

Rosette diffuser for dense effluent – Puck Bay case study

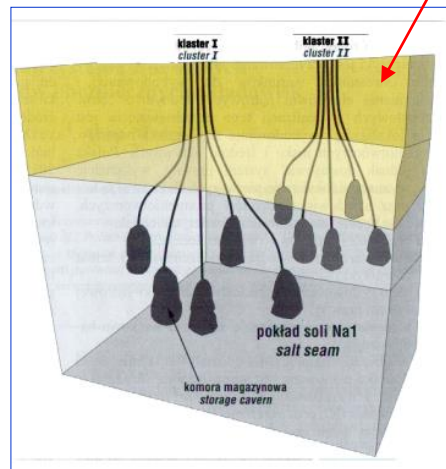
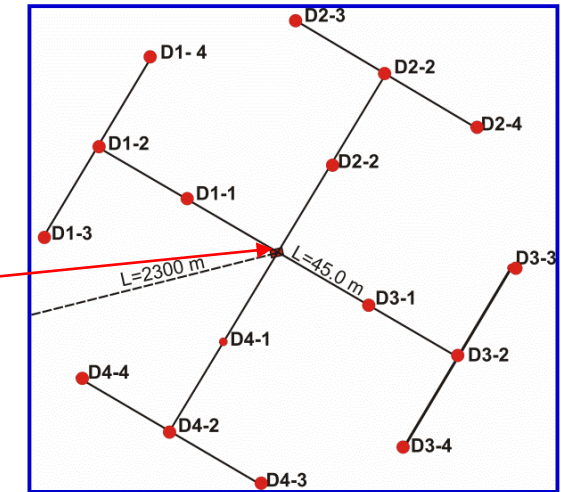
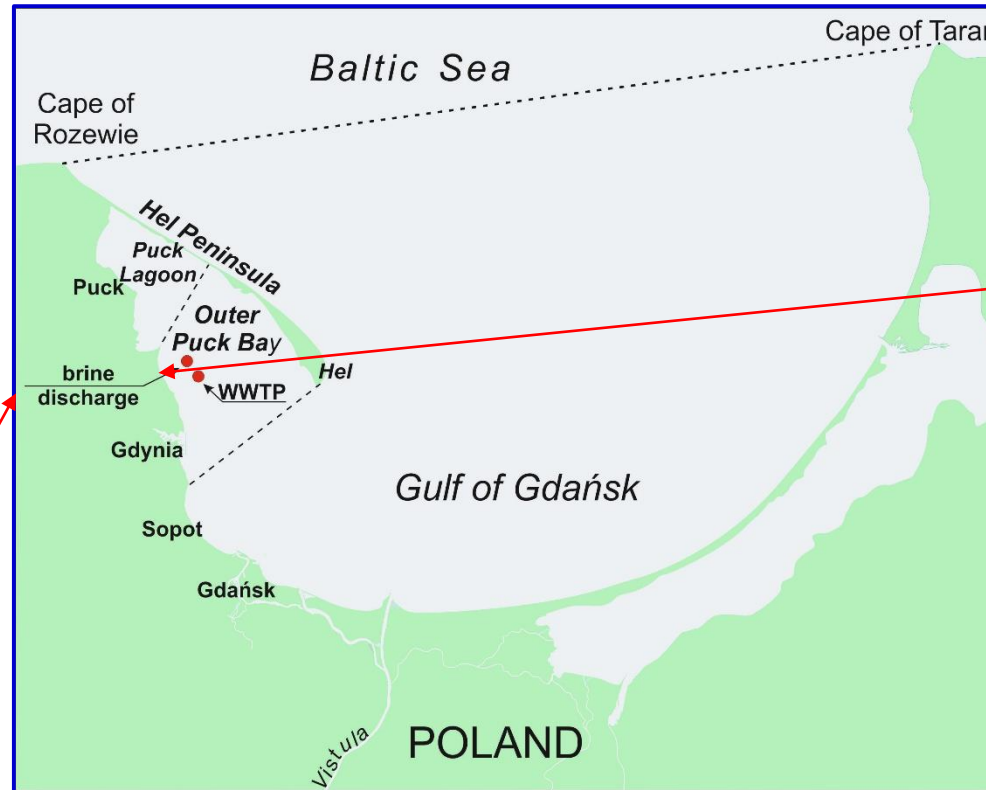
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Gdańsk, Poland

Łąck, 23.05.2019

General characteristics of the investment



- construction of 10 gas stores in salt deposits, depth of 1000-1200 m;
- ~5.6 mln t. of salt to be diluted;
- storage capacity ~ 250 mln m³

max. permissible brine parameters:

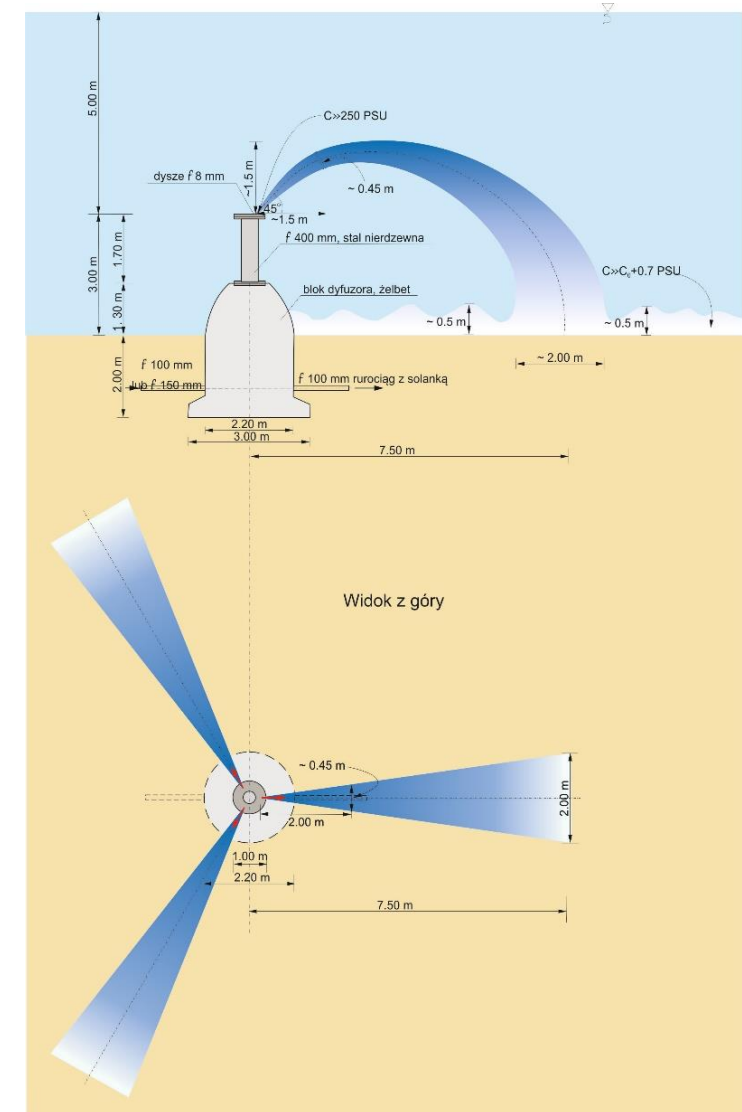
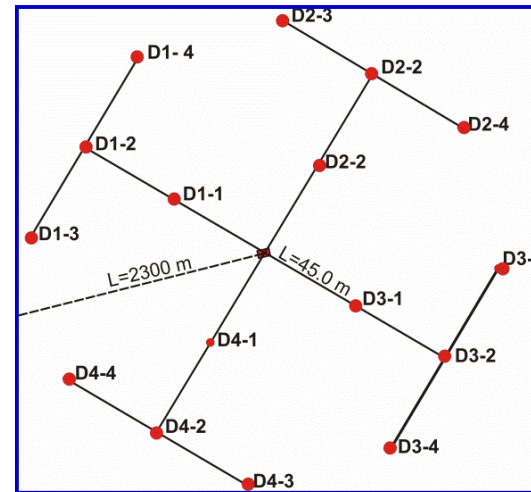
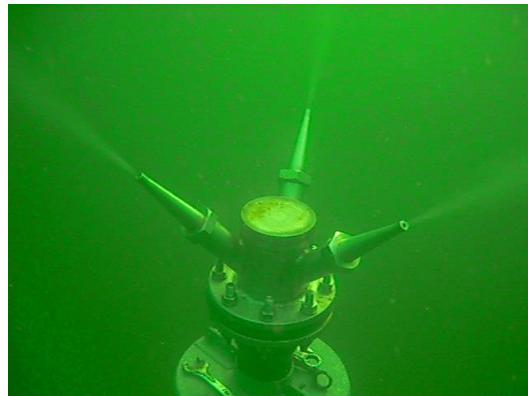
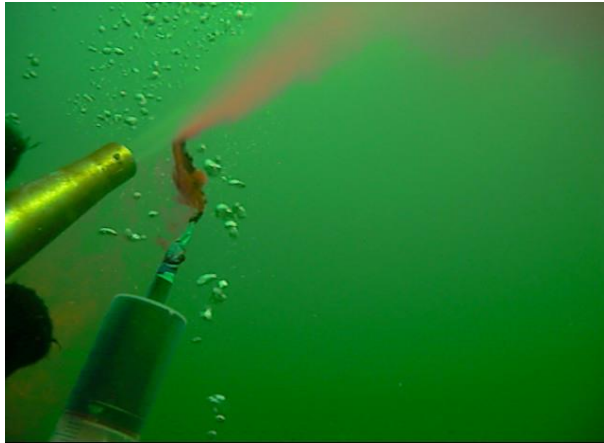
- discharge - 300 m³/h;
- saturation - 250 kg/m³

