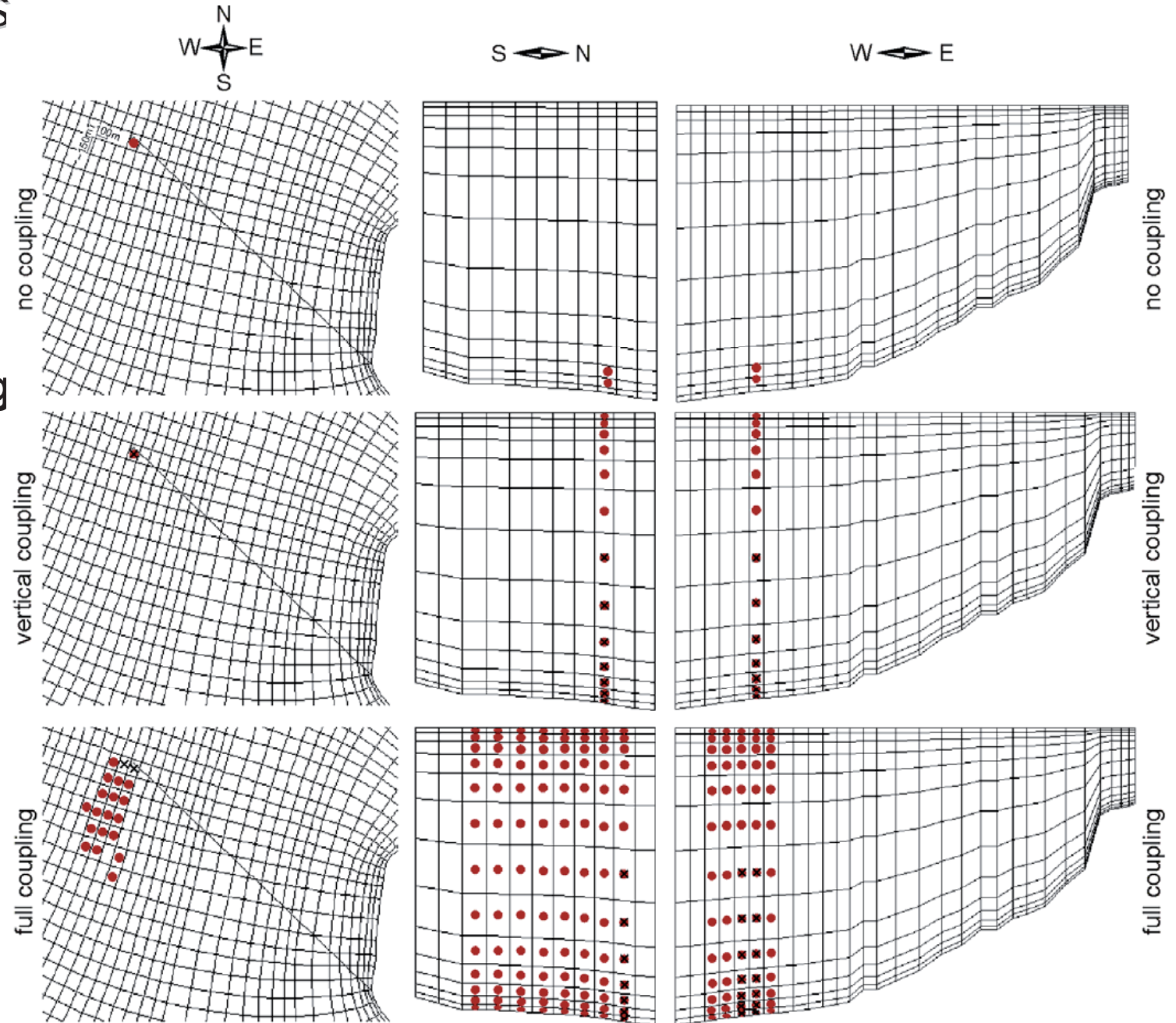
- c) Cross - Section during buoyant spreading along water surface
 B_V = Vertical width
 B_H = Lateral width
 S = Centerline dilution = $\frac{c_0}{c_c}$



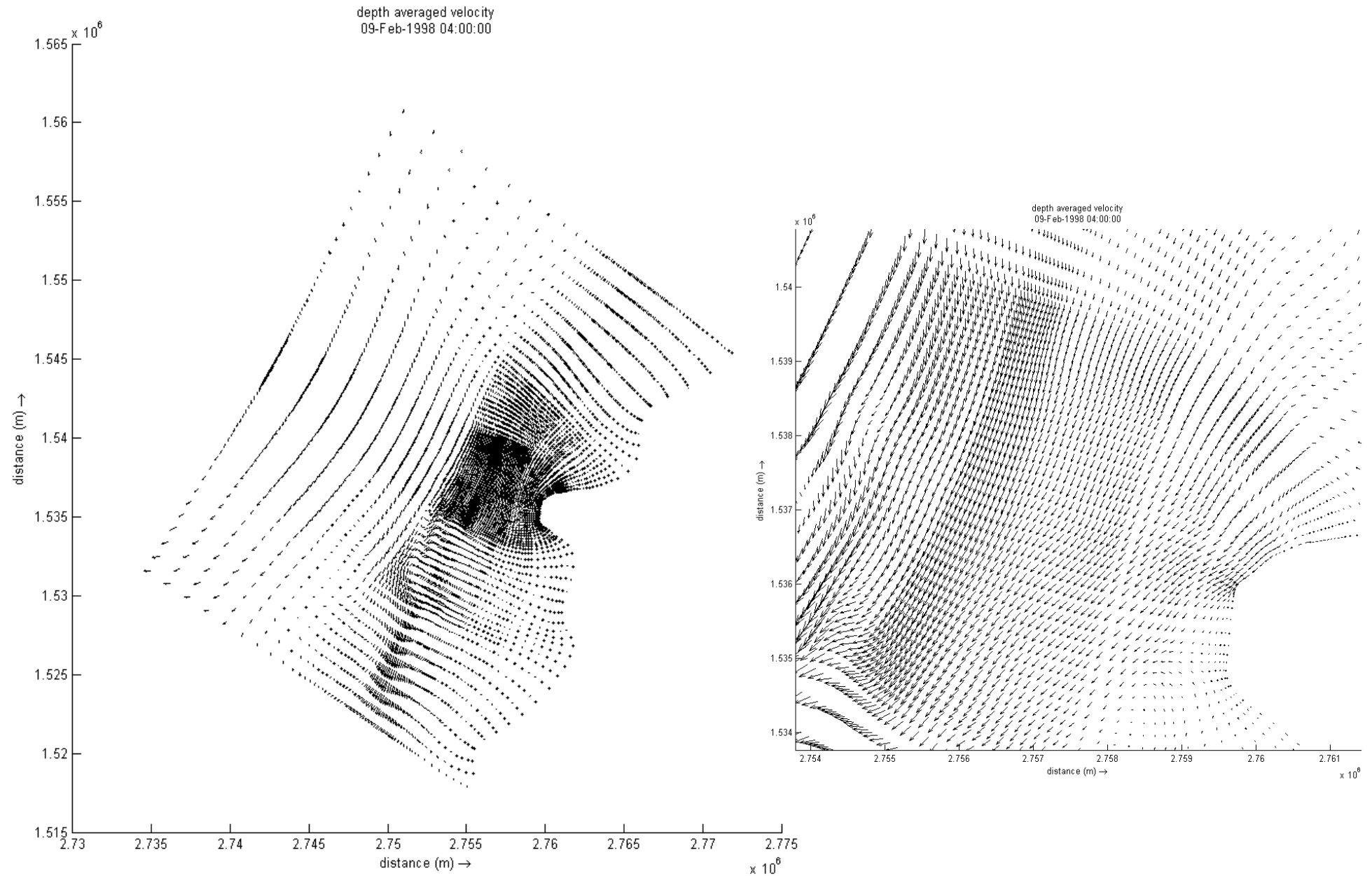
- d) Cross - section during ambient diffusion process
 B_V = Vertical width
 B_H = Lateral width
 S = Centerline dilution = $\frac{c_0}{c_c}$

