BETTER SHIPS, BLUE OCEANS

Impact of low water on sailing performance of ships, design considerations

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Introduction

Low water affects the performance of inland ships

- Less cargo capacity!
- Resistance of the ship, ship + barge convoy and pushboat - barge convoy
- Powering: effectiveness of propulsion (propeller + nozzle + appendices)
- Manoeuvring performance
- Dynamic sinkage and trim: called “squat”

- Note: in 2009 J. Zöllner already presented design considerations in Bonn, see ref 1.

- Not in this presentation: cargo capacity related to ship size, lightweight constructions etc.

Content

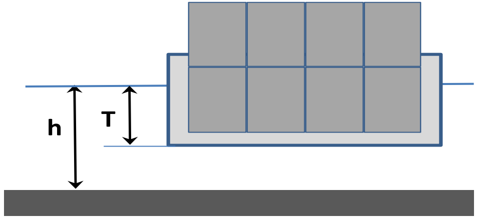
1. Impact of water depth on ship performance (hydrodynamic perspective)
    - Powering
    - Manoeuvring
    - Squat

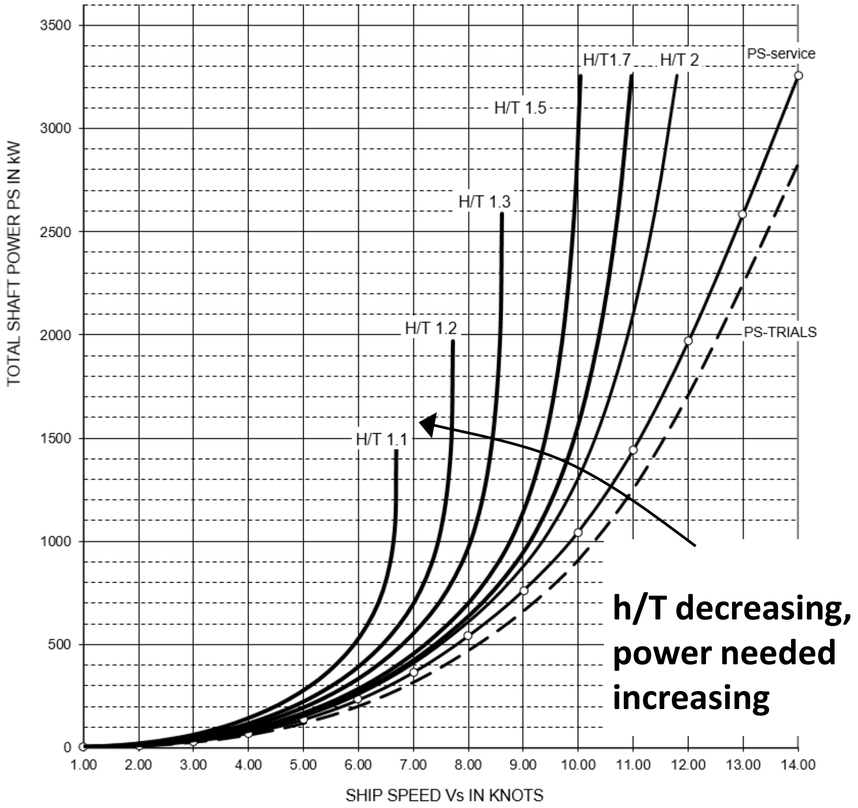
2. Design considerations
    - Starting point: operational profile
    - Bow optimization &
    - Aft ship (tunnel, plate, number of propellers, ….)