limits:

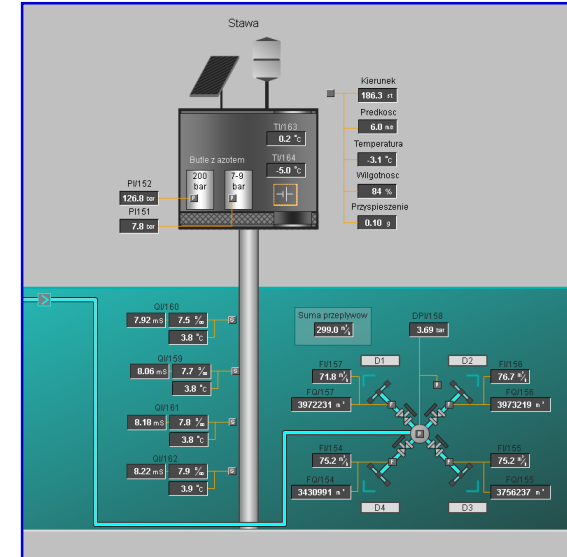
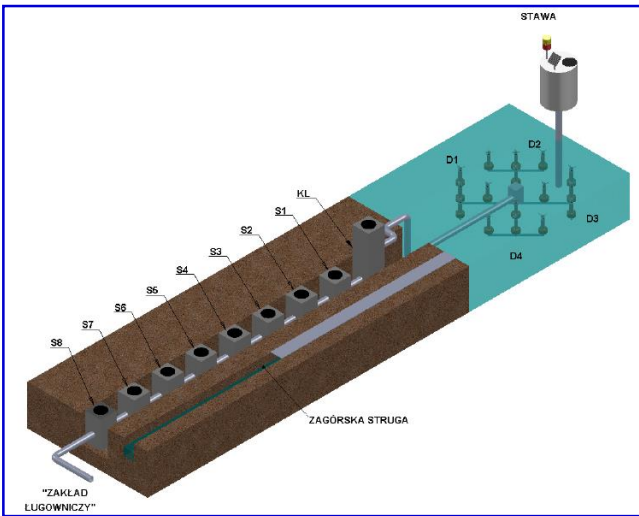
- permissible excess salinity **0.5 psu**
- salinity in the near-field not higher than **9.2 psu**
- distance between installation and free surface at least **5 m**

Selected technical solution of diffuser system

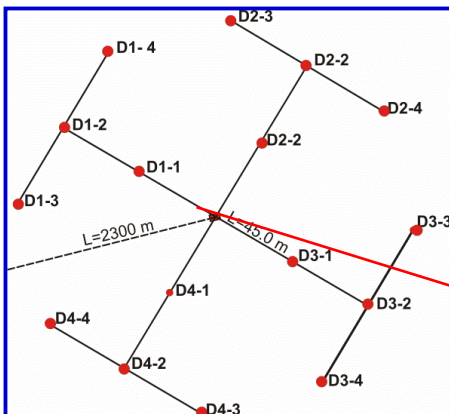
- 16 risers, equipped with 3 nozzles, spaced every 45 m;
- nozzles of 9 mm diameter (enlarged from 8 mm in the testing phase);
- discharge 3 m above the bottom, at an angle of 45°;
- exit flow velocity 27 m/s (expected 35 m/s for 8 mm nozzle);
- off-shore location 2300 m; 8 m depth.



Monitoring program



Monitoring of effluent
 quality and quantity of brine
 technical conditions of discharge



Monitoring of marine environment
 center of installation:
 1.5, 3.5, 5.5, 7.5m below MSL:
 conductivity (salinity), temperature,
 wind conditions
 near-field of installation:
 CTD measurements

Assessment of excess salinity

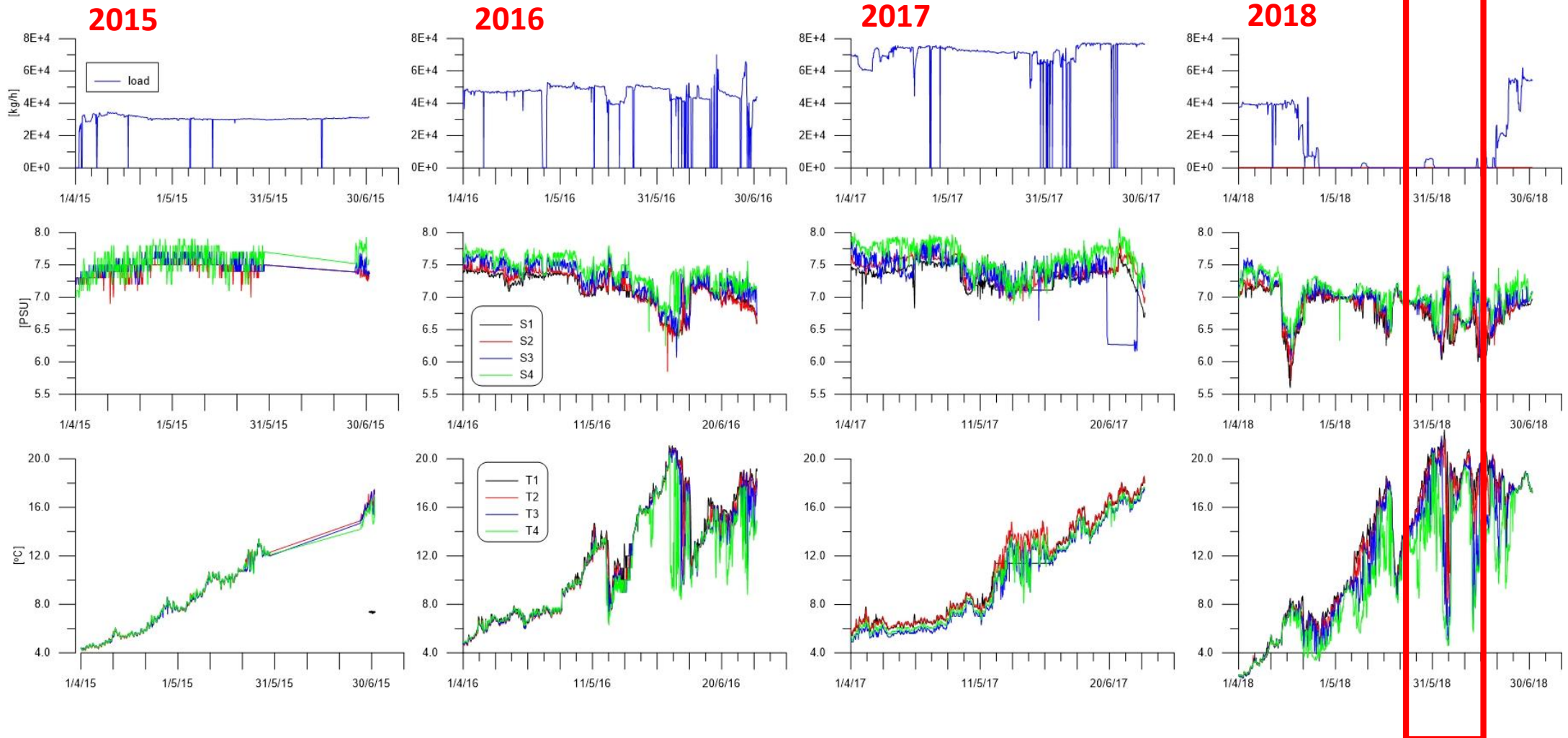
excess salinity due to discharge = salinity measured in situ – natural background