Case study: Coupling configurations

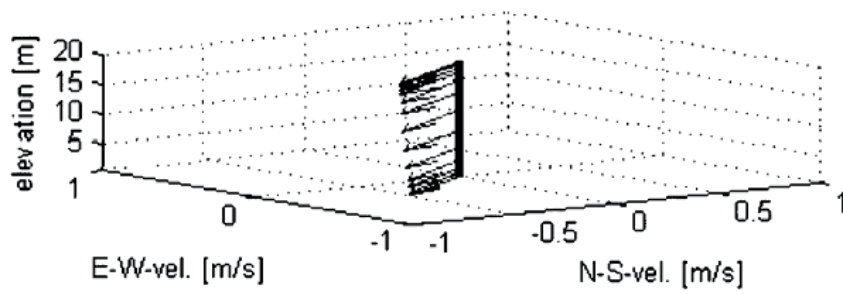
- **no coupling**
neglecting any plume geometry
- **vertical coupling**
considering the plume thickness
- **full coupling**
considering the plume thickness, width and position



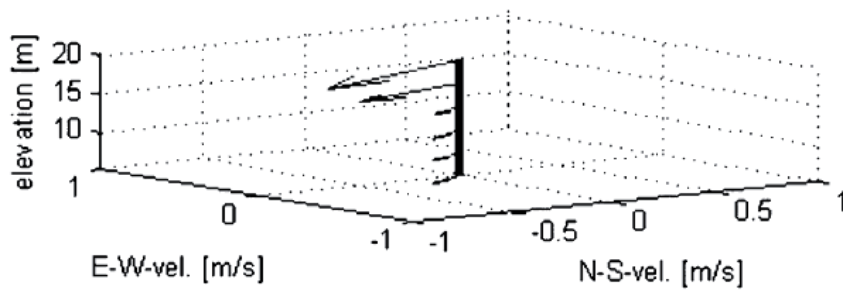
Delft3D - Hydrodynamic model results



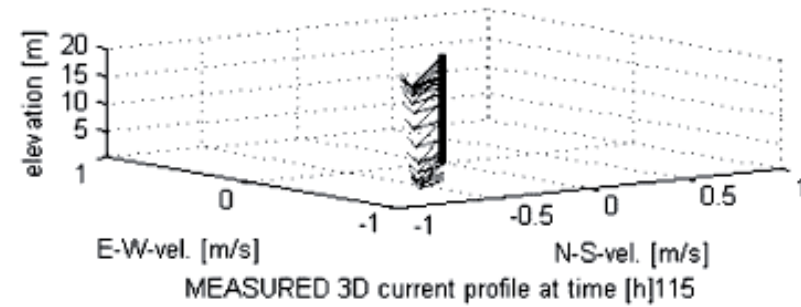
MODELED 3D current profile at time [h]176



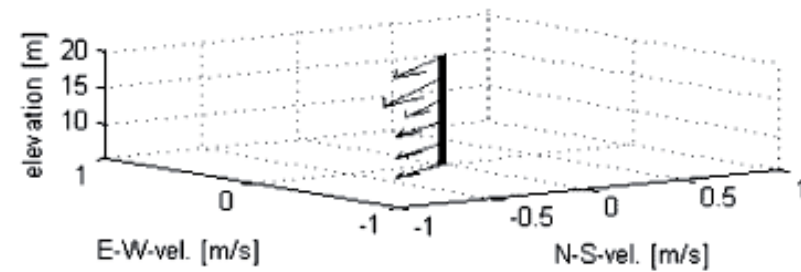
MEASURED 3D current profile at time [h]176



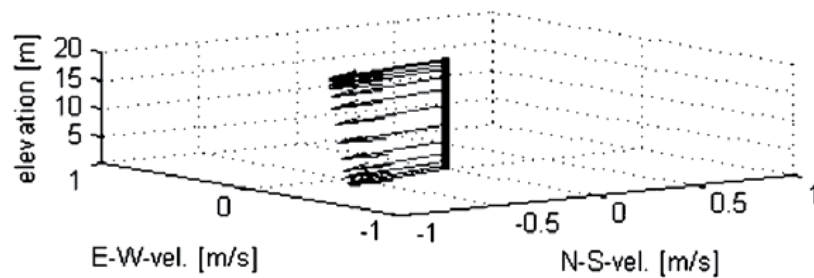
MODELED 3D current profile at time [h]115



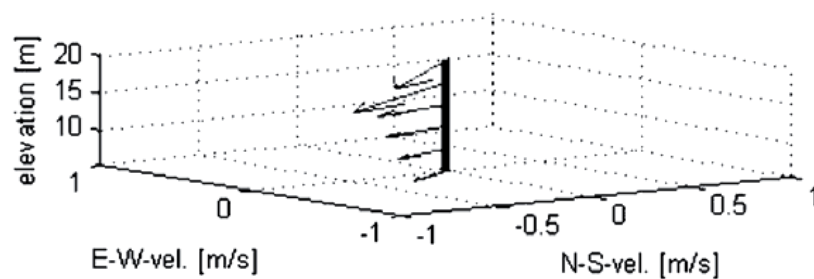
MEASURED 3D current profile at time [h]115



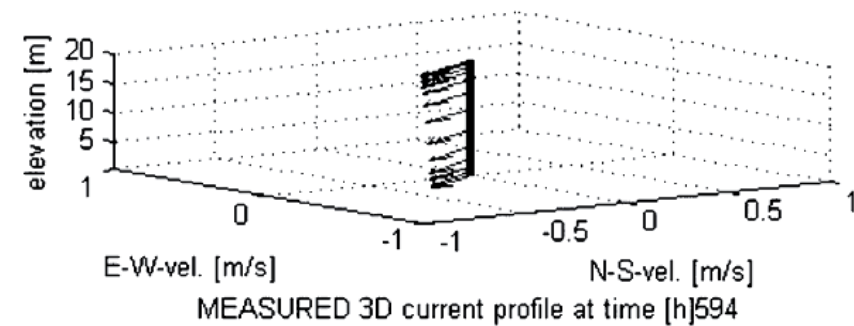
MODELED 3D current profile at time [h]120