3. Examples

4. Research topics

1.1 Resistance of the ship and power needed increases





If water depth (h) decreases, the ratio water depth/draught (h/T) decreases

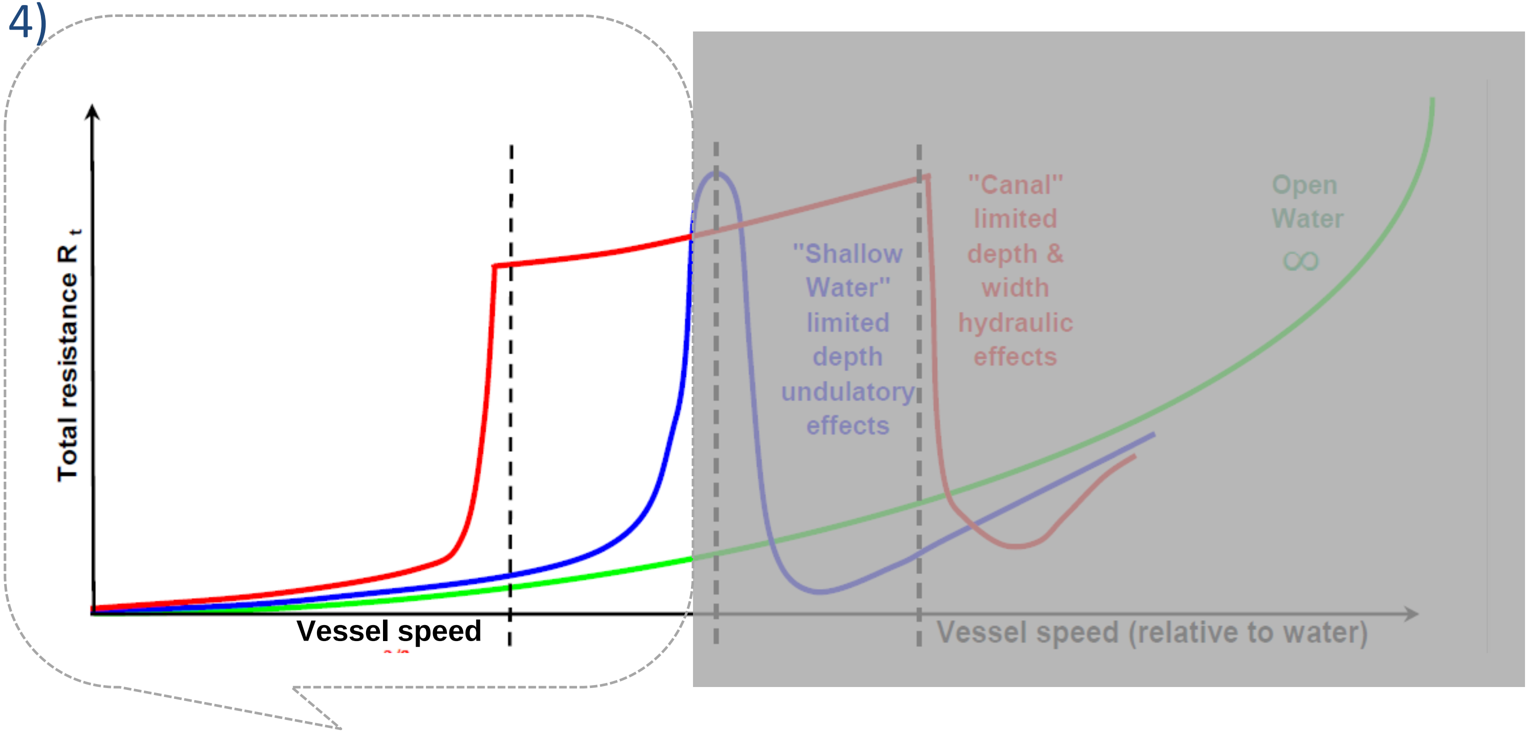
→

Resistance and power increase.

Note: keel clearance = h - T

1.2 Impact of fairway shape on resistance

Typical curves of Resistance in open water, shallow water, restricted water (Pompée, ref 4)

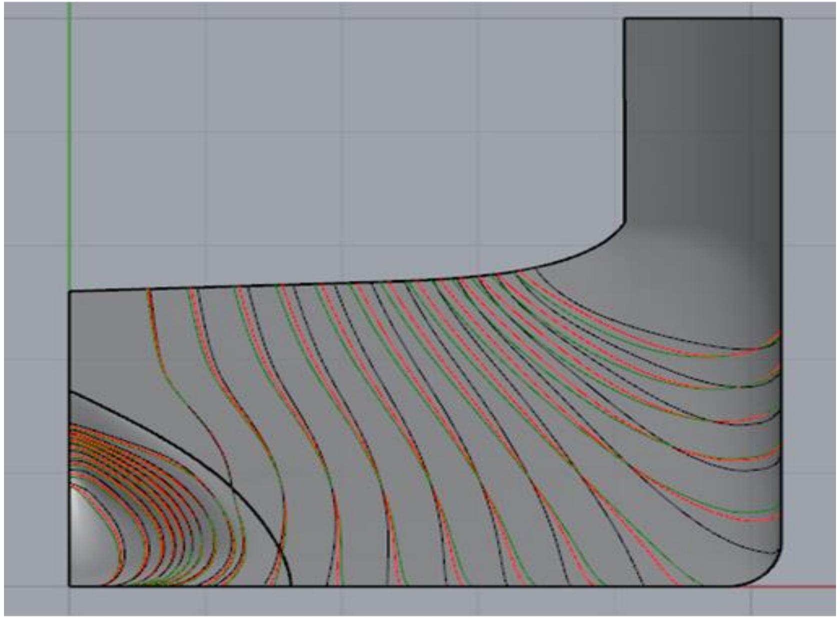


In general inland ships operate in this part of the graph

1.3 Impact shallow water on flow around the stern

Example: streamlines aft ship at different water depths, draught 2.6m, speed 13.5 km/hr.

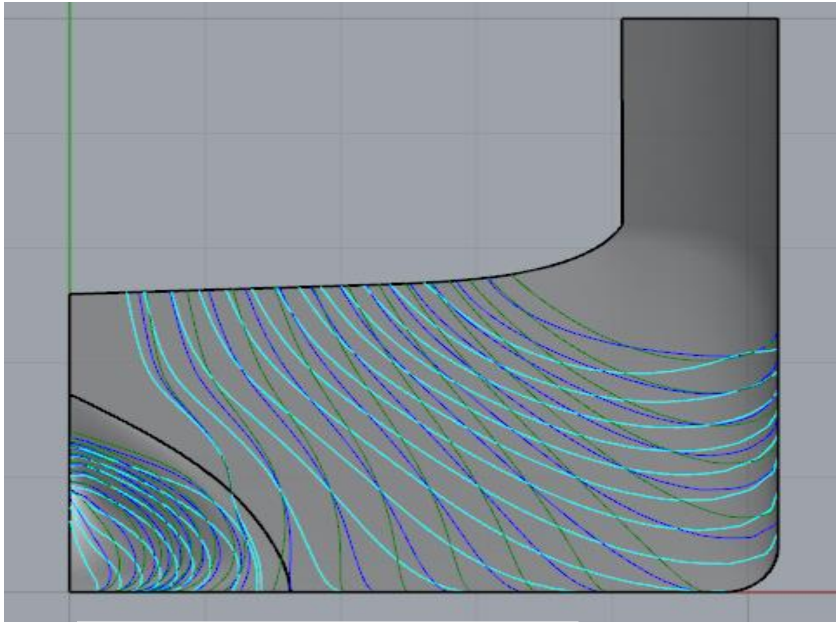
At decreasing keel clearance the flow changes: from "bottom -> up" to "outside -> in"



