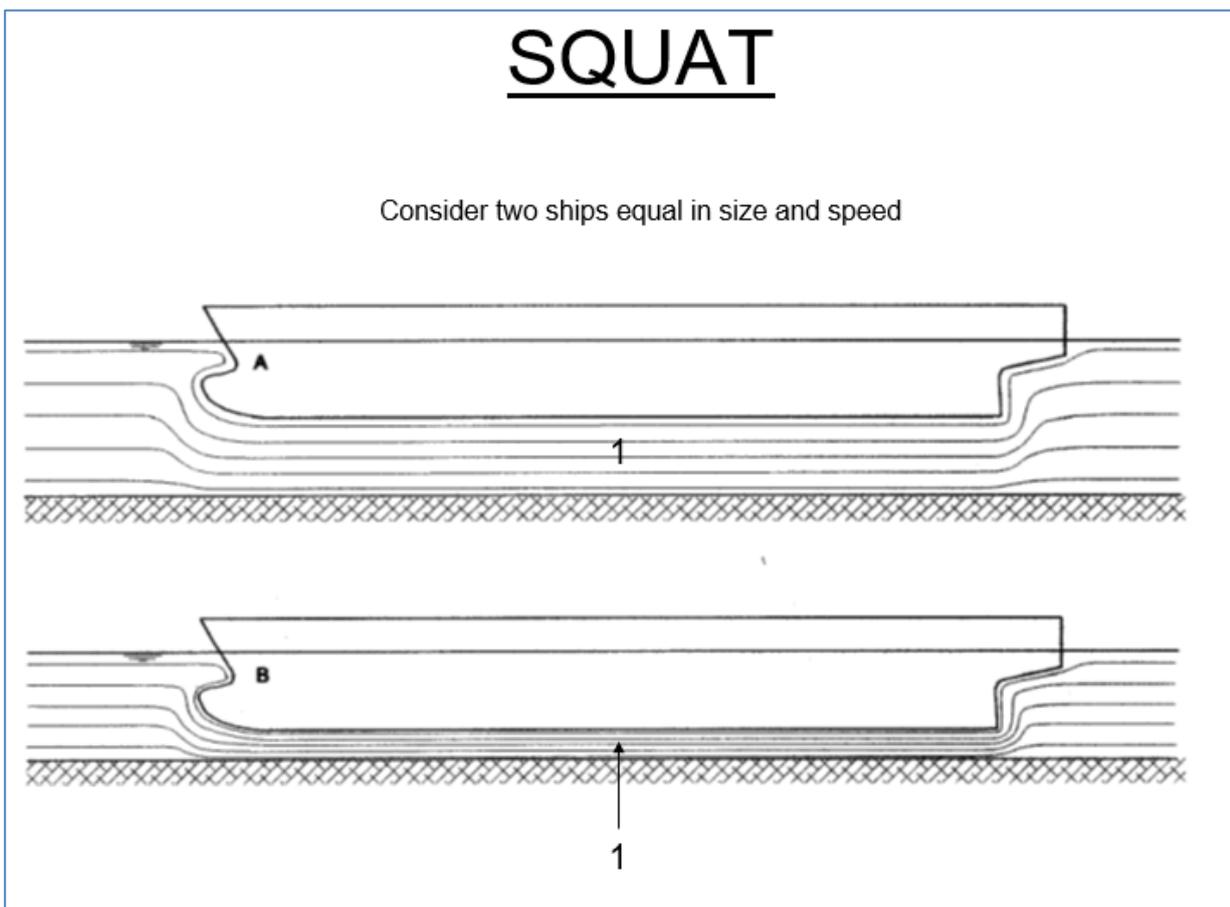


APPENDIX 5: SQUAT AND UNDERKEEL CLEARANCE

HOW ARE HYDRODYNAMIC EFFECTS CAUSED?

