ANALYSIS BY	ANDERS JENSEN
QUALITY CONTROLLED BY	SANNE KJELLERUP
ACCEPTED BY	LEA BJERRE SCHMIDT
DATA	28-06-2022

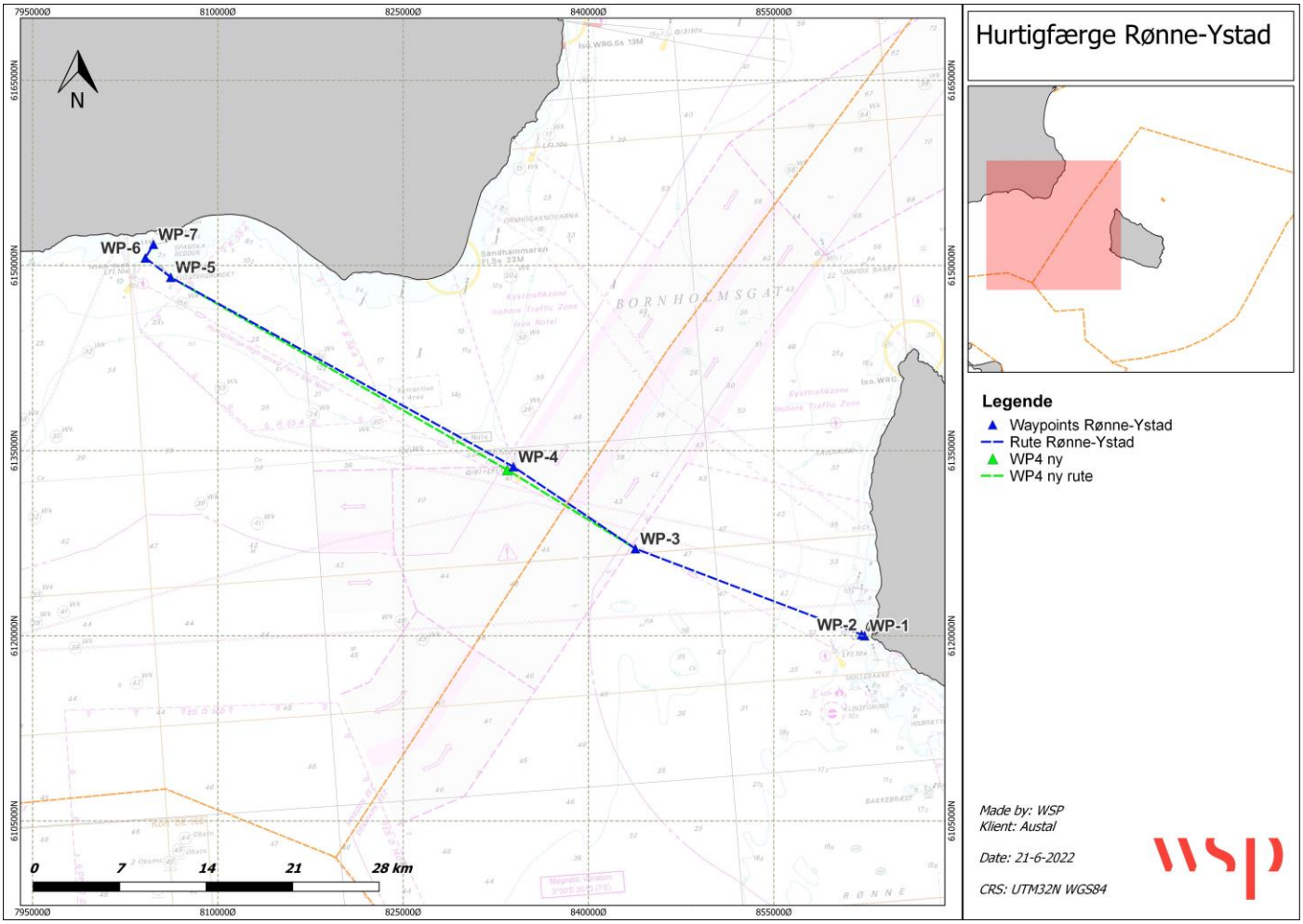
WAKE-WASH-STUDY-EXPRESS-5

NEW ROUTE COMPLIANCE WITH WAKE WAVE CRITERIA

On behalf of Austal, WSP has studied whether the new fast ferry Express 5 comply with the wake wash criteria at the 3 m depth contour along the Danish coast. The study was reported in Ref./1/ and subsequent reviewed by the Danish Maritime Authority (DMA).

DMA have expressed two objections to the study, 1/ that the route for Express 5 proposed by Austal/Molslinjen A/S and tested for compliance with the wake wash criteria, was not acceptable due to proximity to the navigation buoy "Sorte Grund" at position 55 14 071 N and 014 14 727 E and 2/, the non-perpendicular crossing of the traffic separation zone between Bornholm and Sweden.

Based on DMA's objections, Austal/Molslinjen A/S has proposed a new route for Express 5. The new route is shown on Figure 1 and Figure 2 (close-up around Sorte Grunden).



Figur 1. Old and new routes for Express 5 between Rønne and Ystad and return.