Black: water depth infinite

Orange: water depth 6.5m

Green: water depth 5.5m



Green: water depth 5.5m

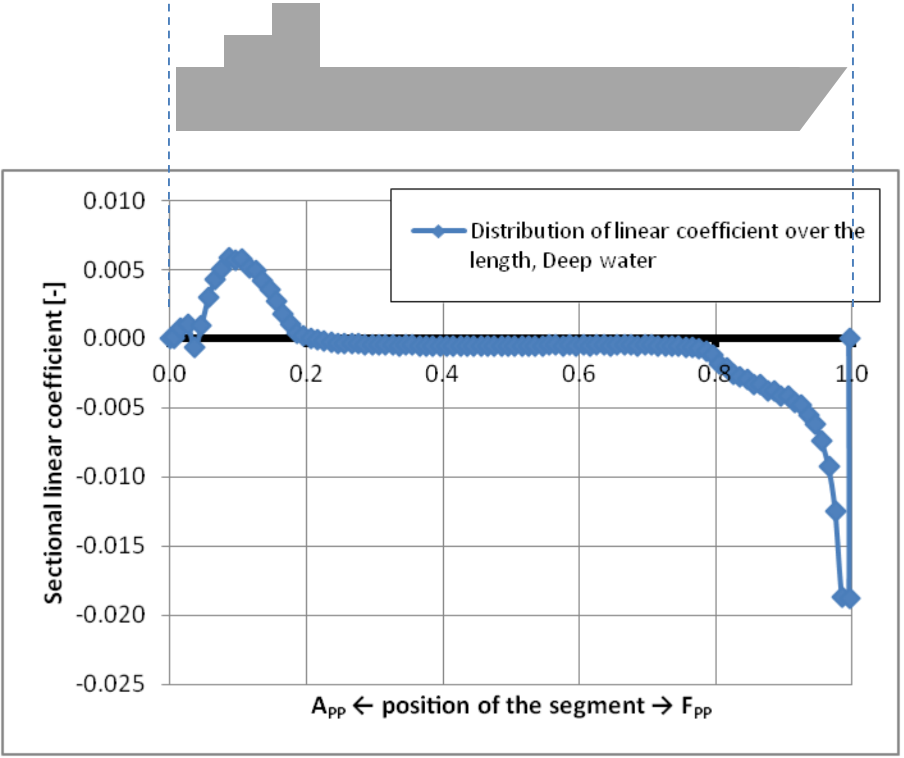
Dark blue: water depth 3.9m

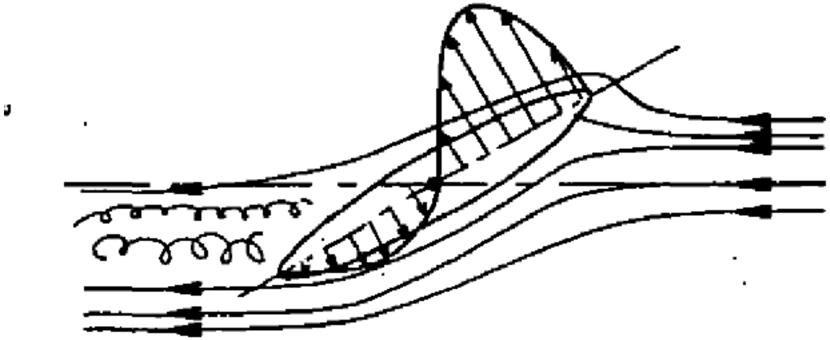
Light blue: water depth 3.1m

1.4 Impact shallow water on manoeuvring

- Increasing hull forces, in longitudinal direction (resistance) and in transverse direction (lift and cross flow drag)
- Decreasing rotation rate, increasing turning circle diameter
- As a result: in general at decreasing keel clearances, smaller drift angles will be needed to compensate for transverse forces (while sailing bends etc.), but turning capabilities will decrease.

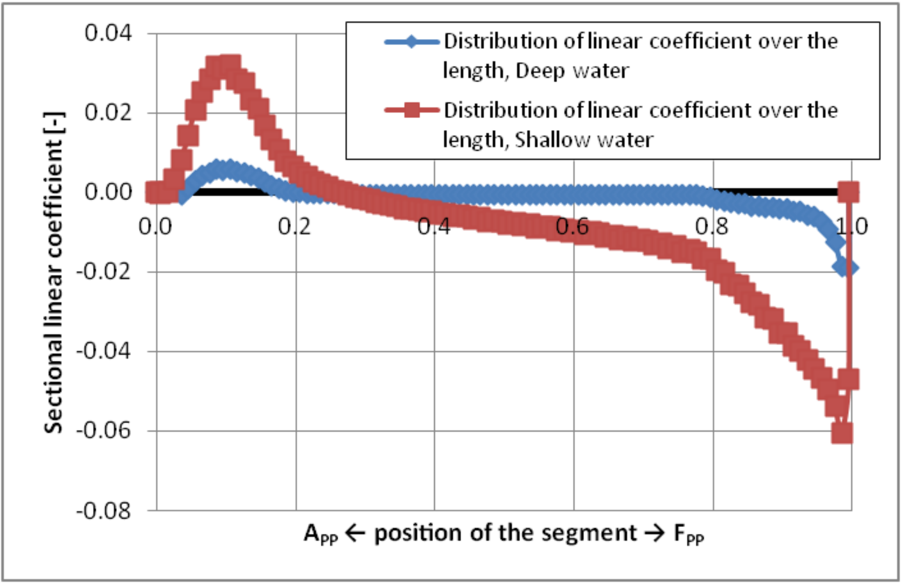
1.5 Example: distribution of lift, deep water (110m inl. ship)

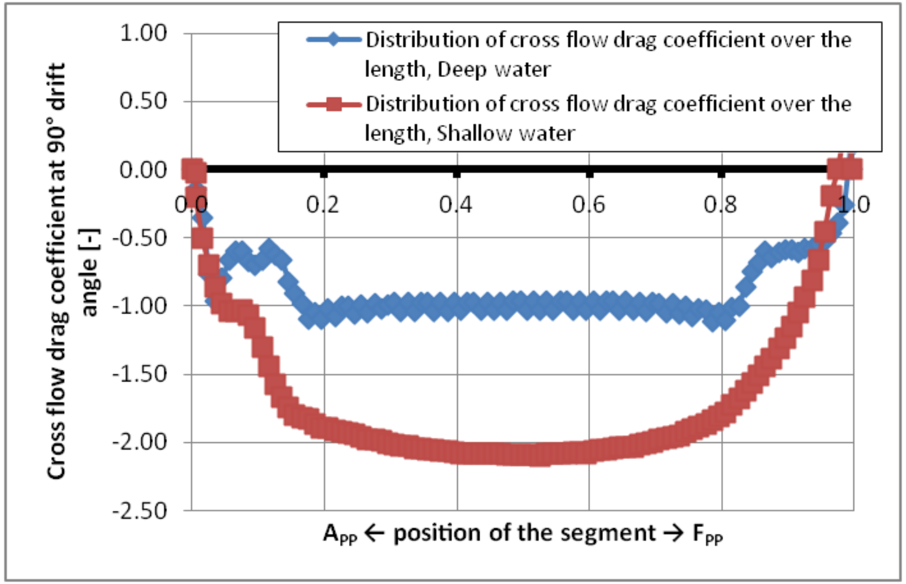




b)

1.6 Distribution of lift & cross flow drag: deep <-> shallow





1.7 Impact shallow water on squat

1. Squat: dynamic sinkage and trim caused by the flow around a sailing vessel
2. In general:
   a. higher speeds, increasing sinkage
   b. less keel clearance (same speed): increasing sinkage
   c. when sailing at less keel clearance often speed will reduce

- State of art presented on Smart Rivers Lyon, September 2019, see ref 3

1.8 Conclusions and future work

1. Midship sinkage
   - Römisch gives best correspondence with model tests
   - Pompée and PIANC 2019 correctly select Römisch
2. Dynamic trim of inland ships
   - Generally
     - bow down,
   - Small draughts, B/T larger
     - Stern down
3. None of investigated equations matches this
4. More model tests research for dynamic trim is and will be performed (2019, 2020,....)