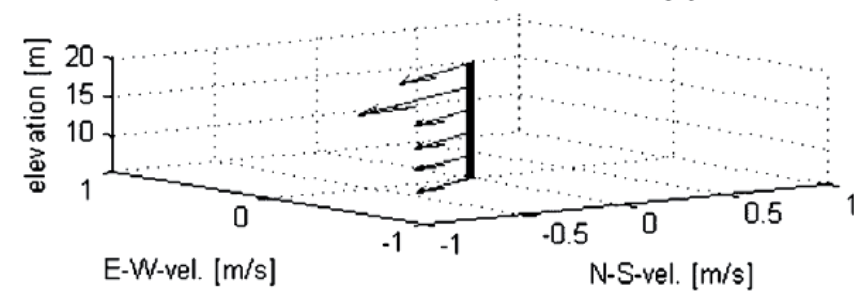
MEASURED 3D current profile at time [h]120



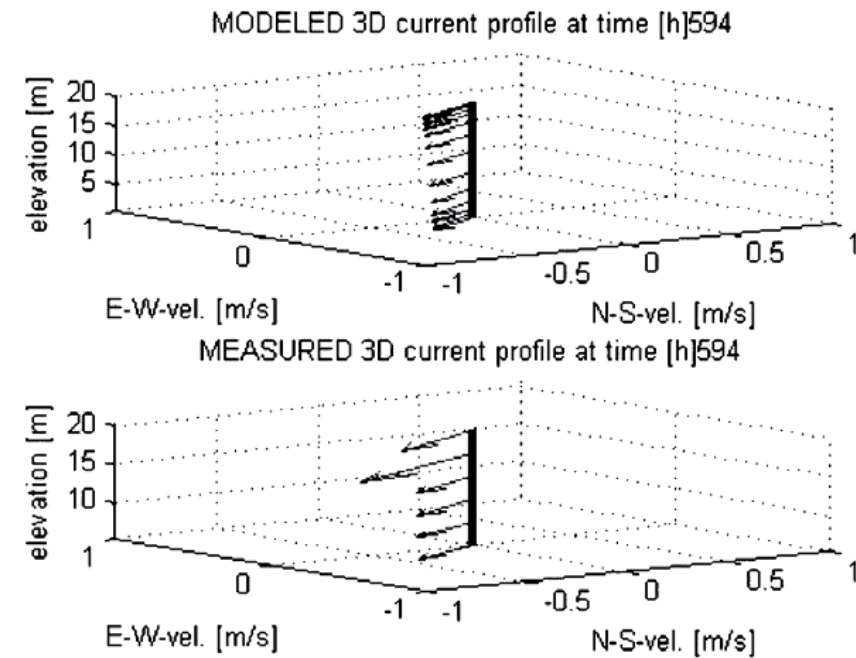
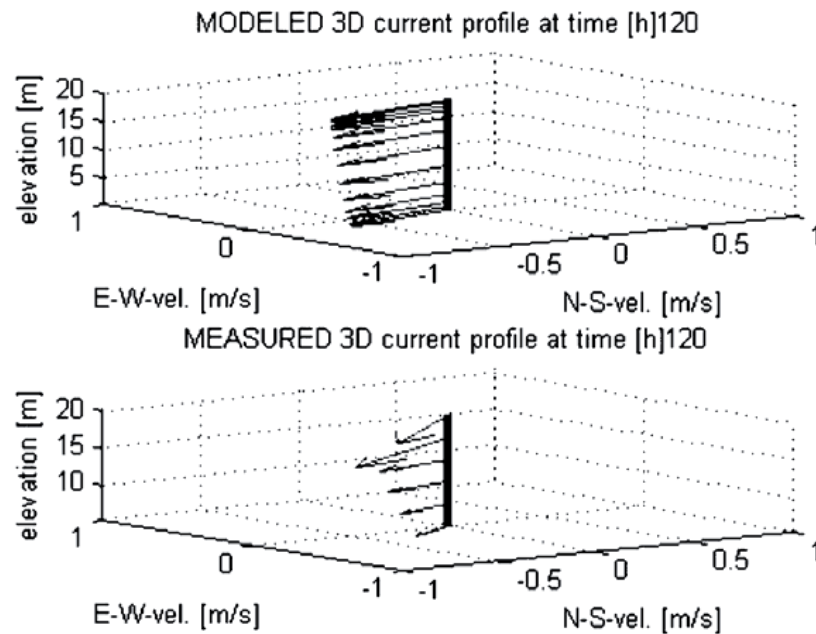
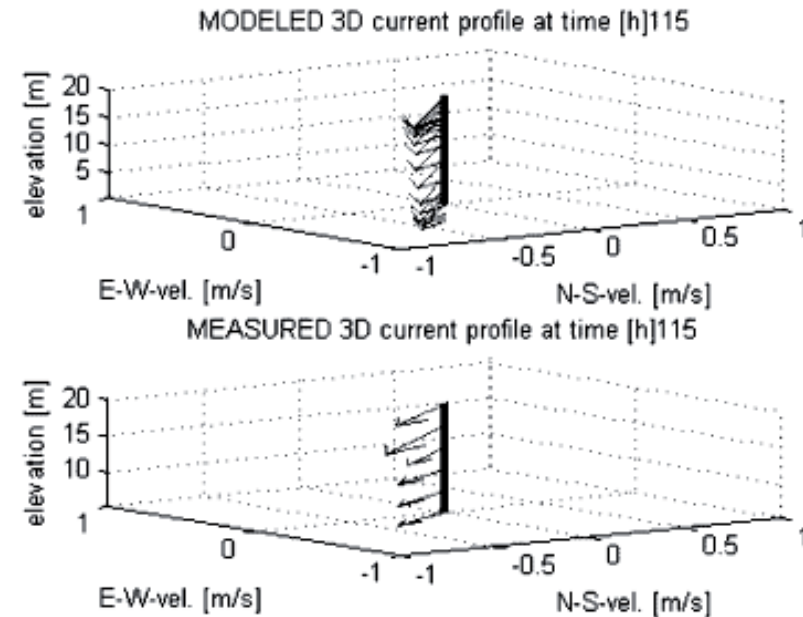
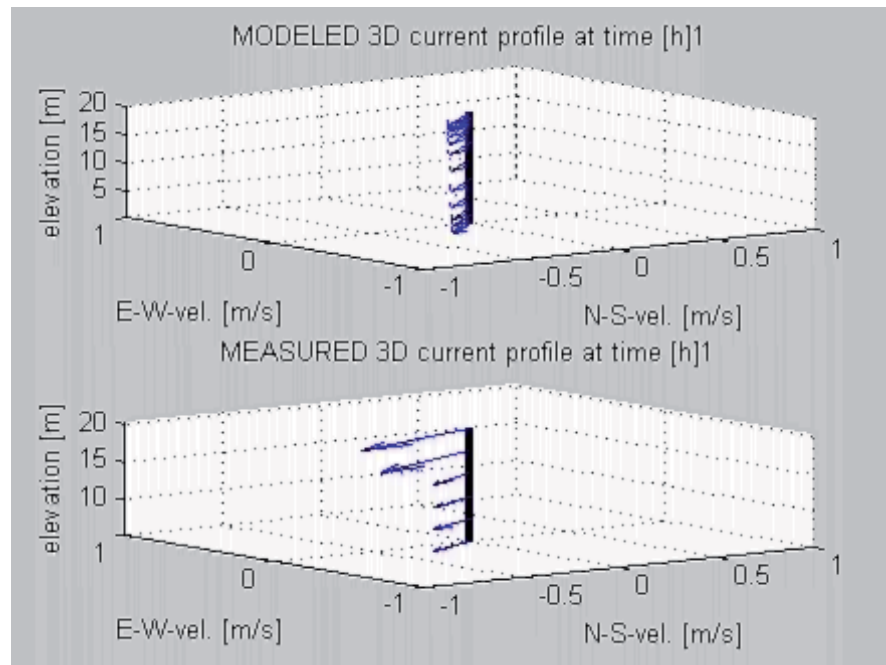
MODELED 3D current profile at time [h]594