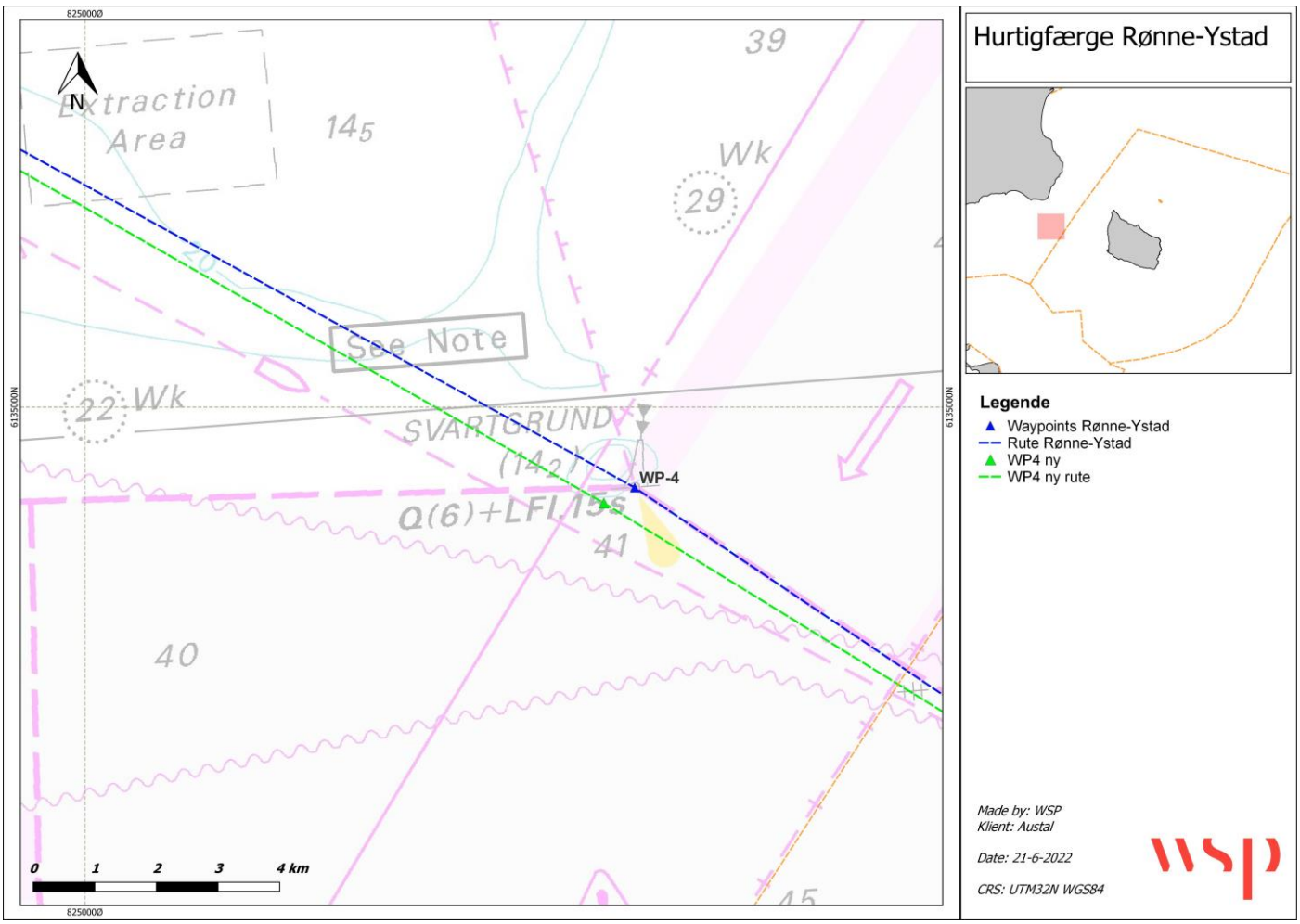


Figure 2. Close up of the difference between the old and new route between Rønne and Ystand and return.

The new route is moved 350 m SW from way point 4 and the navigation buoy at Sorte Grund, otherwise the old and the new route are almost identical. WSP has recommended to Austal and Molslinjen that documentation of the fulfillment of the wake was criteria with the new route is based on a quantitative assessment of the resulting wake wash at the 3 m contour instead of a new modelling using the MIKE 21 wave model.

The difference in the depth profile between the new and old routes are shown on Figure 3 and 4.