Assessment based on salinity measurements:

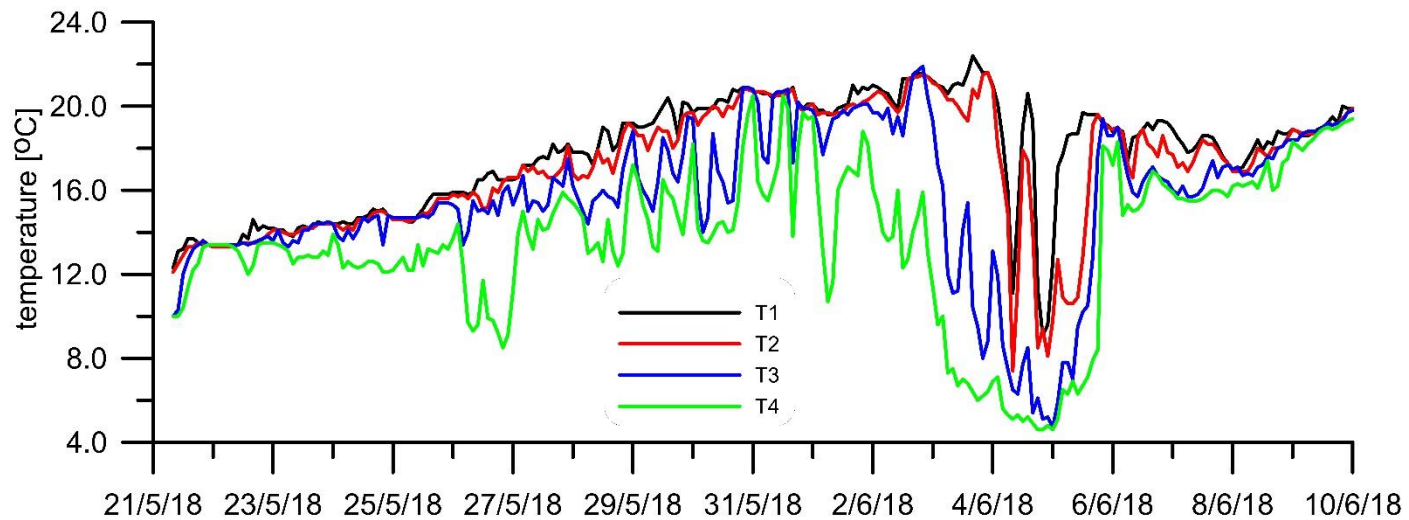
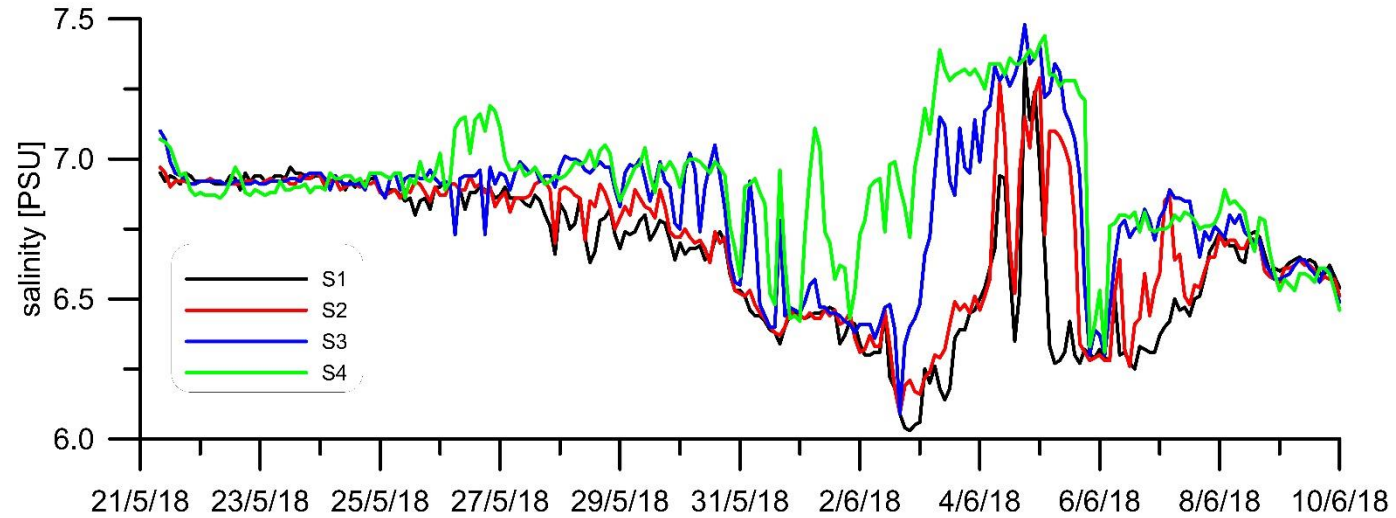
- Simple „operational” approach based on continuous measurements in the center of installation
- Detailed analysis of salinity measurements in the vicinity of installation (spatial measurements)

Assessment based on analysis of discharge conditions

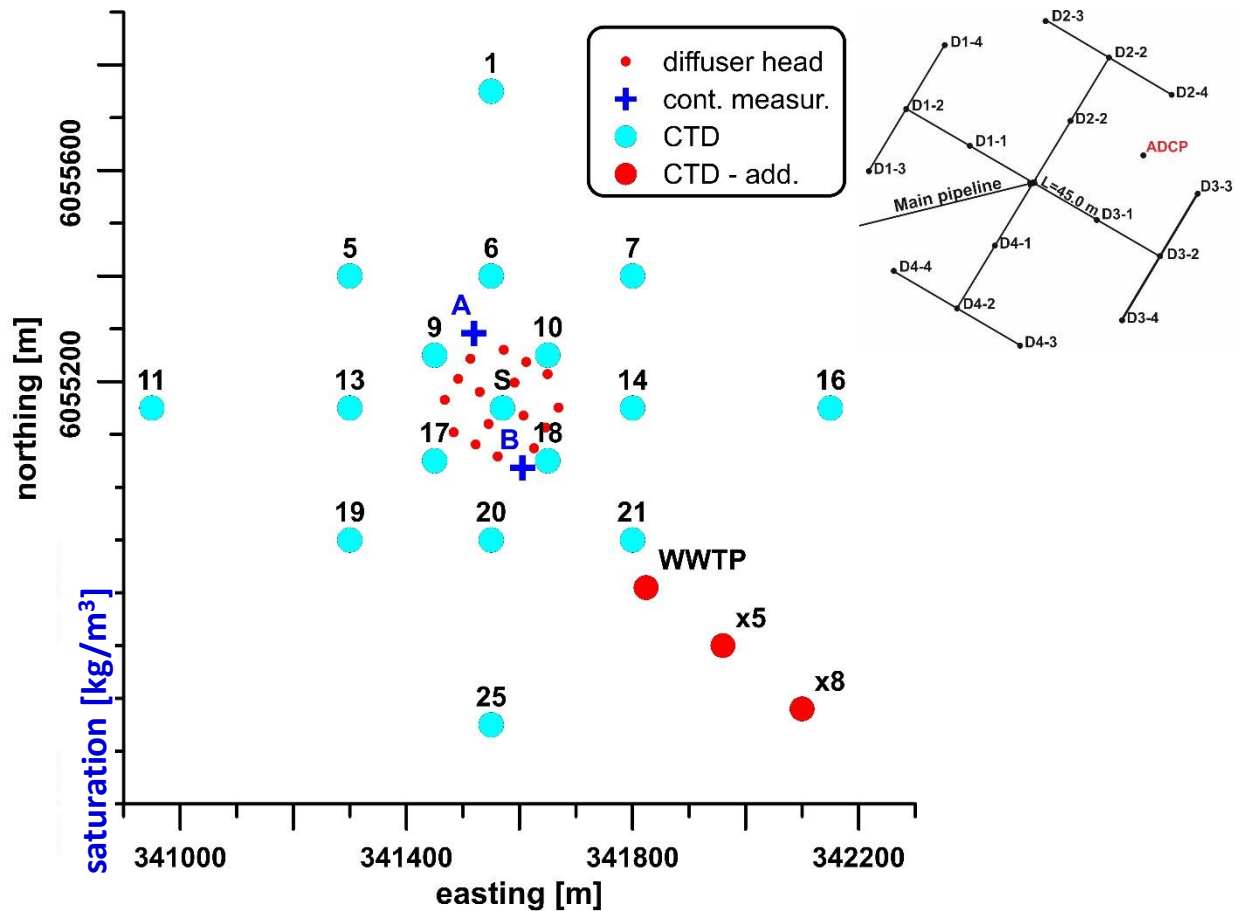
Continuous monitoring – center of installation exemplary results