2.1 Design Considerations

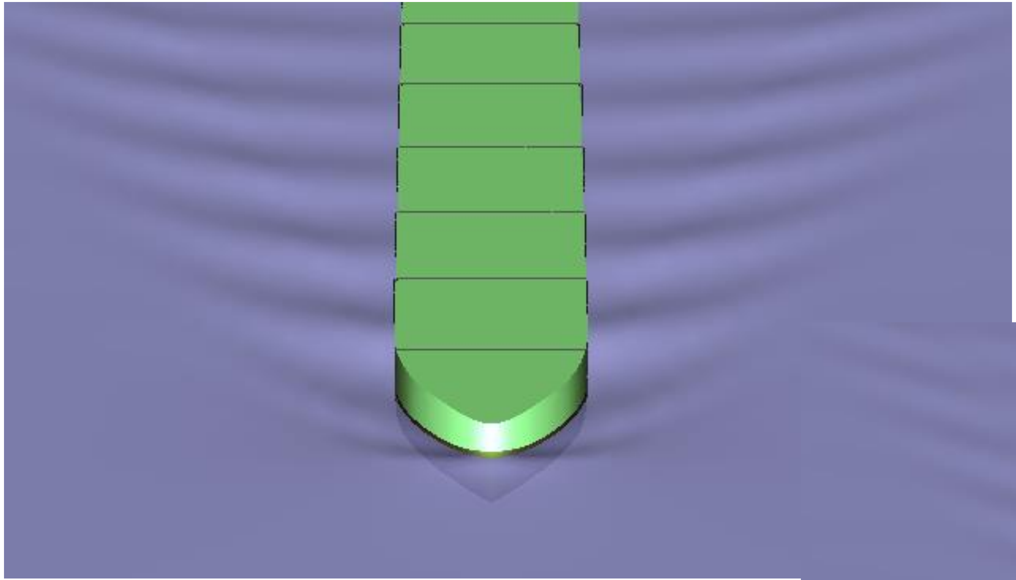
- Design of ship: balancing variables
- Starting point: mission, operational profile

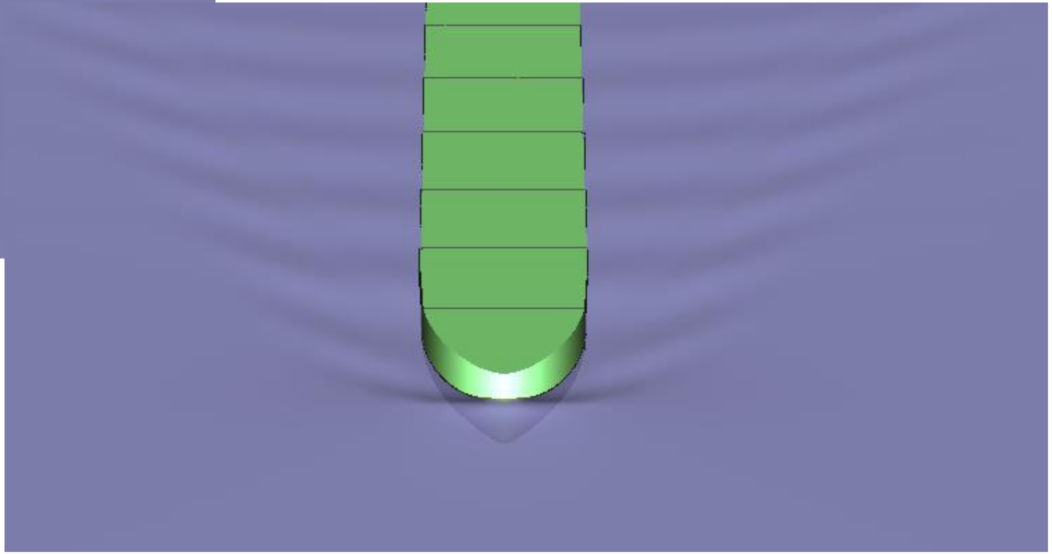
- The broader the mission and the operational profile, the harder it is to optimize a ship design for specific conditions

2.2 Options with respect to hull and propeller design

- Bow design: minimize wave making for the different loading conditions (based on operational profile)
- Propeller: low water. Smaller draught → smaller diameter. Apply modern propeller design and nozzle (Düse)
- Apply two or more propellers
- Prevent air suction to the propeller: tunnel, flex tunnel, cover plate,.....