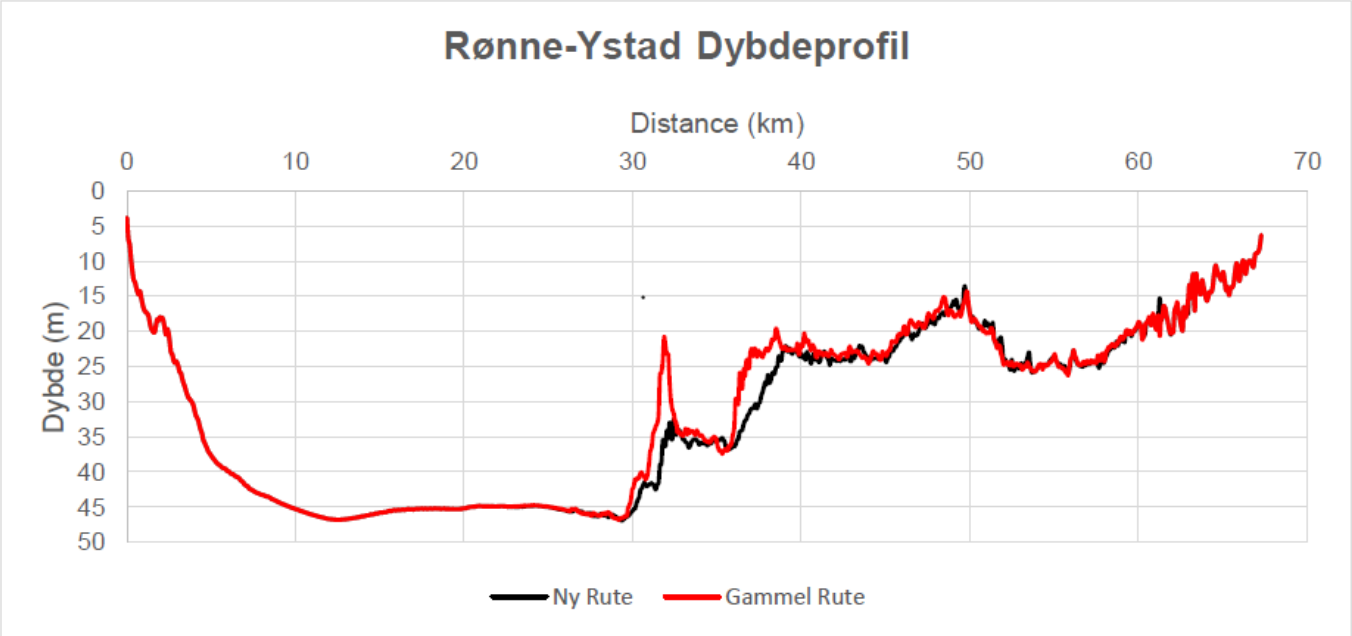


Figure 3. Depth profile of the new and the old routes sailing from Rønne to Ystad.