Continuous monitoring – center of installation



Monitoring in the near-field of installation



Start-up monitoring (2010 - 2012)

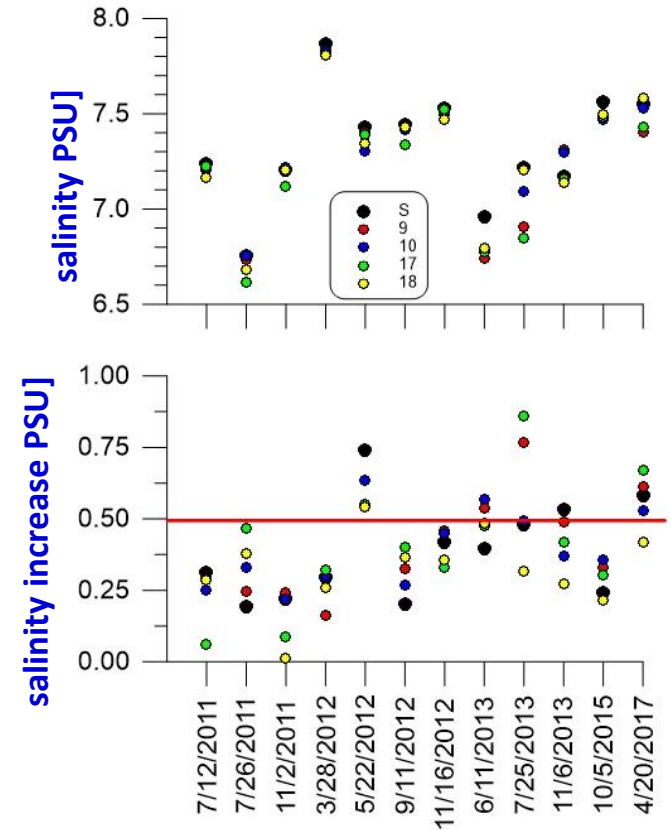
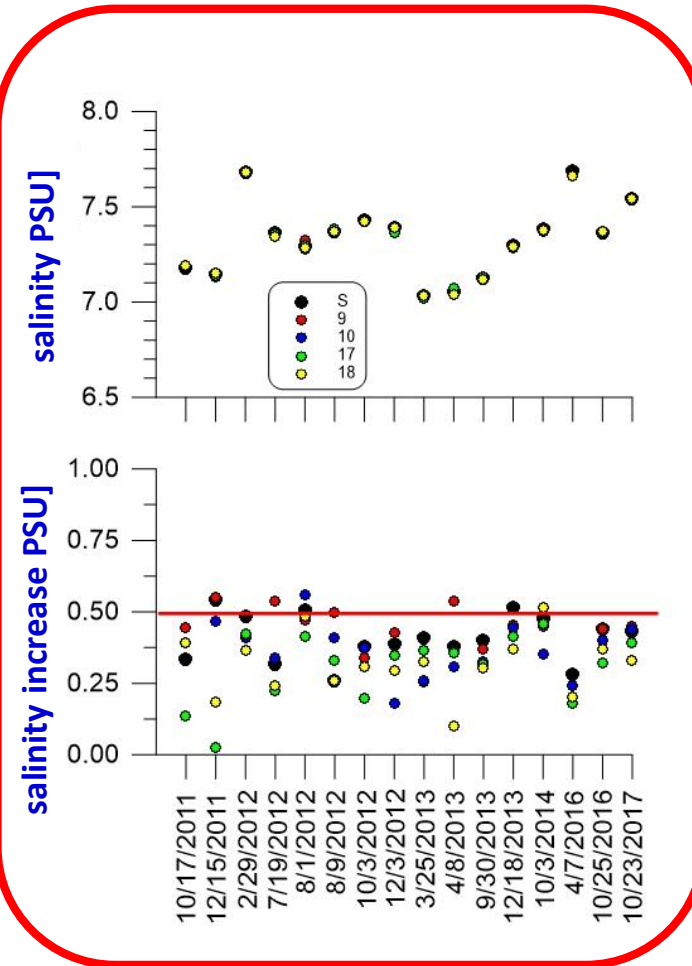
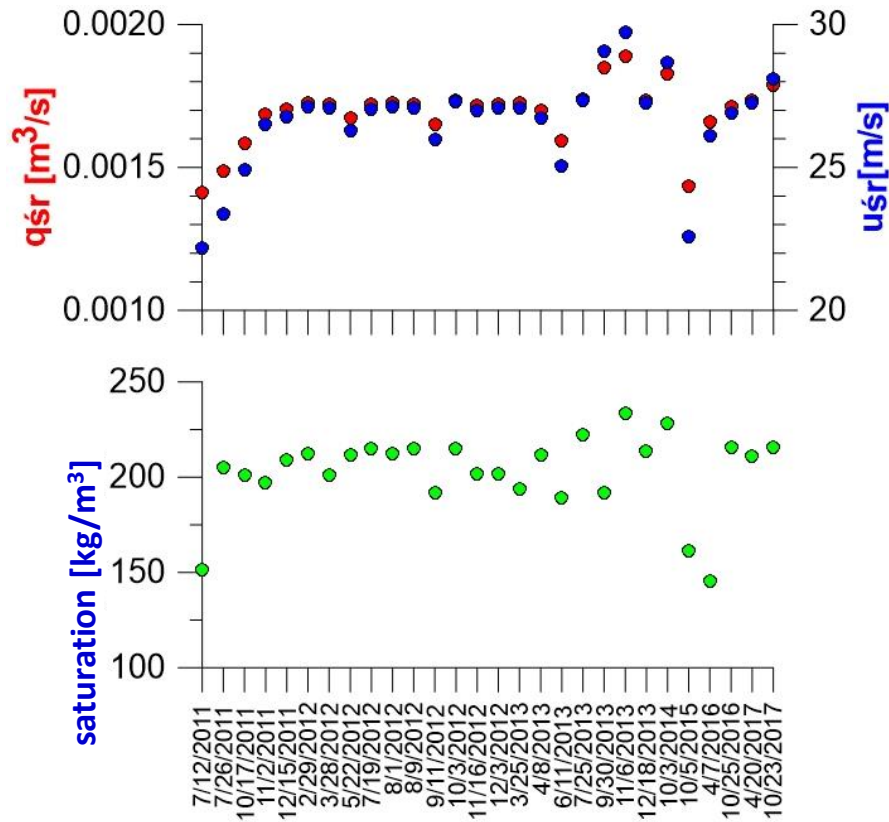
- *Continuous measurements* (locations A & B)
 - 13.10 – 26.11.2010
 - 12.07 – 26.08.2011
 - 22.05 – 9.08.2012
- *Spatial measurements* (17 verticals - CTD)
 - 21 series
- *Local measurements* (vicinity of head)
 - 2 experiments (2011, 2012)