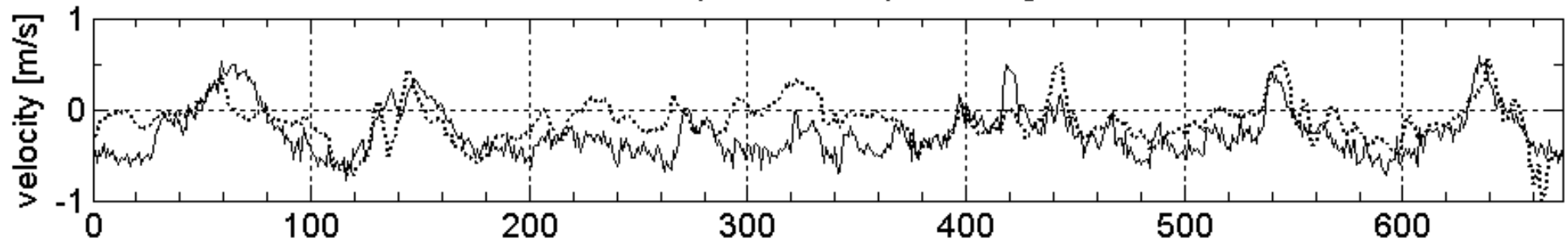
MEASURED 3D current profile at time [h]594



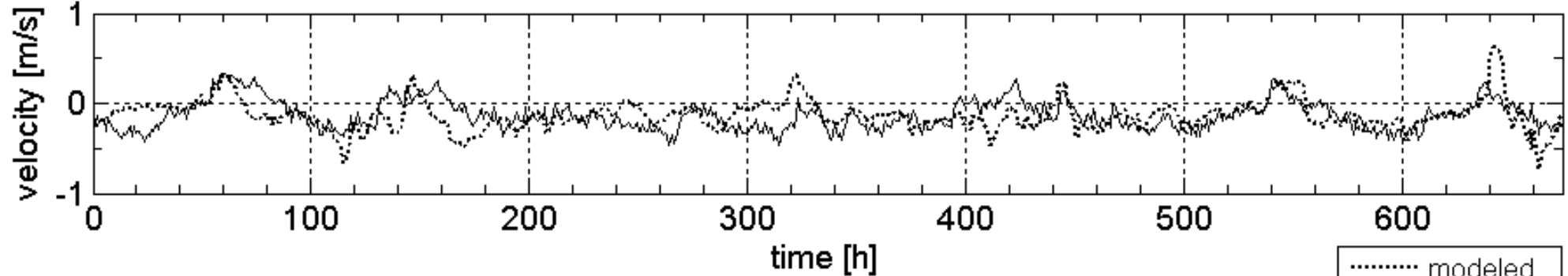
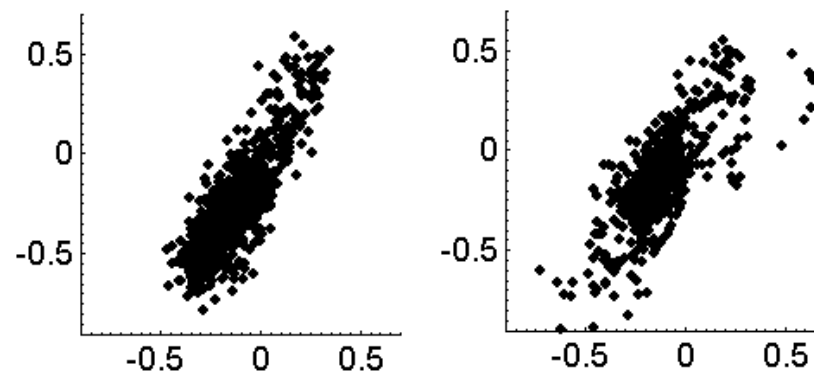
Delft3D - Hydrodynamic model results