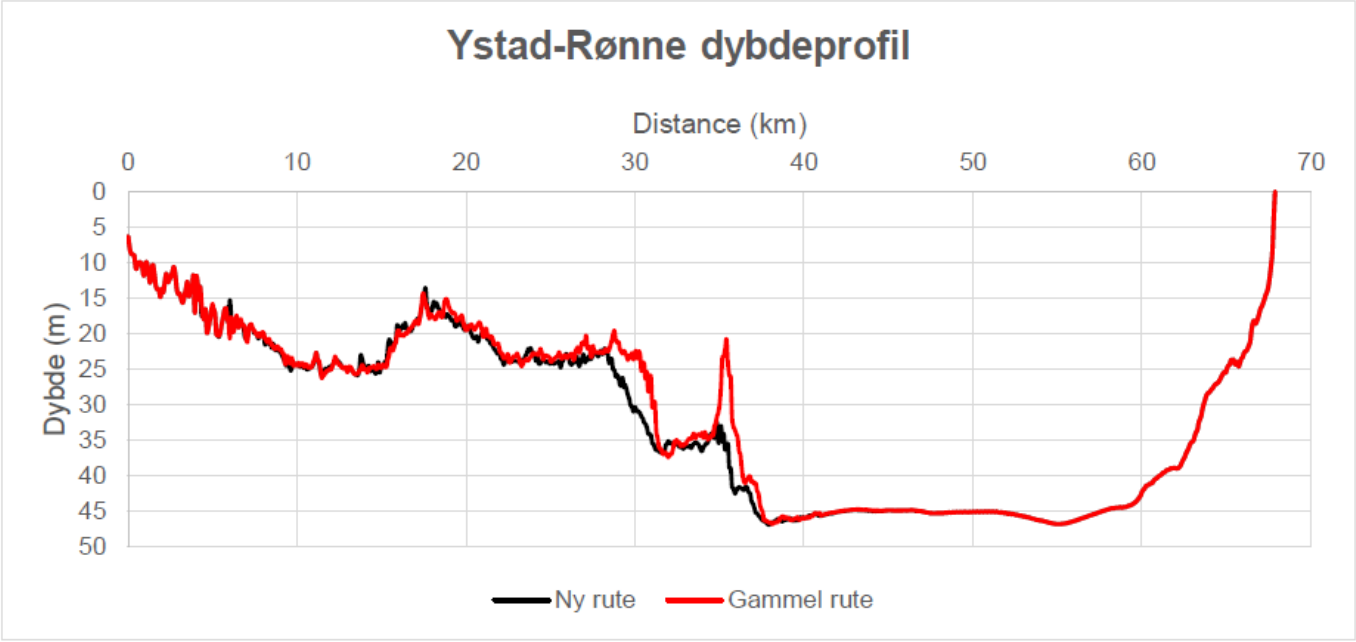


Figure 4. Depth profile of the new and the old routes sailing from Ystad to Rønne.