Basic monitoring (2013 –)

- *Spatial measurements* (5/17 verticals):
 - 2013 – 10 series
 - since 2014 – april, october
- **Additional measurements**
- *Influence of WWTP Dębogórze* (2017 -)
 - cross-section x5 – x8
- *Currents* (ADCP) in the vicinity of installation (X 2018- V 2019)

Verification of „operational method” based on short-term measurements (IBW PAN)

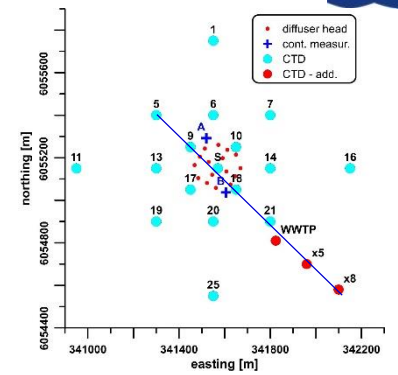
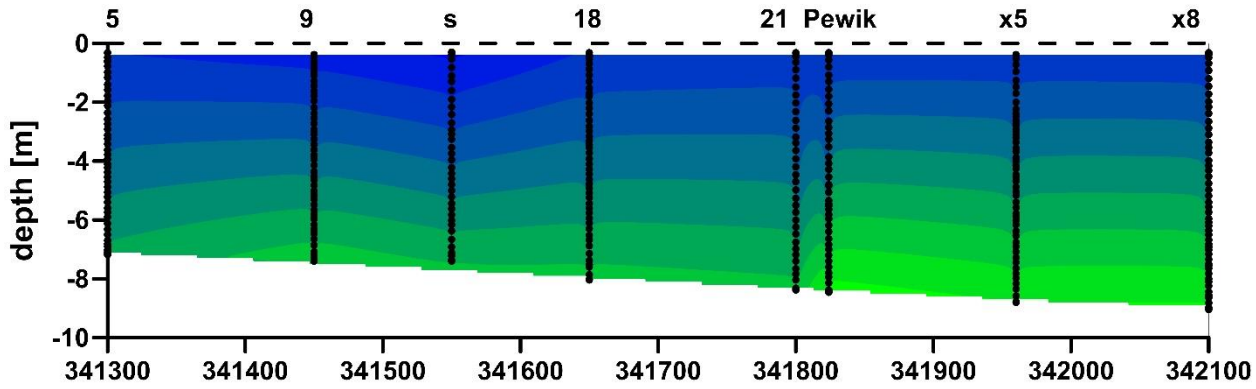
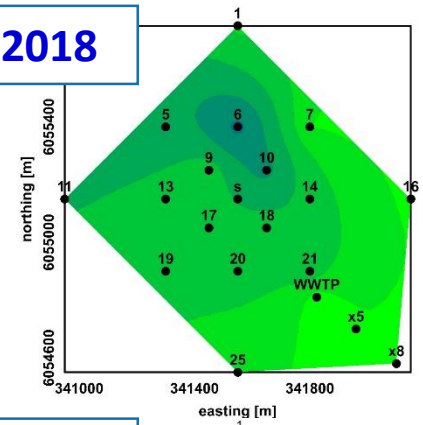
analysis based on data from 2011 – 2017 (at least 3 days of continuous discharge)



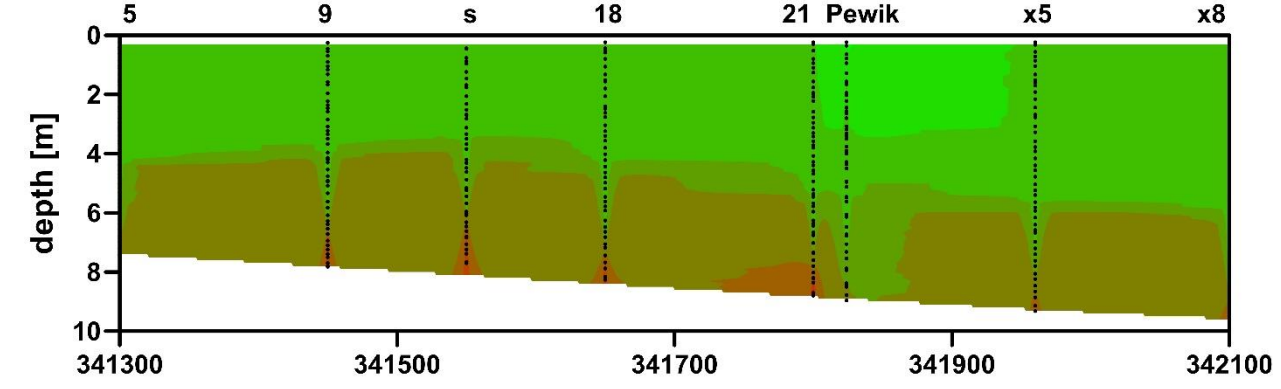
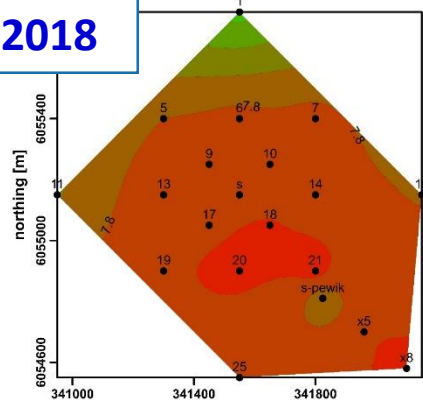
Monitoring of brine mixing – CTD measurements



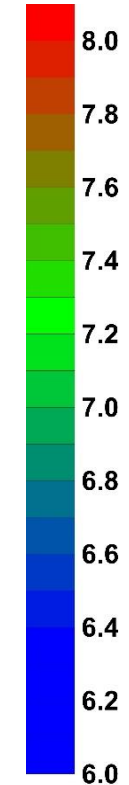
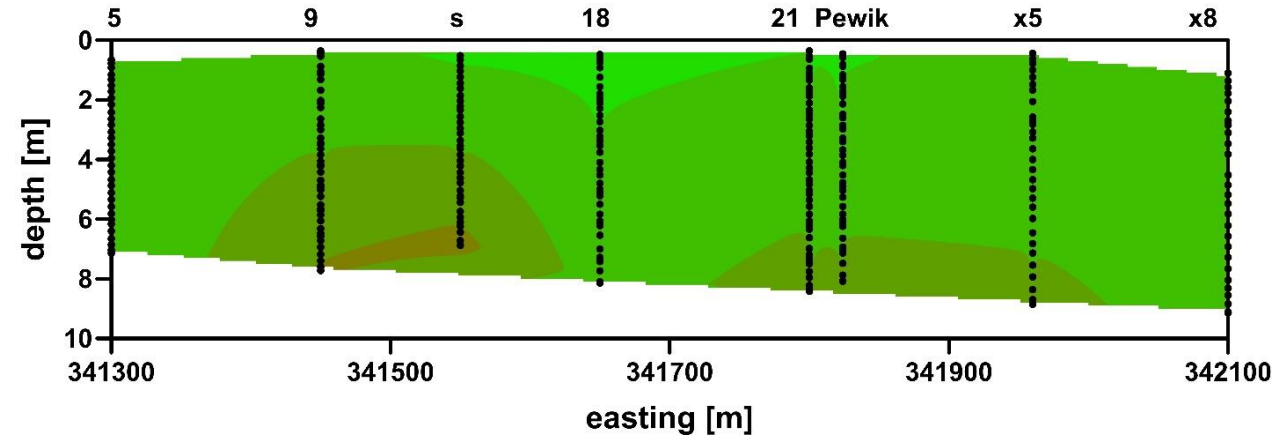
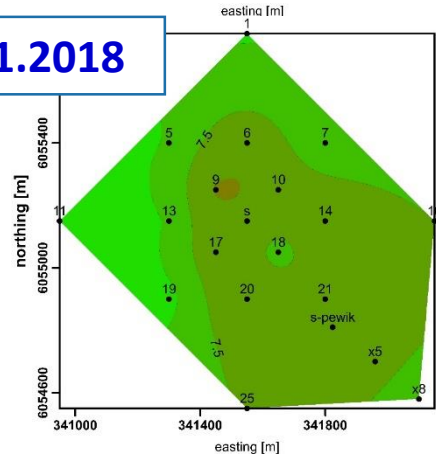
18.04.2018