2.3 Example 110 * 13.50 inland tanker (1)





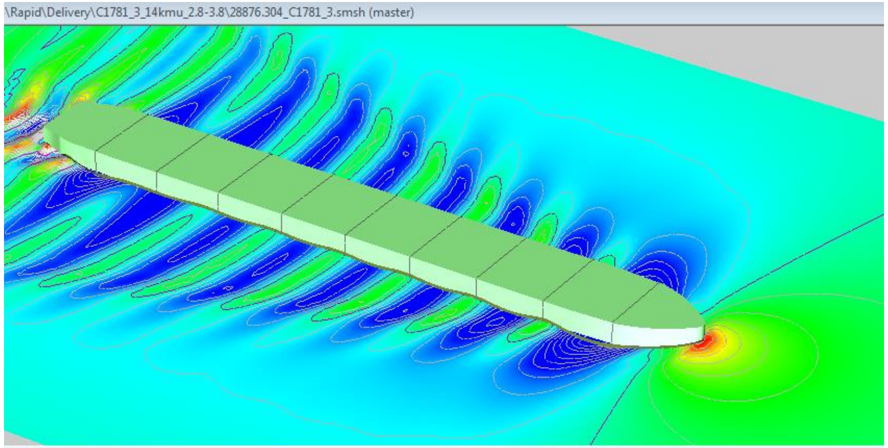
Up: before optimization

- Draught 3,50m
- Water depth 6 m

Right: after optimization

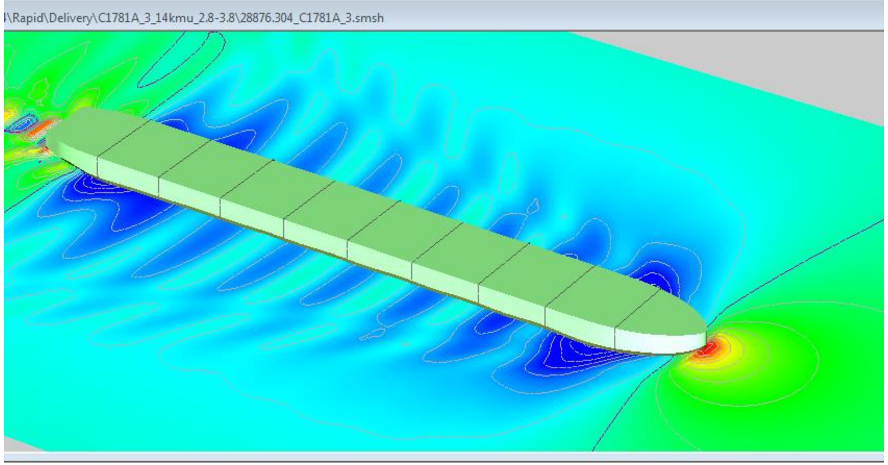
2.4 Example 110 * 13.50 inland tanker (2)

Before optimization:

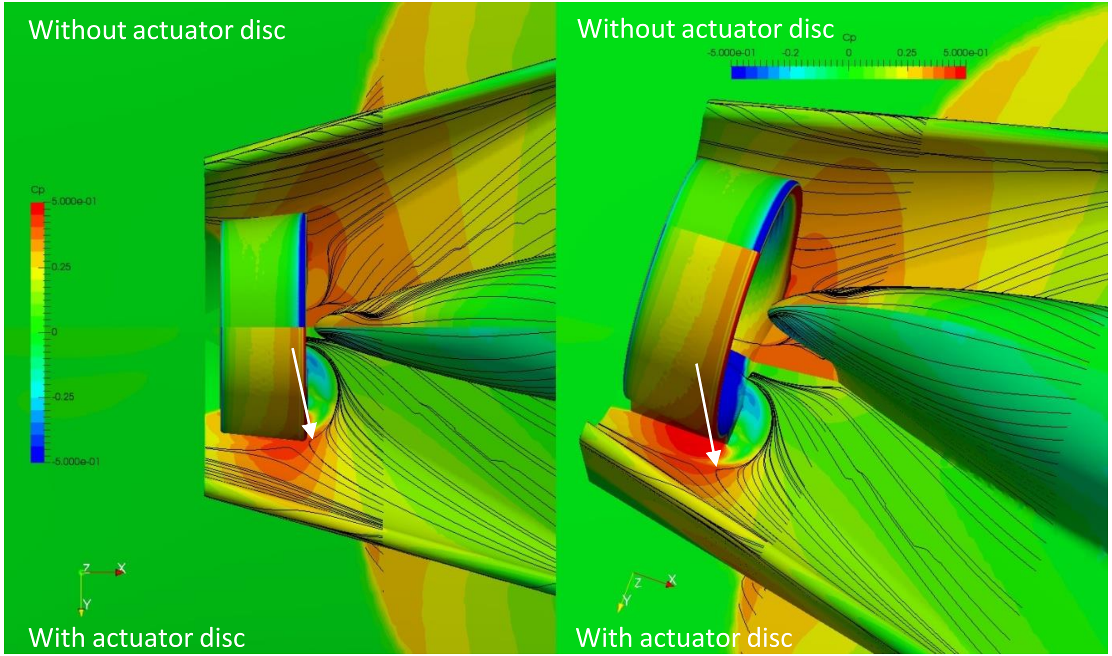


- Draught 2,80m
- Water depth 3,80m

After optimization:



2.5 Example study comparison tunnel designs (1)



Inland container ship

Dynamic pressure coefficient distribution with limiting streamlines for

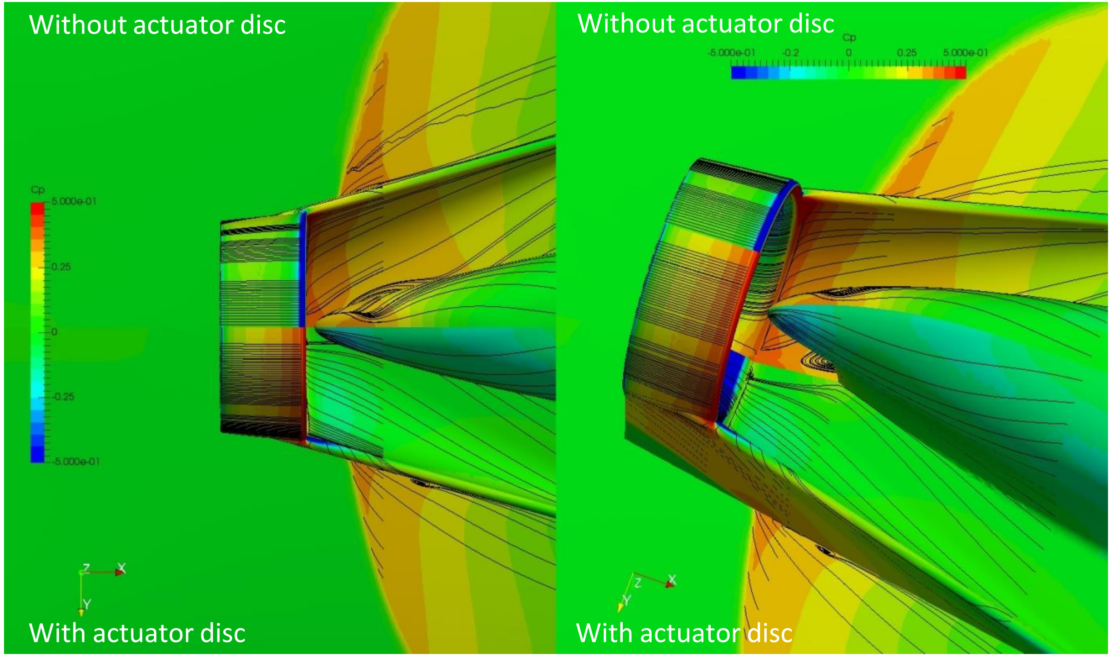
- Inland ship hull,
  tunnel wider than nozzle