The new route is significantly deeper (15 m) around way point 4 (32 km from Rønne and 35 km from Ystad) which have an implication for the depth related Froudes number and consequently also for the resulting initial wake wash height and period from Express 5. It is only around way point 4 and Sorte Grund that there is a significant difference between the old and new route when it comes to parameters affecting the wake wash.

Table 2 shows values representing the old and new route at way point 4 of Froudes number, wave height and wave period. The values for wave height and wave period are calculated based on the 'semi'-empirical fits from Austal's CFD-models of the wake wash generation along the old route, see Ref. /1/ table 2 and Figure 5.

Table 1 – Values of Froudes number, wave height and wave period calculated based on on 'semi'-empirical fits from Austal's CFD-models, see Ref. /1/ table 2 and Figure 5.

WAYPOINT/ROUTE	FERRY SPEED	WATER DEPTH M	FROUDES NR.	WAVE HEIGHT (M)	WAVE PERIOD (S)
Wp 4 / Old	40	20	1.44	0.38	13.0
Wp 4 / New	40	35	1.12	0.68	14.4

The finite length of the ship affects the generated waves which spread out from the vessel like rings in the water. Without post-processing, the wave-heights along the track, which are enforced by the boundary conditions, leads to overestimation of the near-shore wave heights.

The diffraction effect caused by this finite vessel length, on wake wave heights, have been studied extensively through measurement campaigns of wake wash wave patterns behind real life inserted high-speed crafts. From these studies, of which Ref. /2/ is critical, an expression of the spatial wave decay as a function of ship length and distance away from the ship, has been established:

$$\frac{H}{H_0} = \left(\frac{s}{s_0}\right)^r$$

Where, H, is the wave height at a distance, s, from the ship. H_0 is the wave height 2.5 ship lengths from the centerline of the vessel, s, is the distance from the center line of the vessel, s_0 is 2.5 times the ship's length and r, is a decay constant empirically determined. Decay constant, r, is determined by Ref. /2/ to have a value of -0.55 through a linear least-squares fit.

I the original study, ref. /1/, a spectral wave model (MIKE 21) was used for simulating the decay and transformation of wake wash caused by shoaling, friction and bathymetry between the origin along the route and the 3 m depth contour at the coastline. Omitting the effect of friction will make the results conservative as this effect will reduce the amount of energy in the wake waves arriving at the 3 m contour. Shoaling cannot be ignored as this effect will increase the wave height at the 3 m contour line.

The shoaling coefficient determines the resulting wave height as $H = Ks \cdot H_0$ where Ks is calculated as function of the waves phase velocity, the deep water wave height and water depth at the point of interest. For a wave with a period of 14.4 seconds the resulting shoaling coefficient becomes 2.50 which is used for calculating the resulting wake wash height shown in table 2.

Table 3 shows the calculated wave height and period for wake wash generated at way point 4 for the new route at the nearest 3 m contour point on the Danish coast (29 km away) and the nearest point on the Swedish coast (16 km away).

Table 2 Wake wash parameters at the nearest points on the Danish and Swedish coasts

WAYPOINT/ROUTE	WAVE HIGHT	WAVE PERIOD	CRITERIA[1]	COMPLIANCE
Danish Coast	0.125 m	14.4 s	0.44	Yes
Swedish Coast	0.25 m	14.4 s	0.89	Yes

[1] The criteria is defined as:

$$\frac{H}{0.5 \cdot \sqrt{\frac{4.5}{T}}} \leq 1$$

Based on these conservative calculations of the resulting wake wash parameters at the 3 m depth contour line at the Danish and Swedish coast lines nearest to way point 4 shows that the new route is in compliance with wake wash criteria.

REFERENCES

Ref. /1/ Austal Ships PTY limited Wake Wash Study Express 5. Report by WSP Denmark A/S 16 March 2022

Ref. /2/ Kirkegaard Jens and H. K.-H. (1998). Wake wash of high-speed craft in coastal areas. Coastal engineering 1998