17.10.2018

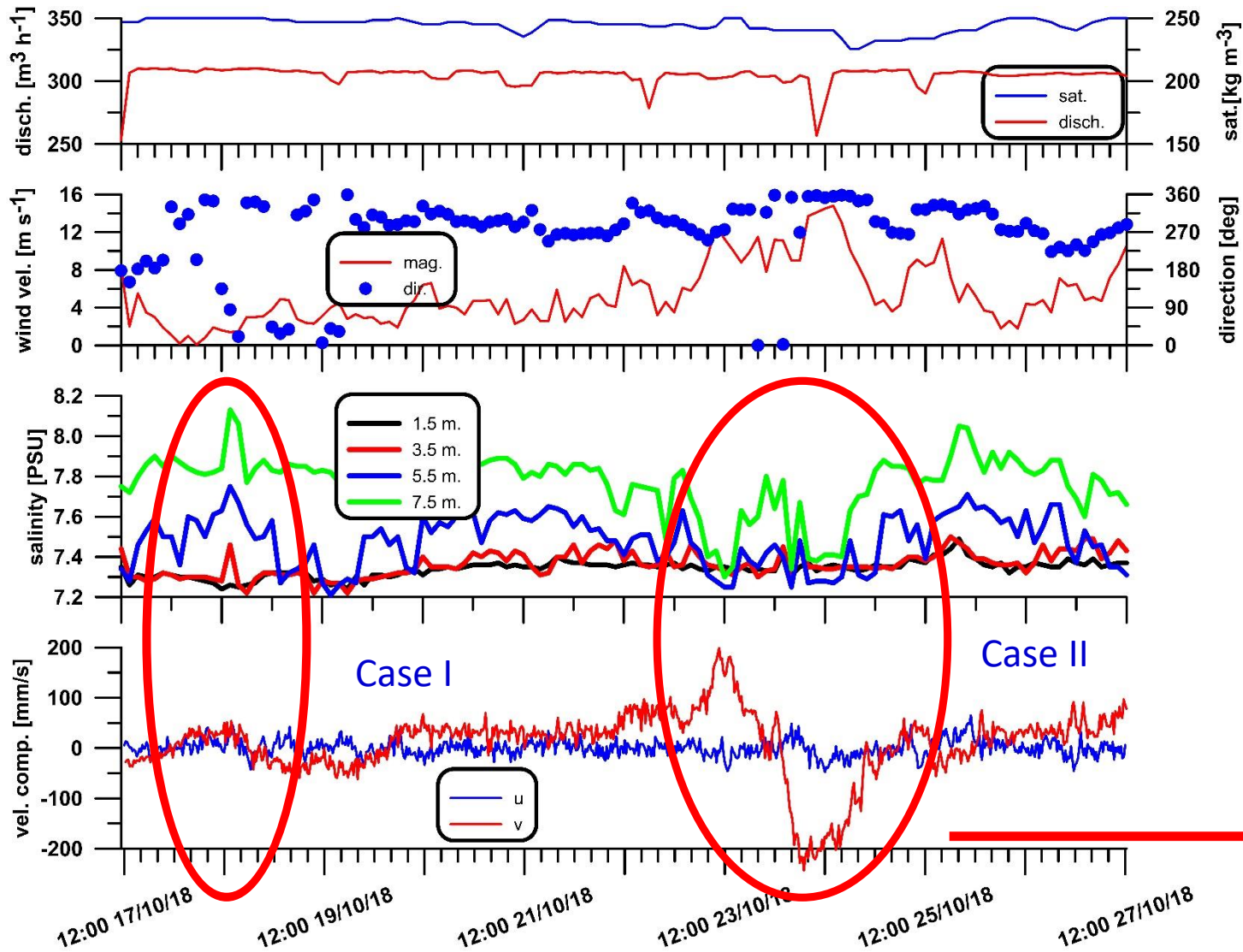


28.11.2018

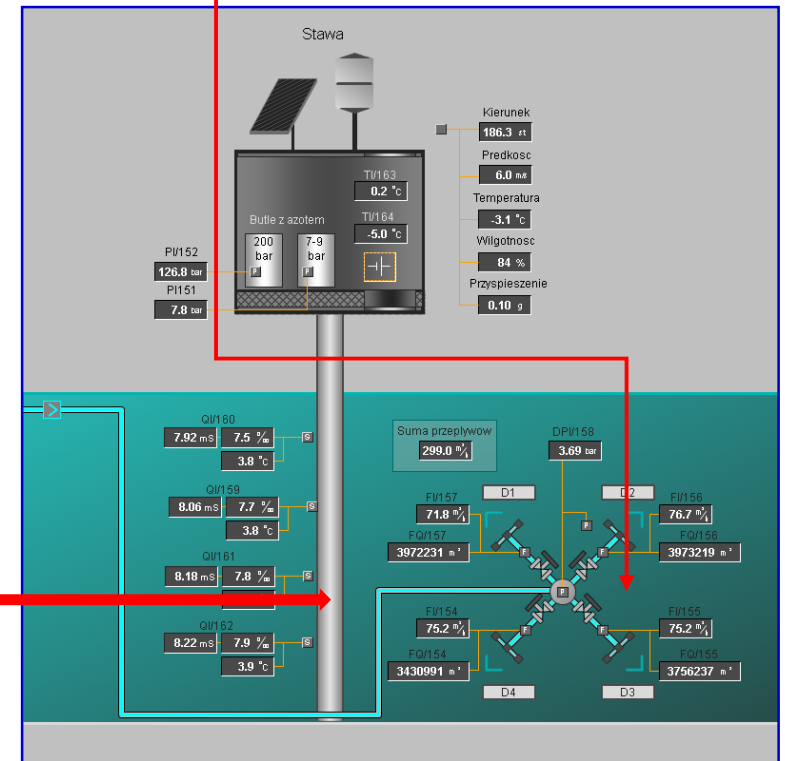


Salinity [PSU]