  L = 90m, draught loaded ca 2.6m, actual draught 1.5 m

Note: compare top < - > down
(pictures left-right are different views of output of the same calculation)

- Upper half without propeller – without actuator disk
- Lower half with propeller modelled as an actuator disk

2.6 Example study comparison tunnel designs (2)



Dynamic pressure coefficient distribution with limiting streamlines for

- Inland ship hull,
  tunnel aligned to nozzle

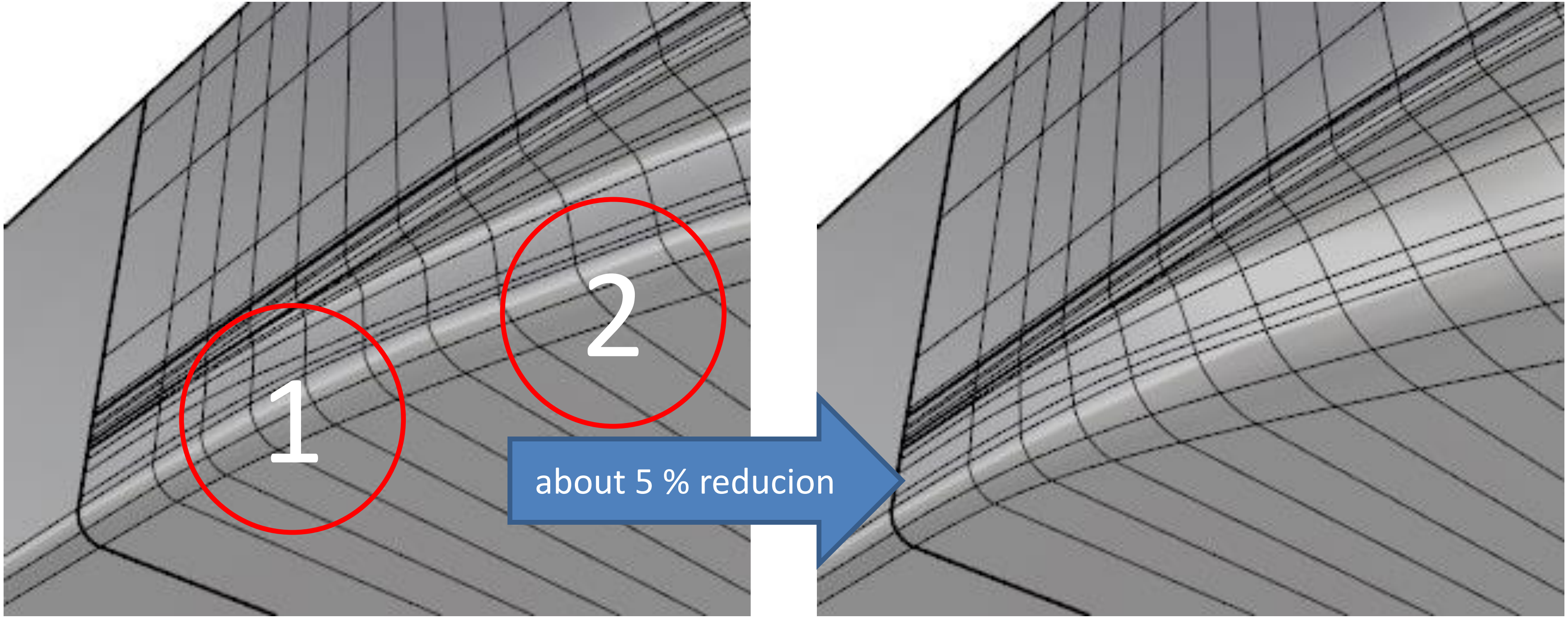
L = 90m, draught loaded ca 2.6m, actual draught 1.5 m

Note: compare left < - > right

- Upper half without propeller – without actuator disk
- Lower half with propeller modelled as an actuator disk

2.7 Example "Topships": impact roundings of bilge (1)

- Increase of the radius of the bilge-rounding has a positive effect on resistance



***Topships**: Joint Industry project focused on "Influence of inland vessel stern shape aspects on propulsive performance", see Ref 4.*

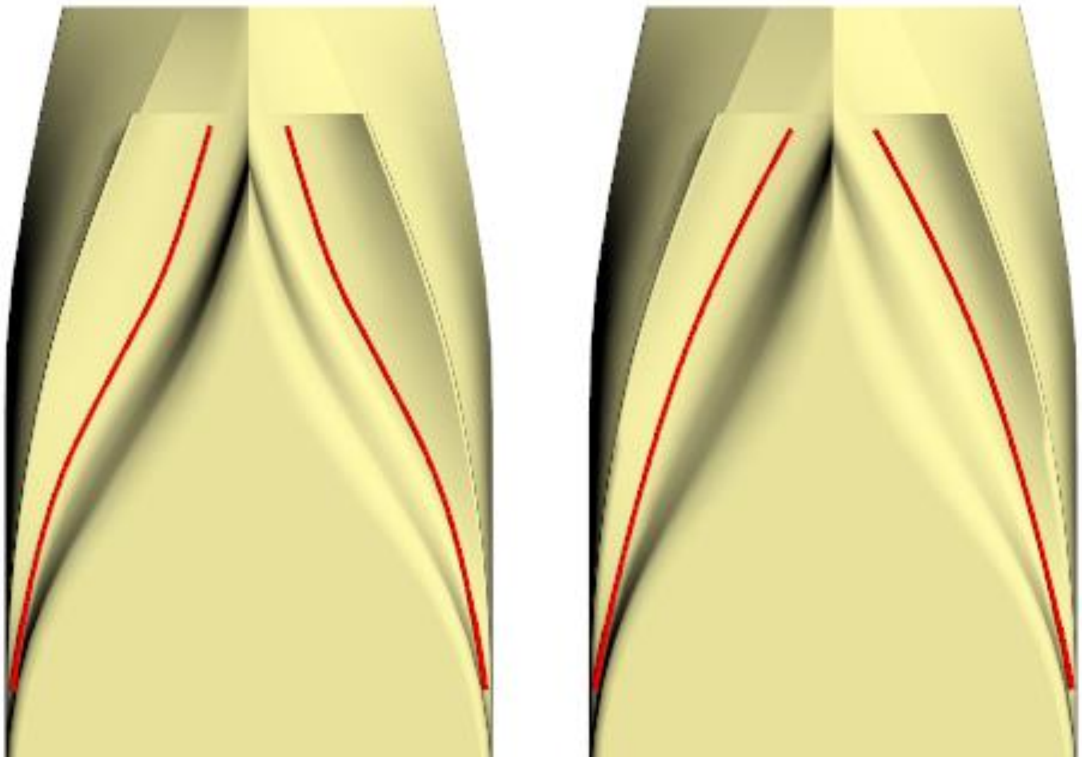
2.8 Example "Topships" (2) tunnel top curvature