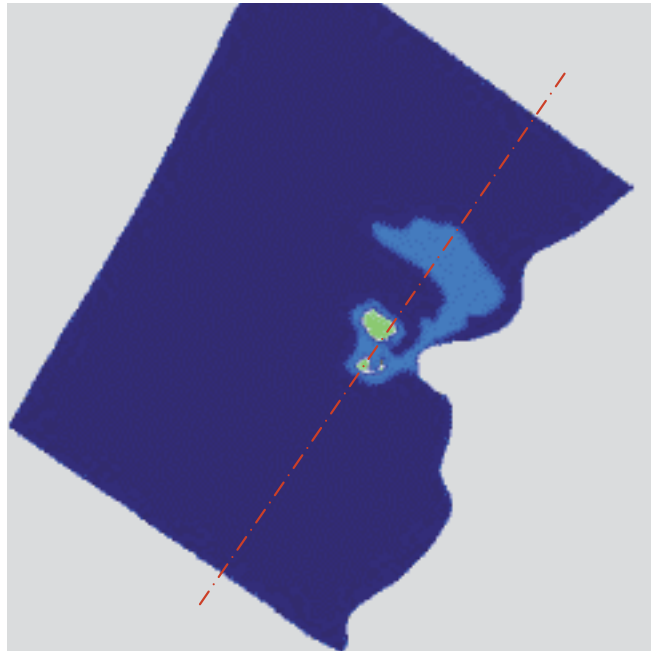


north-south-component of depth averaged current

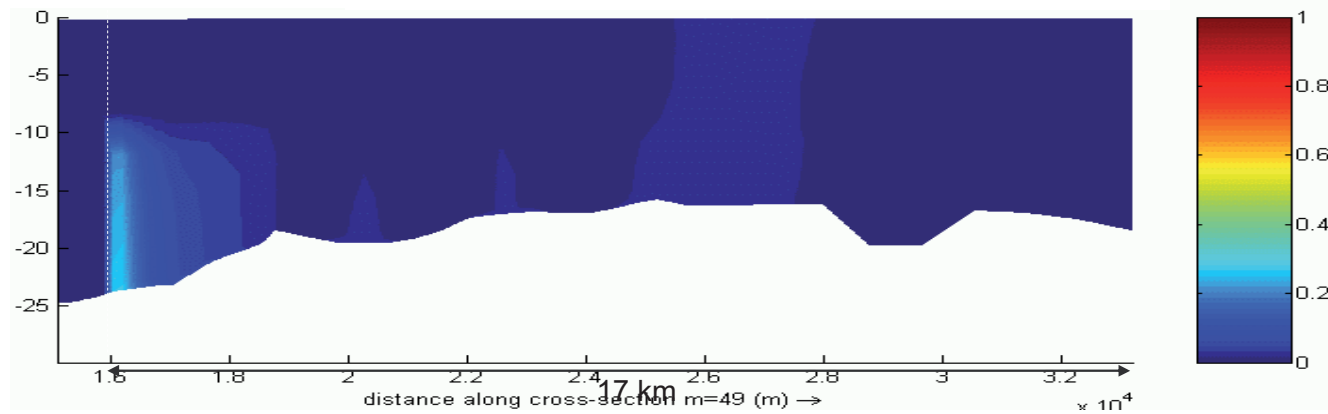


east-west-component of depth averaged current

scatter of depth averaged velocity [m/s]
measured - modeled

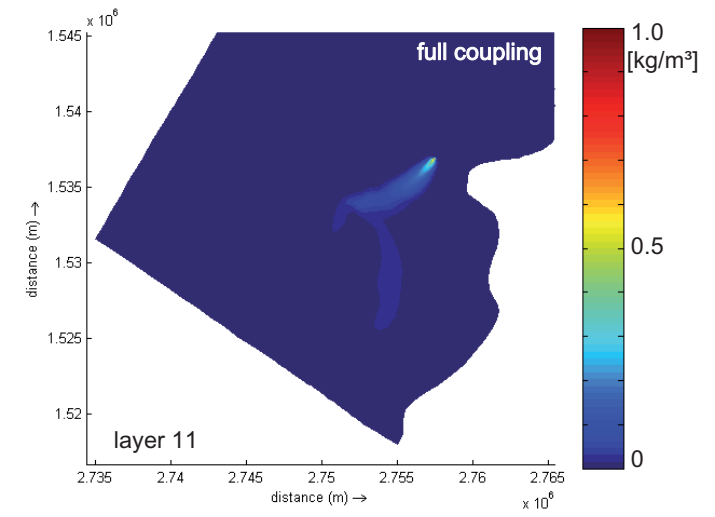
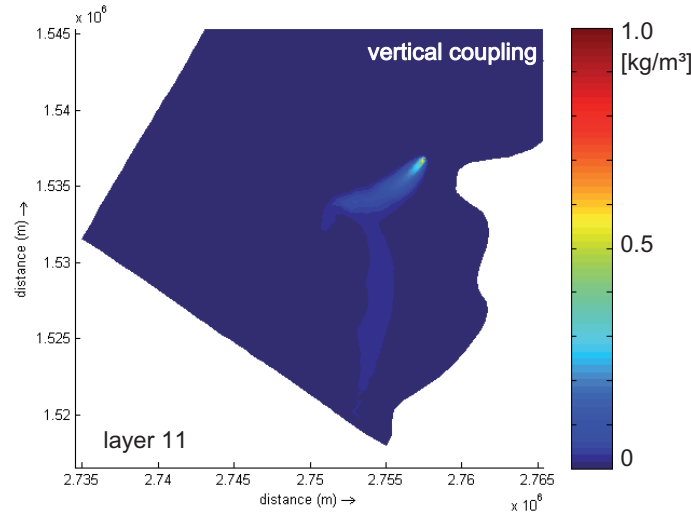
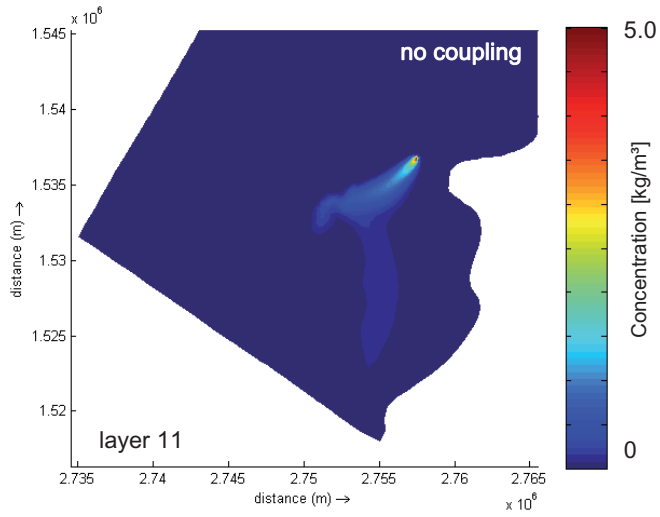


48 time steps (= 2 days)

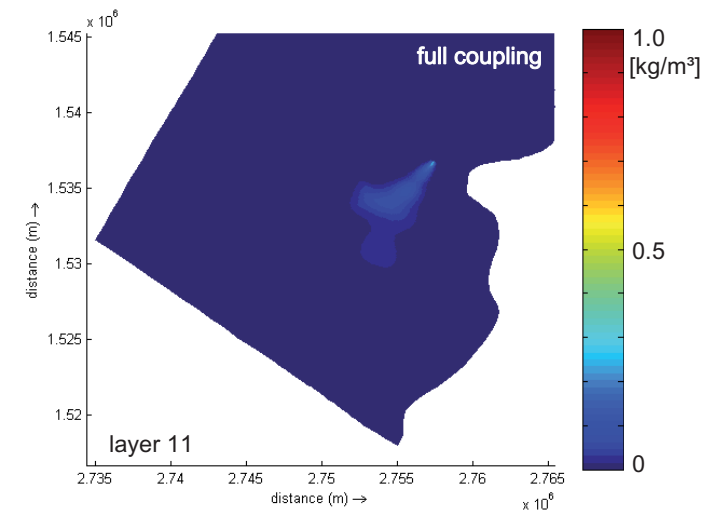
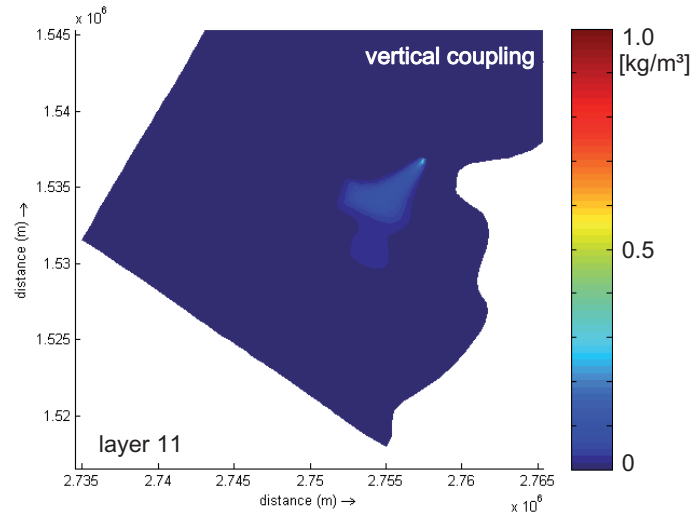
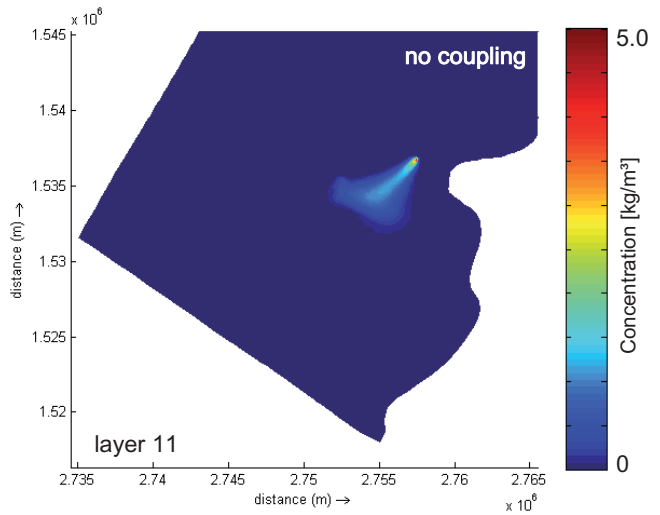