- APP 5: 1.0 As a ship approaches relatively shallow water, the water flowing past the hull has to increase speed as the available flow area decreases.
- APP 5: 1.1 This causes a reduction in the pressure acting on the hull in the vertical direction, which has to be compensated for by an increase in the buoyancy forces, so the ship has to increase its draught to maintain the state of equilibrium.
- APP 5: 1.2 Because of the shape of a ship and because of the adhesive effects of water, the changes in pressure are not the same forward and aft.
- APP 5: 1.3 This causes the ship to trim by the head or stern, depending on the hull shape.
- APP 5: 1.4 Therefore, the magnitude of squat depends on the hull shape, the side and underkeel clearance and the **speed** through the water. A ship with a block co-efficient of more than 0.8 will generally trim by the bow.



APP 5, FIGURE 1: Comparison of the water flow under the keel of a vessel proceeding in both shallow and deep water. The under-keel flow-lines are much closer together at shallow draft, indicating that the water will move faster (Venturi principle) (Source: Norwest Interaction, Hydrodynamic training programme (2008))

EXPLANATION OF APP 5: FIGURE 1 (Above)

- APP 5: 2.0 A ship that is moving has to push the water out of its way. When navigating in open seas there is plenty of space for the water to evacuate. In the case of rivers or channels the space is rather limited. When both ships in Figure 1 navigate at the same speed, the flow rate of the water is equal, but as the under keel clearance for ship B is smaller, the flow lines converge and the flow speed increases. According to Bernoulli an increase of flow speed at location 1 results in a decrease of pressure at location 1.
- APP 5: 2..1 One of the consequences of this pressure drop is a decrease of the water plane near the ship. To counteract this loss of buoyancy the ship will sink deeper into the water. As common ships do not have athwart symmetry the loss of buoyancy will be different between fore and aft of the ship, resulting in a different sinkage and thus a trim.
- APP 5: 2.2 This combination of sinkage and trim is referred to as **squat**.

SIGNS OF SQUAT IN DEVELOPING INTERACTION

- APP 5: 3.1 The vessel will 'Squat' ie sink deeper into the water to maintain buoyancy.
- APP 5: 3.2 The vessels speed will decrease
- APP 5: 3.3 Larger helm movements are required to maintain course.
- APP 5: 3.4 There may be an increase in vibration.
- APP 5: 3.5 Bow wave may increase sharply
- APP 5: 3.6 Stern wake width increases significantly
- APP 5: 3.7 If the vessel is close to a sandbank, the vessel may shear violently away from the bank.
- APP 5: 3.8 If the vessel is passing another vessel, the interaction forces may be to such extent that collision occurs.
- APP 5: 3.9 The squat will be larger in shallow water and the probability of bottom touching will increase.
- APP 5: 3.10 Another effect of the changed blockage is that due to the dropping pressure the hydrodynamic forces will rapidly increase. The manoeuvring behaviour of the ship will become increasingly more difficult over a short space of time – a fact that may not be readily apparent to mariners who are unaware of the developing dynamic.
- APP 5: 3.11 The size of the ship's turning circle increases with decreasing depth;
- APP 5: 3.12 The straight-line (that is, directional) stability of the ship may change as the relative (to the ships draft) water depth decreases from the medium range. Increased directional stability will require more effort (from the rudder) to turn the ship and the side-slipping effect will also increase significantly.
- APP 5: 3.13 The lateral deviations during a stop are larger in shallow water.



APP 5: FIGURE 2: Vessel experiencing significant 'squat' effect, as characterised by the water being 'drawn-down' in the area of its maximum vertical blockage point (advancing underwater cross-sectional area).