Deep water:

Single curved tunnel top curvature favorable (right)

Shallow water:

S curved tunnel top curvature favorable (left)



2.9 Example pushboat Quattro

From: Binnenvaartkrant, 27 mei 2016

Pushboat Quattro operating for Chemgas:

- Length * Width = 29.90m * 11.20m
- Draught 1,40m
- 4 propellers, diameter 1.30m
- 4 diesel engines

Accommodation of aluminum

Sister ship Otto delivered in 2019

2.10 Example newbuilding tanker Oudcomb

From Schuttevaer, 11 juni 2018

Chemical tanker: 110m*14m, deadweight 4.700 ton

Designed for 700 ton cargo at a draught of 1.45m

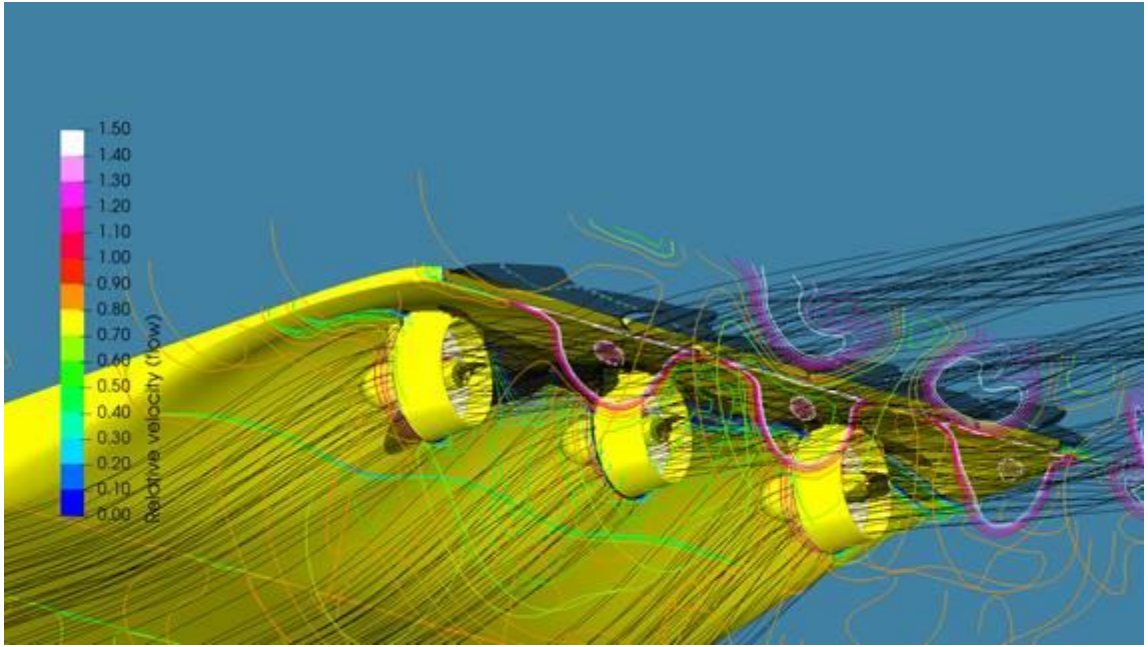
Delivery planned December 2019

Photo: S. Oudakker

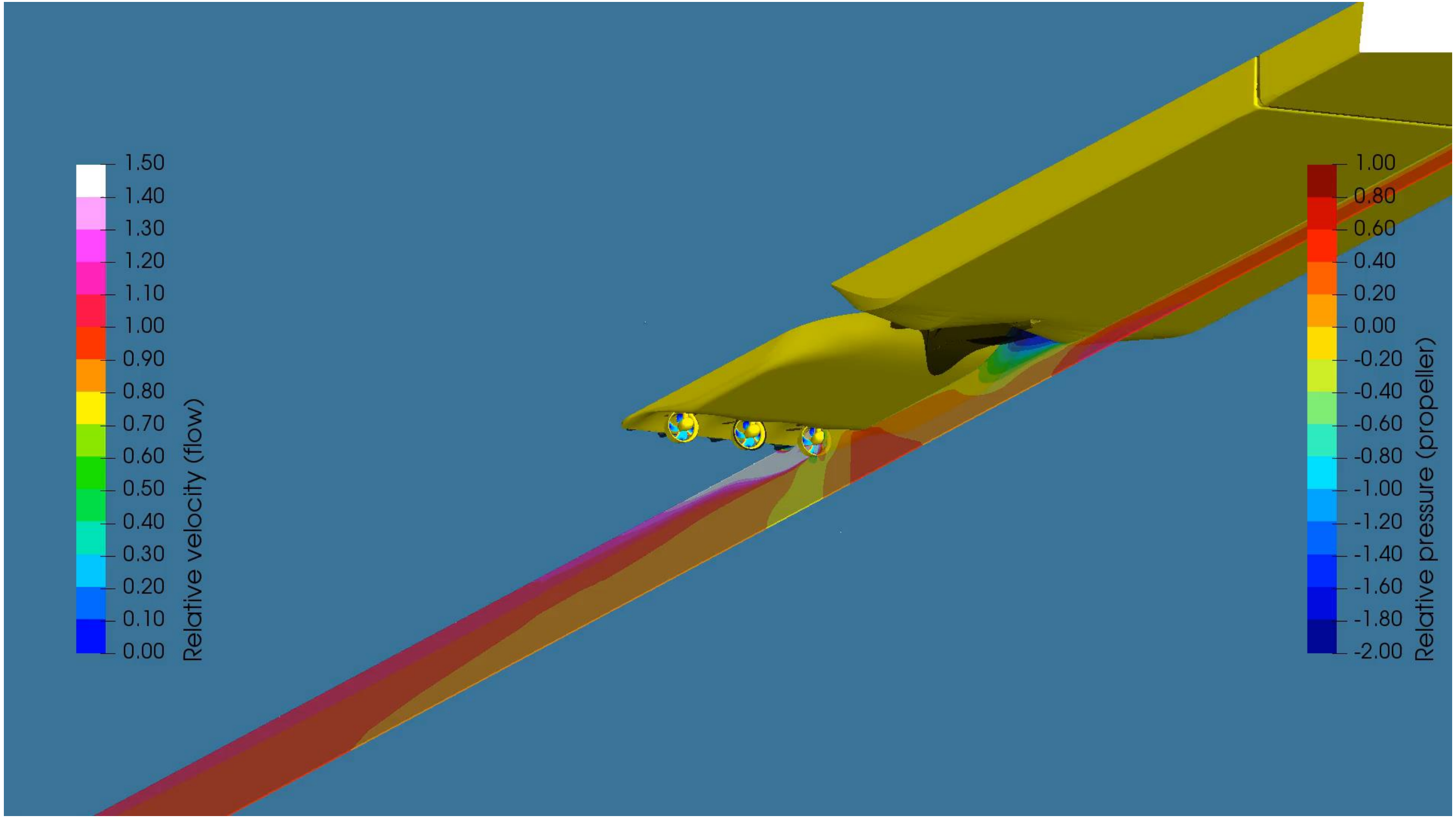
2.11 Example CFD study on different propulsions