Case study: Results of Delft3D

Time step I

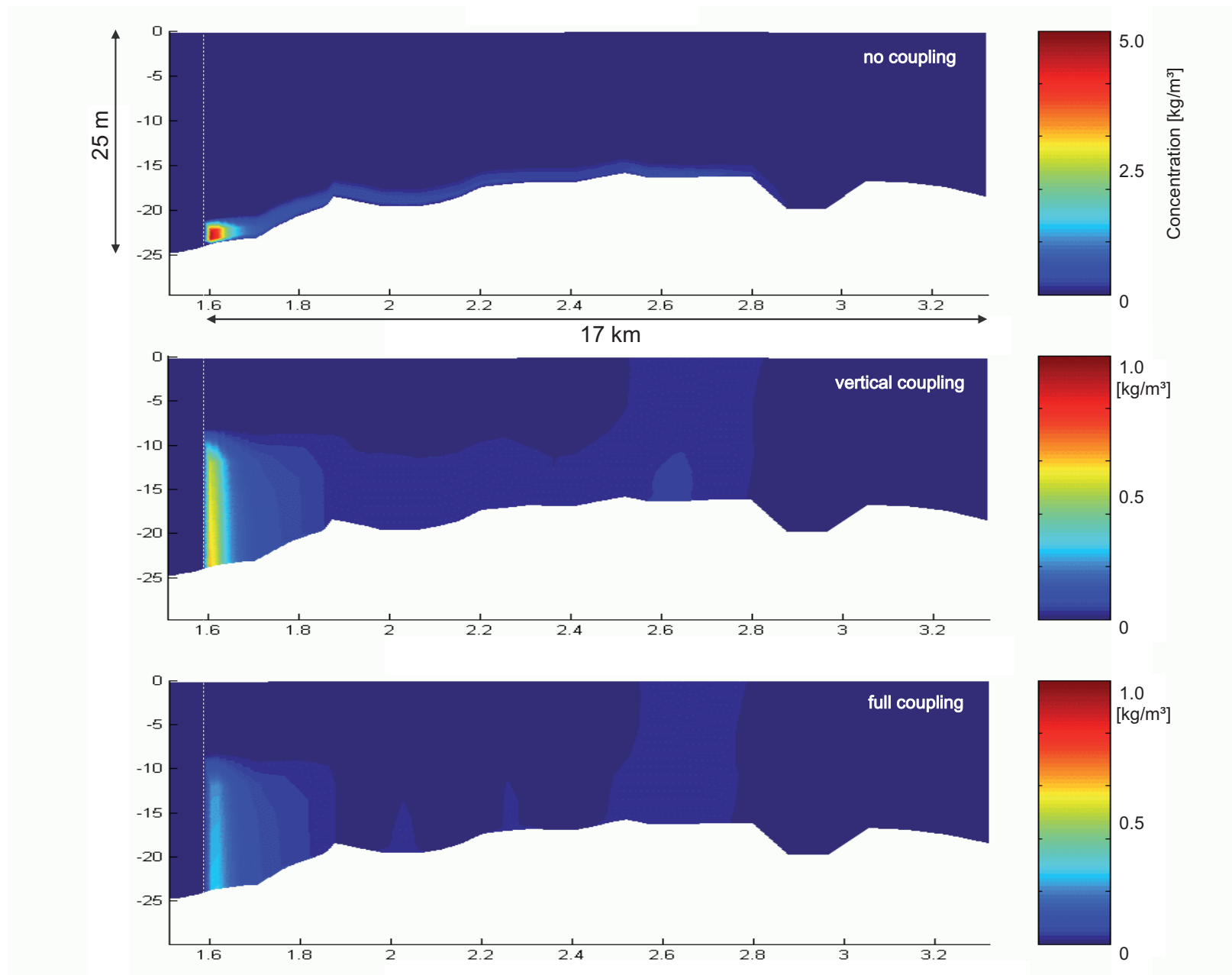


Time step II



Case study: Results of Delft3D

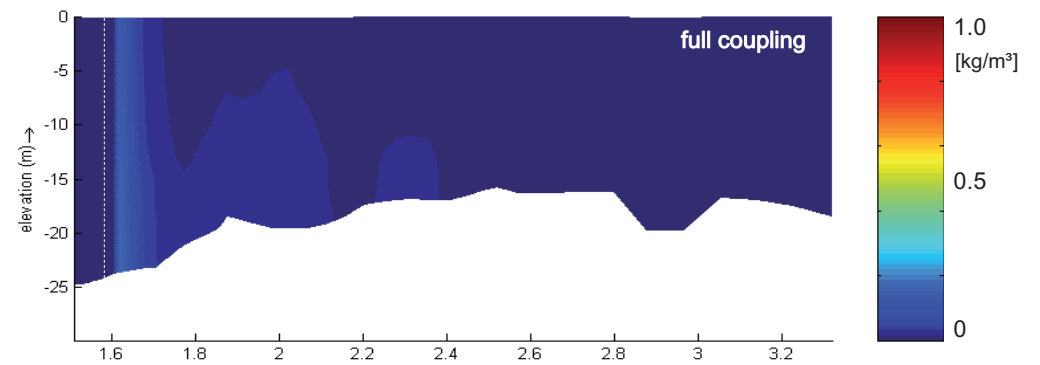
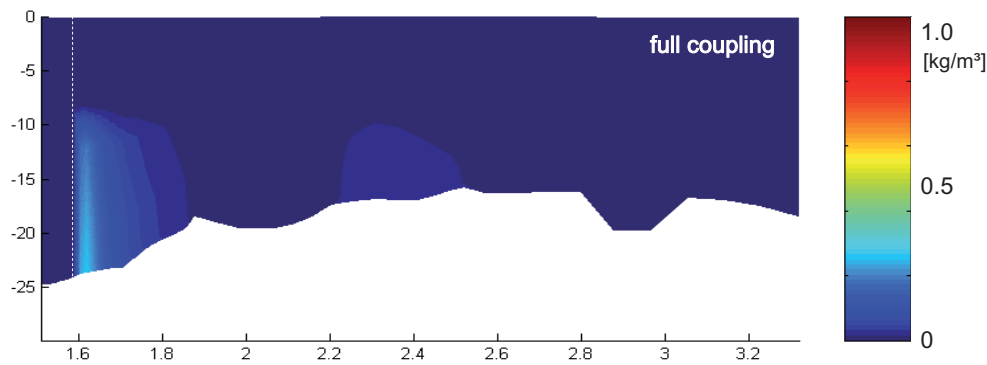
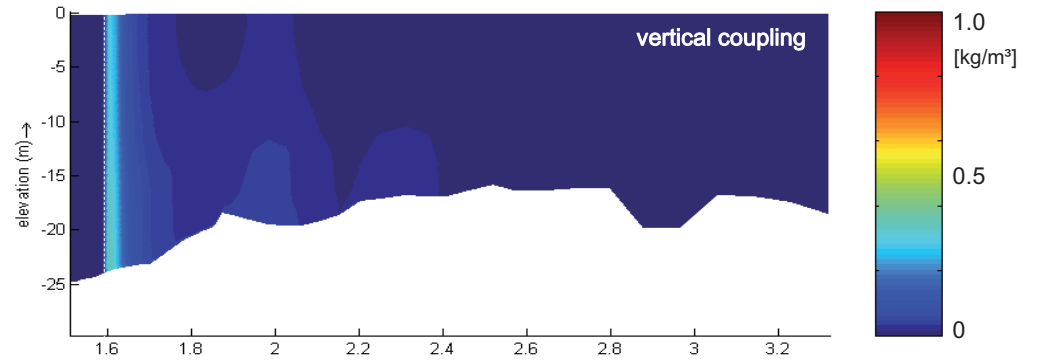
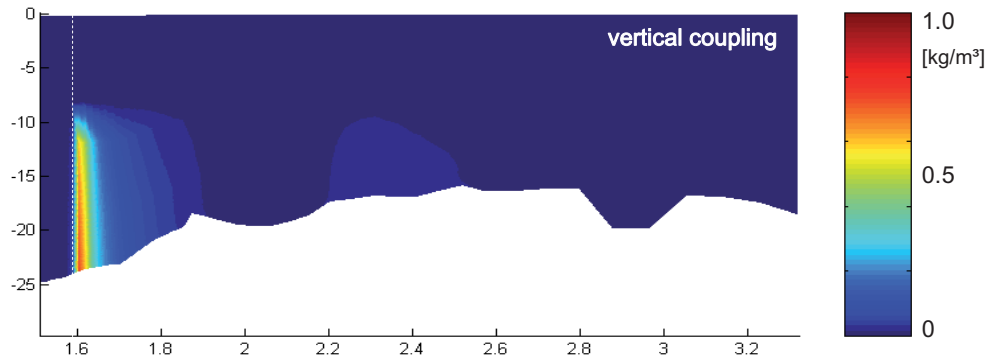
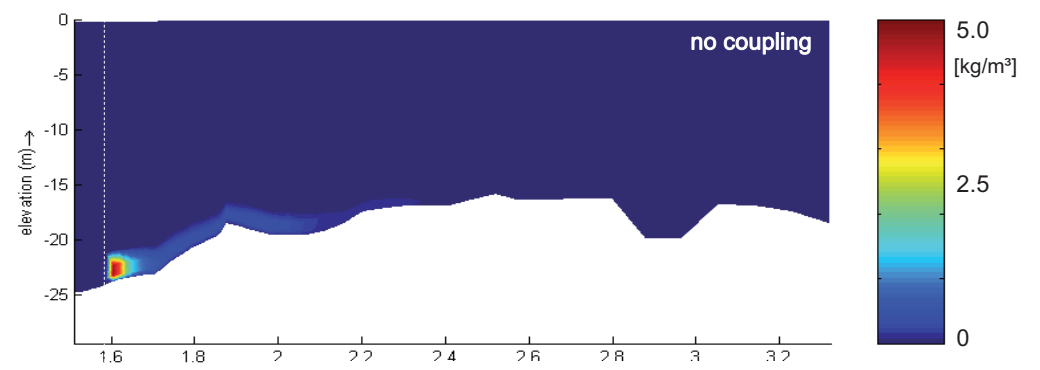
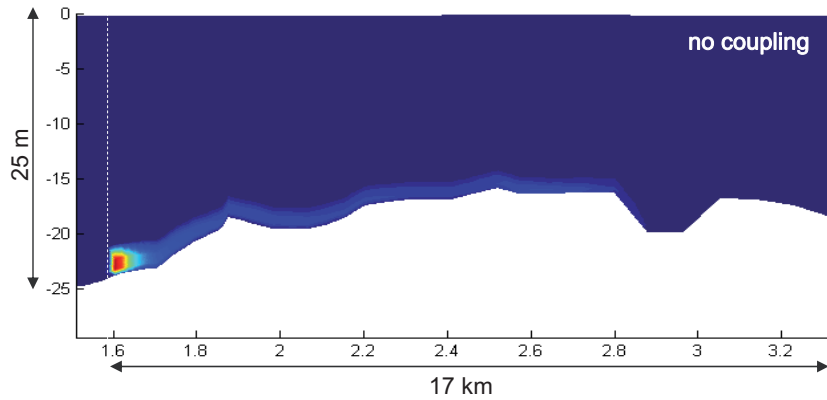
48 time steps (= 2 days)