Support of brine mixing monitoring by ADCP measurements

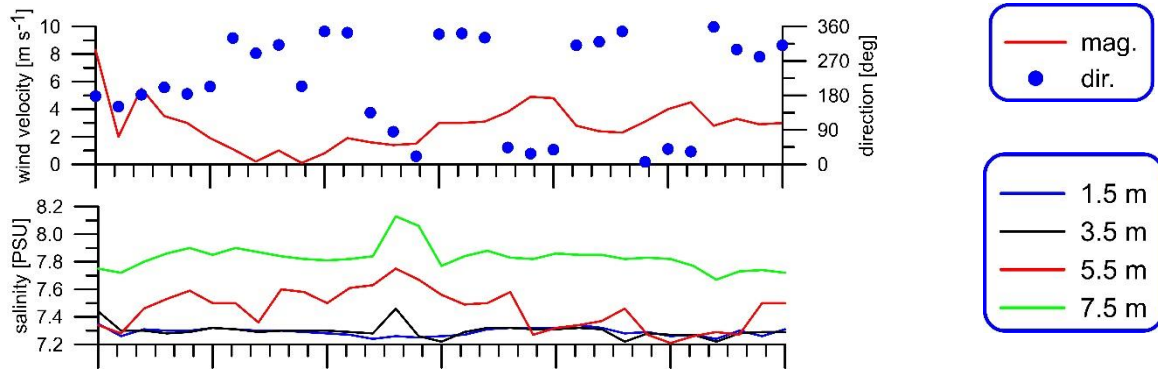


Workhorse Sentinel
ADCP RDI

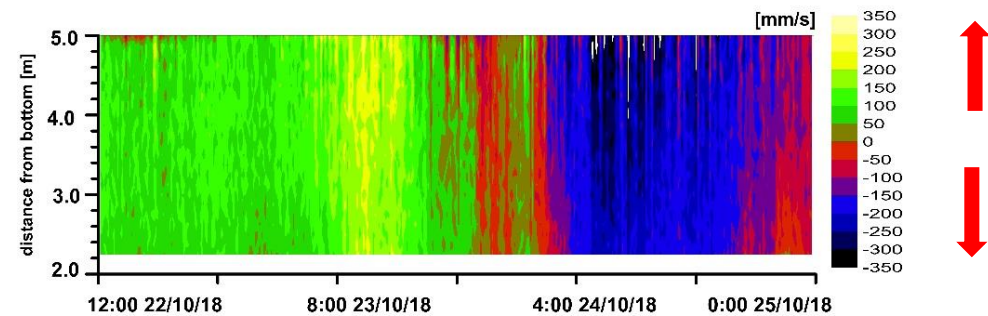
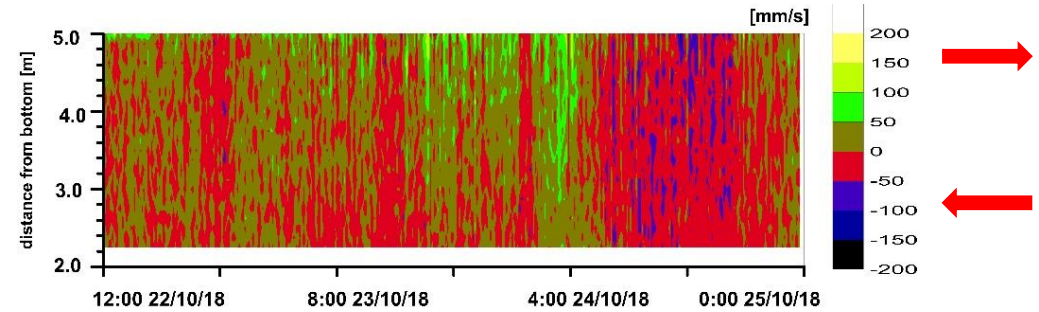
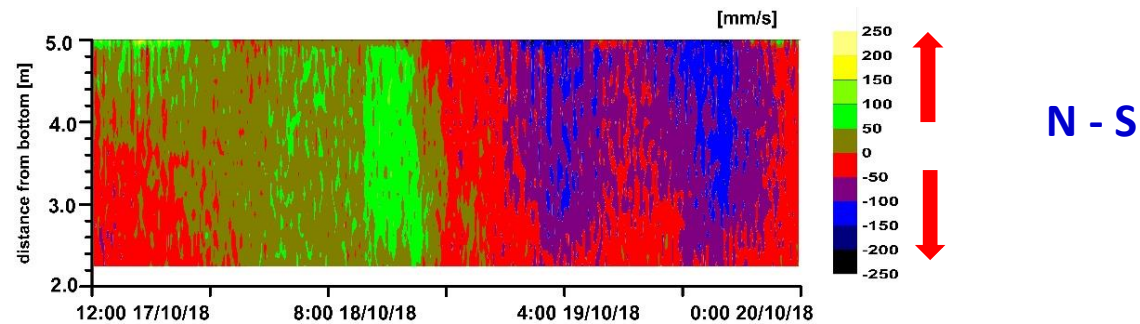
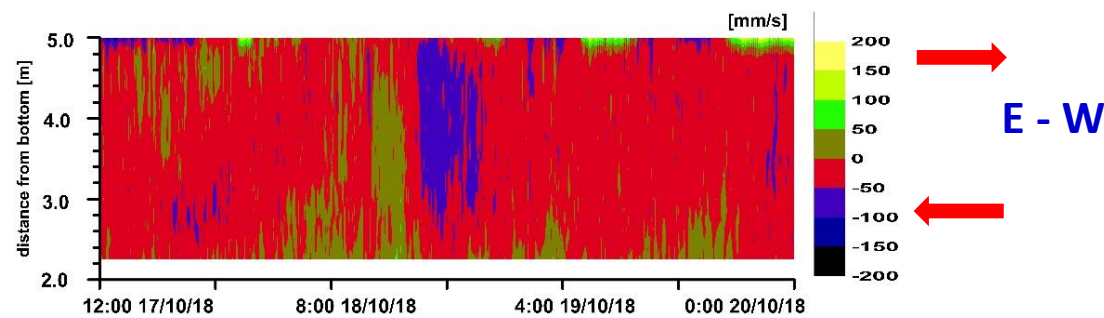
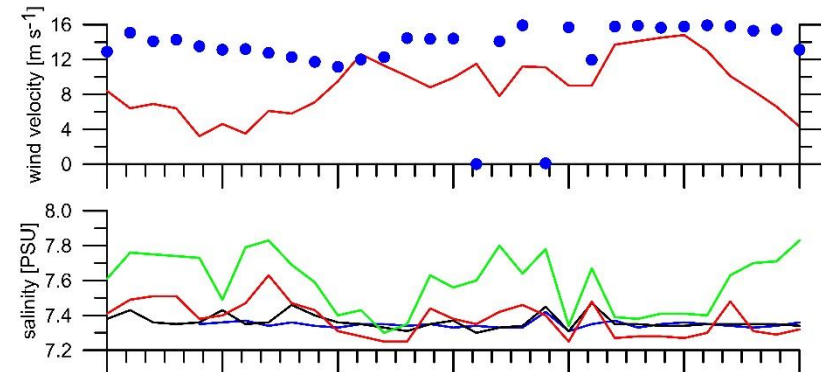