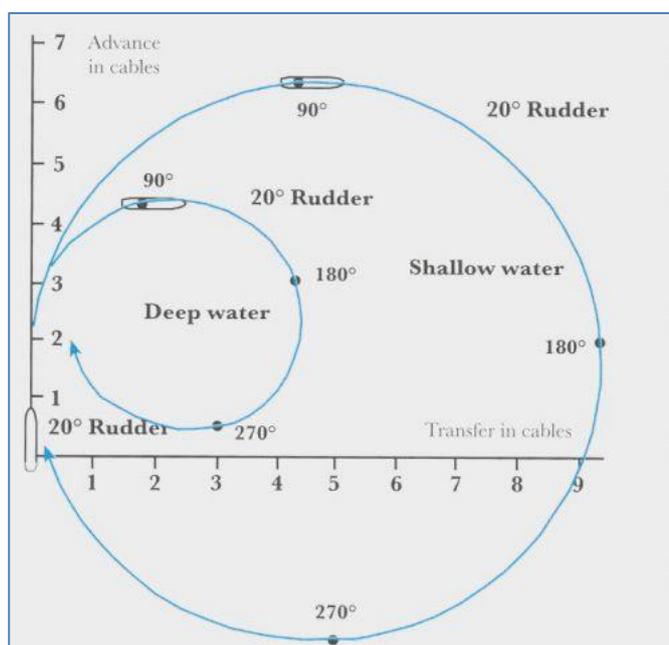
(Source: Norwest Interaction, Hydrodynamic training programme (2008))

BANK EFFECT

- APP 5: 4.1 The interaction is not only restricted to the vertical plane, but also acts in lateral (horizontal) plane and can extend a significant distance from the vessel generating the pressure field.
- APP 5: 4.2 When navigating in the middle of a symmetric access channel the water can as easily evacuate along the starboard side as it would do along the port side. In this case the pressure is balanced
- APP 5: 4.3 However when the ship draws closer to one of the channel boundaries the flow around the hull will be influenced by the presence of this boundary, and consequently the hydrodynamic forces acting on the ship, and on other craft acting nearby, will be affected.
- APP 5: 4.4 The effects of the presence of a lateral boundary can be classified as follows:
- APP 5: 4.4.1 *Bank effects* due to a ship's motion parallel to the bank and/or propeller action;
 - APP 5: 4.4.2 *Cushion effect*: the lateral force acting on a ship hull moving laterally at constant speed towards a solid boundary increases with decreasing bank clearance;

TURNING CIRCLE FOR VESSELS EXPERIENCING SHALLOW WATER EFFECTS

- APP 5: 5..0 The These effects are well known to mariners, as are their causes and the areas where they can be expected. Vessels are required to carry information on such effects (for example *MGN 199(M) (Dangers of Interaction)*) and officers and Masters are expected to be trained in, and familiar with, both the concepts and the effects.
- APP 5: 5..1 It is commonly taught in maritime schools, bridge simulator courses, ship-handling courses and manned model ship handling courses that, in shallow water, the diameter of a turning circle can double or triple.
- APP 5: 5..2 It is usually emphasised that the speed with which a turn is made, has **NO** effect whatsoever on the diameter of this turning circle. Further, it is a common misconception to believe that slowing a vessel down will reduce the turning circle diameter in shallow water.



APP 5: FIGURE 3: Difference in turning circles for a vessel operating in deep water as opposed to shallow water.

NOTE: The tracks shown relate to the vessels centre of rotation. In reality, the bow and stern will describe slightly different arcs and are encompassed in what is known as the 'sweep' of the vessel.

- APP 5: 5..3 For example, in 2005 *Gerardus Mercator* entered Palm Island II, Dubai, fully loaded and made a 200 degrees turn, to enter another channel - for the first time during that project.
- APP 5: 5..4 Initial ship's speed was 7 knots. *Gerardus Mercator* (Suction hopper dredger. Built: 1997 L: 152 m. B: 30 m. gt: 18972. DWT: 28350 t.) made an unexpectedly wide turn, due to squat, and contacted the side slope of the channel with a forward speed of 4 knots. It was found that, due to the shallow water effect, the diameter of the turning circle was much larger than anticipated.
- APP 5: 5.5 More recently, MAIB report 23/2009 (November 2009) the *Vallermosa* collided with vessels alongside Hamble Oil Terminal, Southampton. The *Vallermosa* is a case in point where shallow water effects at speed substantially altered the vessel handling characteristics,

including the effectiveness of engine demands - although MAIB report does not specifically mention shallow water effect as a cause of the incident.