Goal: comparing a conventional Propeller – Rudder configuration
with an Azimuthing Stern Drive configuration

Below: example of (output) CFD calculation for the Azimuthing Stern Drive configuration
(also mentioned “Z-drive” or “rudder propeller”)

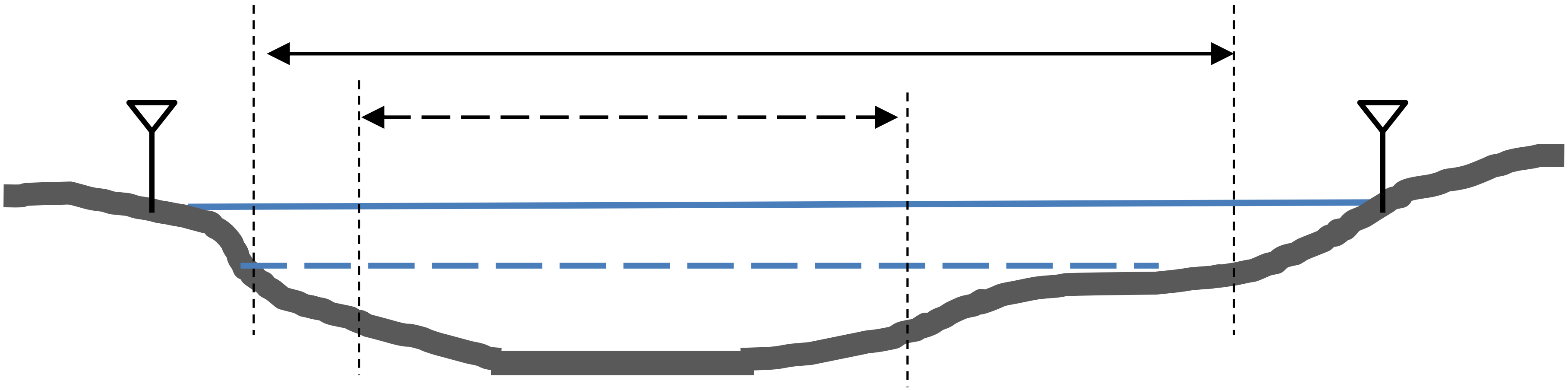


2.12 Example CFD study on different propulsions



Final notes

1. Impact low(er) water levels on fairway width: in general the available fairway width will at best remain unchanged or will decrease if the water levels go down.
2. Lower water levels ➔ less draught ➔ less cargo/ship ➔ more ships to transport same amount of cargo!
3. Both 1. and 2. will result in increasing traffic intensity.



One needs a certain minimum level of water depth for the inland waterway transport system to perform!

Wrap up, conclusions

1. Lower water levels affect sailing behavior of (inland-) ships from a hydrodynamic point of view:
   - More power needed
   - Squat increases
   - Reducing manoeuvring capacity
2. These impacts can be dealt with in the ship design, with limitations!
3. The mission and operational profile of a ship (design) are the starting point.
   Specialization might provide some more options for optimization.
4. In order to improve predictions, some important research topics are:
   - Interaction aft ship – propeller(s) – nozzle(s) – rudder(s) – tunnel etc. in (extreme) shallow water
   - Ship - waterway interaction
   - Ship - ship interaction
   - Shipping traffic in confined waters

- This is reflected in the MARIN R&D agenda for 2020 and beyond.

Don't forget: shipping traffic (management) in confined waterways.

A Dutch saying: “de wal keert het schip” – the shore turns the ship or the river bottom level is the limit.
The inland waterway system needs a certain minimum level of water depth!

References

1. J. Zöllner, *Strömungstechnische Möglichkeiten zur Reduzierung des Kraftstoffverbrauchs und der CO2-Emissionen von Binnenschiffen*, Vortrag beim ZKR Kongress „Rheinschifffahrt und Klimawandel“. Bonn, 24./25. Juni 2009
2. Pierre-Jean Pompée, *About modelling inland vessels resistance and propulsion and interaction vessel – waterway. Key parameters driving restricted/shallow water effects.* Smart Rivers 2015, Buenos Aires, September 2016
3. Anke Cotteleer, Hoyte Raven, Arno Bons, *Validation of squat formulas for inland vessels*, presentation at Smart Rivers, Lyon, 2019
4. Erik Rotteveel, *Influence of vessel stern shapes on propulsive performance*, TU Delft, Delft University of Technology, 2019

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