Case study: Results of Delft3D

Time step I

Time step II



Australia

Perth, Cockburn Sound:

- 144,000 m³/d
- intake:
 - submerged (-11 m)
 - 300 m offshore
- discharge: 216,000 m³/d
 - multiport diffuser (40 jets), -10 m depth
 - 500 m offshore
- energy demand: 185 GWh/a (3.5 kWh/m³)
 - associated 82 MW wind farm
 - 272 GWh/a expected energy production



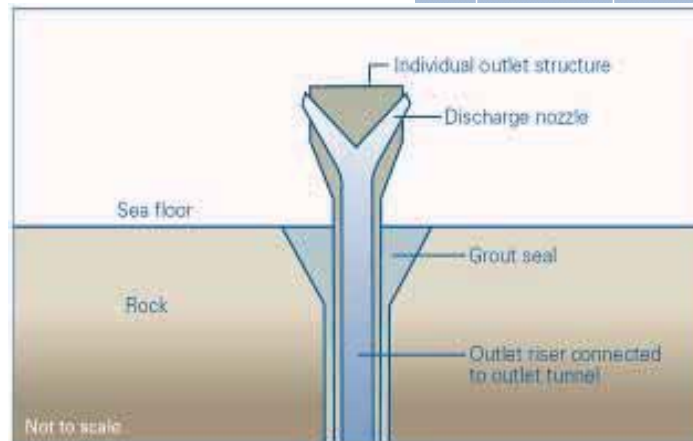
Source: Crisp (2006)