Support of brine mixing monitoring by ADCP measurements

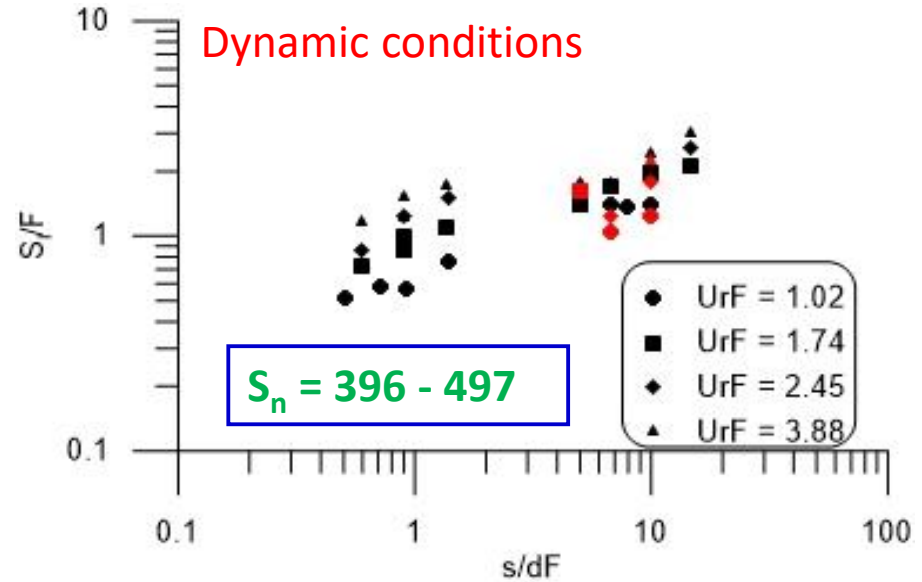
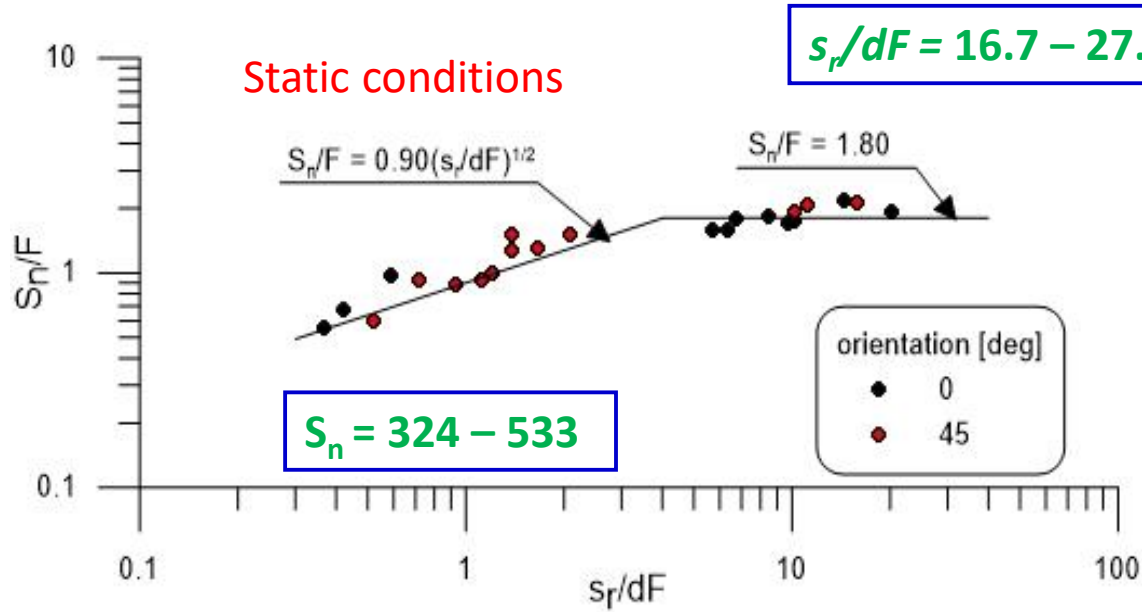
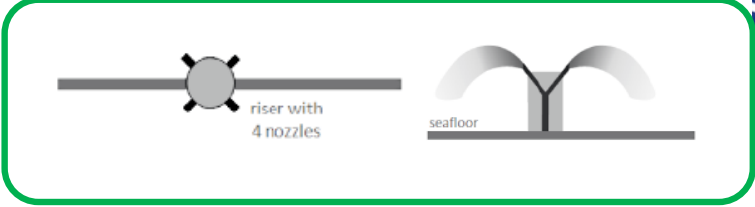
Case I – salinity increase at the bottom



Case II – full mixing in the water column



Application of laboratory experiments for rosette type diffuser - (Abessi & Roberts 2014, 2016)



s_r - distance between risers
 S_n - dilution level

$s_r/dF \gg 1$ - no interaction between jets from neighbouring risers

$s_r/dF \ll 1$ - interaction between jets

$$F = \frac{u_0}{\sqrt{g'_0 d}}; \quad g'_0 = \frac{(\rho_0 - \rho_a)g}{\rho_a}$$

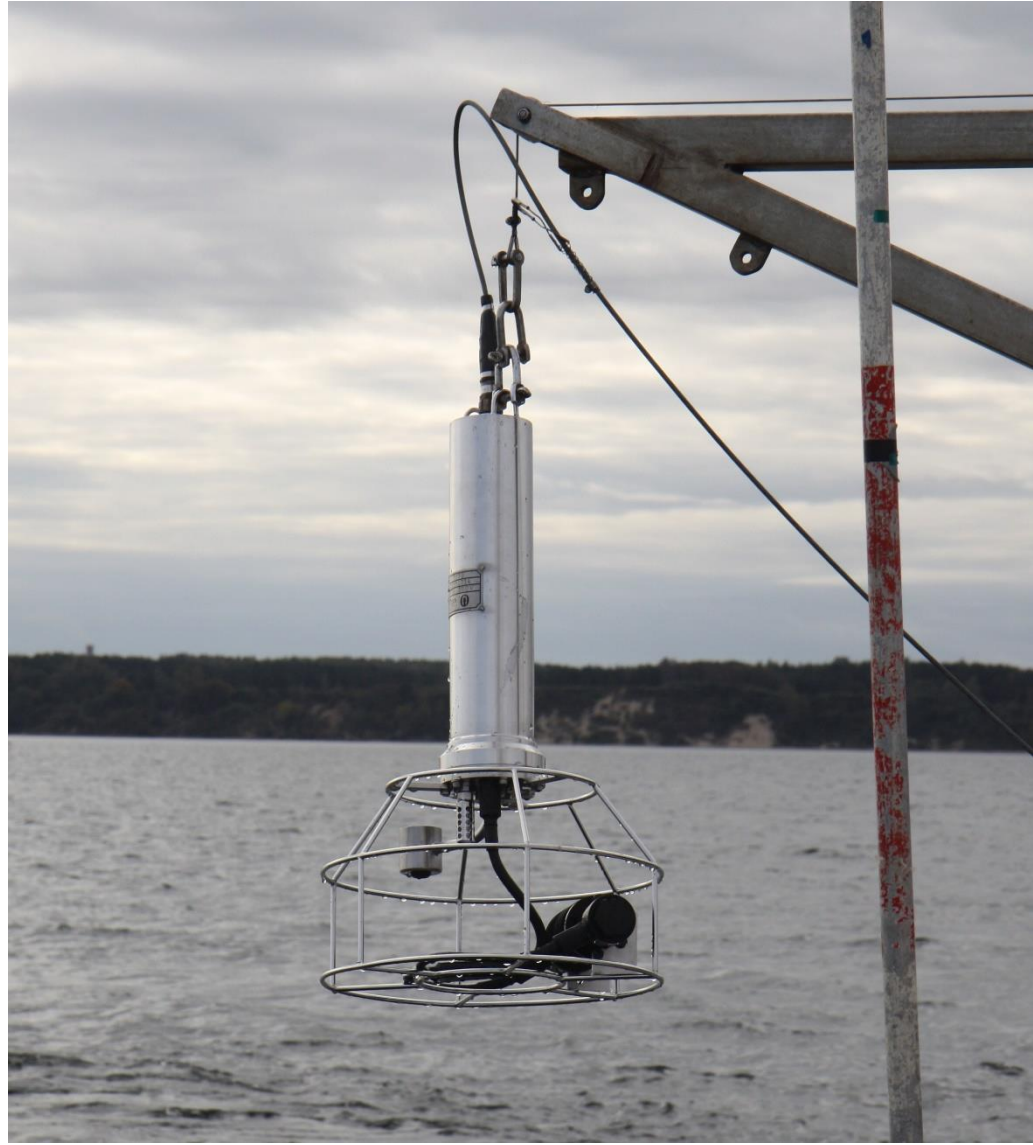
$F = \text{av. } 252, \text{ min. } 217, \text{ max } 284$

F - densimetric Froude number
 u_0 - exit flow velocity
 u_f - ambient flow velocity
 d - nozzle diameter
 ρ_0 - brine density
 ρ_a - ambient density
 g - acceleration due to gravity

Summary and conclusions

- Results of the start-up and basic monitoring carried out in the years 2010 - 2018 confirm that excess salinity in the near-field of installation does not exceed 0.5 PSU in relations to natural background.
- The on-going monitoring confirms good mixing of brine with marine waters of Puck Bay by the use of the rosette-type diffuser system.
- To monitor excess salinity on the daily basis investor (Gas Storage Poland) introduced „operational procedure” based on continues measurements in the central location.
- The proposed method fails in some specific conditions: (1) inflow of saline water from the deep part of the Gulf of Gdańsk, (2) inflow of fresh water originating from Vistula river or wastewater treatment plant. Measurements of currents using ADCP can support their explanation.
- Continuous monitoring of should be used assess excess salinity when break of salinity monitoring occurs.

Acknowledgments: This study has been financially supported by Gas Storage Poland
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Assessment of excess salinity

excess salinity due to discharge = salinity measured in situ – natural background

Assessment based on salinity measurements

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Assessment based on analysis of discharge conditions