Source: Lattemann and Höpner, 2008

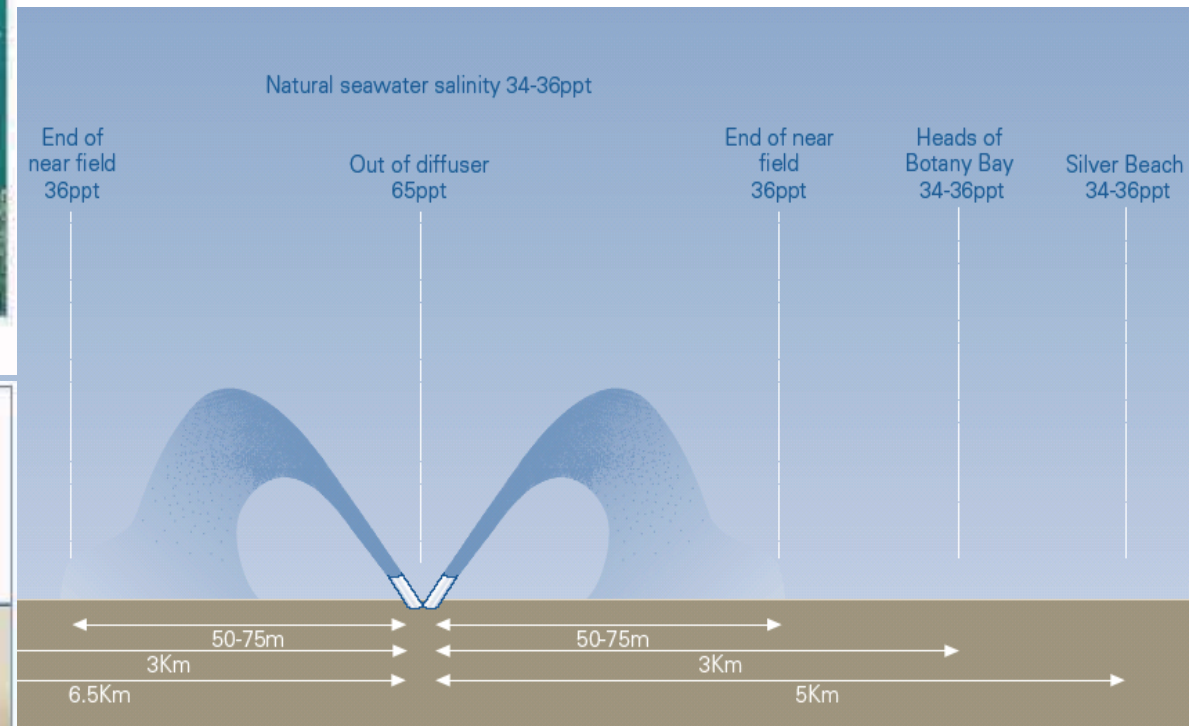
**Actual design:
250 m offshore
at 20-25 m depth
exit velocity 7m/s**



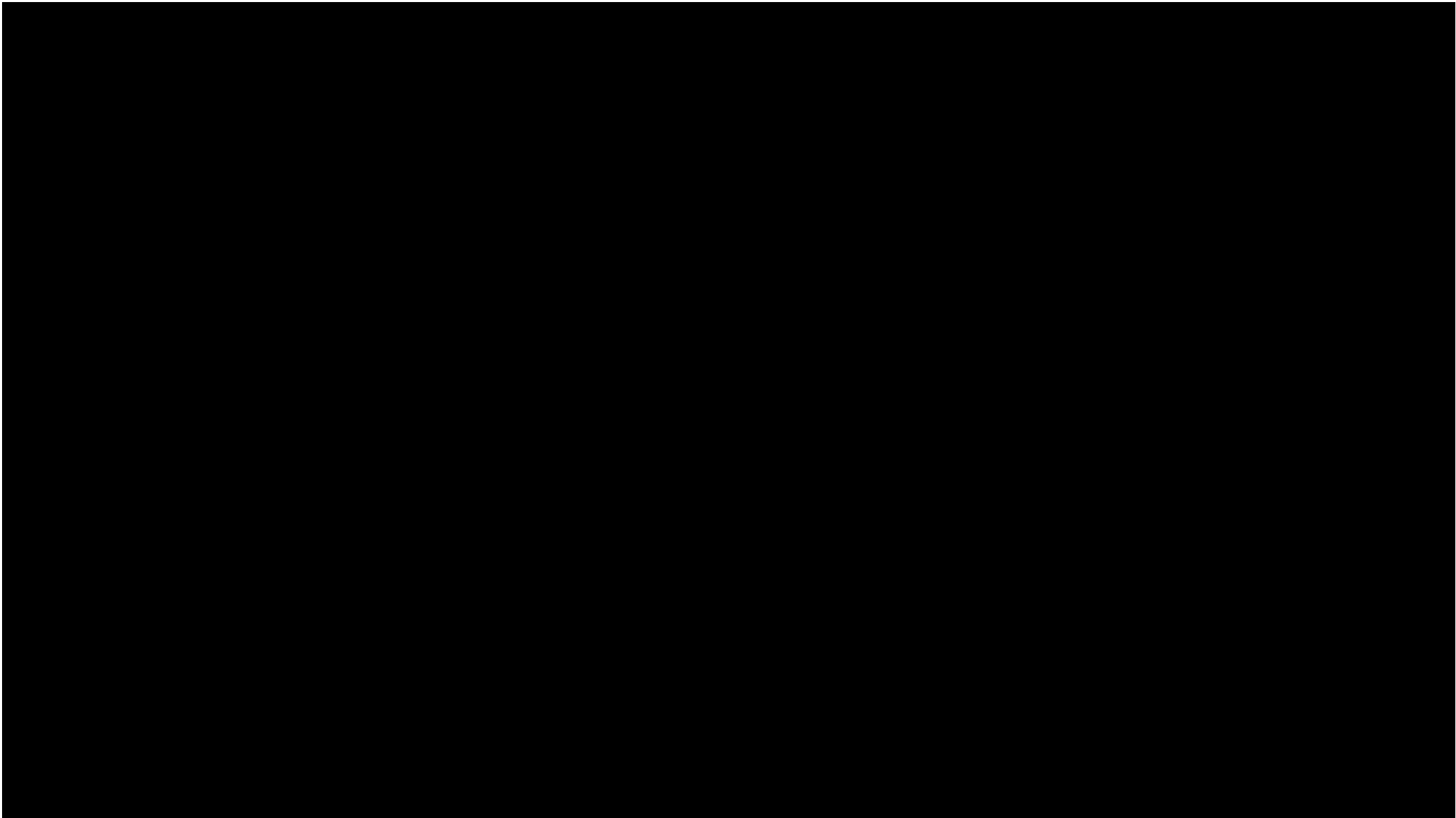
Location of seawater intakes and outlets



Seawater concentrate outlet design features



source: www.sydneywater.com.au



Example II: Impact of salinity on seagrasses

Salinity thresholds:

Western Australian guidelines:

- median* salinity increase of < 5 % from background
- ΔS of about 1.5–2

Salinity limits Perth SWRO:

- within 1.2 units of ambient within 50 m
- within 0.8 units of ambient within 1000 m



Source: Google Earth

* MEDIAN: the number separating the higher half of a sample from the lower half.

Source: WEC 2002

Source: Lattemann and Höpner, 2008

- Water quality protection needs careful blend of technologies
 - source reduction and contaminant substitution
 - treatment technologies
 - discharge technologies
- EQS need mixing zone definition for point source discharges
- A multitude of hydrodynamic processes affect mixing and transport of effluent. Discharges optimally should
 - be sited offshore
 - be submerged
 - have high velocities
 - consist of multiple ports
- Simple screening equations and models are available
- Comprehensive design models improve and optimize design and siting
- Need for intense pre- and post-operational monitoring
- → great potential for environmental and operational optimization of existing and new plants due to technological solutions

Institute for Hydromechanics

www.ifh.uni-karlsruhe.de/science/envflu/

MEDRC research project

www.brinedis.net.ms

IAHR / IWA Committee on Marine Outfall Systems

www.outfalls.net.ms

Models:

- CORMIX V 5.0, www.cormix.info
- Delft3D, www.wldelft.nl

