# Appendix DD
# Evaluation of Potential Impacts of Propwash on Shoreline Erosion

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## Technical Memo for the Environmental Impact Statement for the Proposed Marine Container Terminal at the Charleston Naval Complex

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# Evaluation of Potential Impacts of Propwash on Shoreline Erosion – Technical Memo

This technical memo examines potential shoreline erosion impacts associated with tug propwash that may occur as a result of the operation of the proposed marine container terminal at the Charleston Naval Complex (the Proposed Project). Large tugs will assist the turning of containerships in the turning basin located on the Daniel Island Range of the federal navigation channel in the Lower Cooper River. These tugs will generate a current field behind the ship propeller (propwash). This memo estimates the propwash current magnitudes behind the vessel and evaluates the potential for erosion of the river bottom sediments and the possibility of consequential shoreline erosion along Daniel Island.

For the purposes of this evaluation, one of the largest tugs in the harbor was used to characterize the vessel characteristics. The Elizabeth Turecamo is a 6,140 Hp tug with 2 Z-drive propellers, each with a wheel diameter of 2.7 m. The propeller axel depth is approximately 2.5 m.

This memo calculates the bottom velocities behind a tug based on the empirical method given by Maynord (2000), who describes the flow field behind a tug as having two distinct zones (Figure 1). Zone 1 is the first zone where the propeller jet velocity is dominated by the central rudder effects and the two jets have not merged. Zone 1 ends where the maximum jet velocity location is at the water surface (at a distance from the propeller, $X_p$ equal to about 10 times the propeller diameter, $D_p$).

Based on Maynord (2000), the following steps were followed to calculate the velocity field along the river bottom behind the tug:

1. **Thrust, per propeller.** The relationship between thrust (in pounds) and applied power and speed relative to water (in miles m[per hour) is given by the Toutant (1982) equations for Kort nozzle propellers as:

   $$EP_k = 31.82\ HP^{0.974} - 5.4(S)^2(HP)^{0.5} \qquad (1)$$

   For a conservative analysis, the vessel speed was assumed to be zero. For the 6,140 HP tug, the applied thrust per propeller is 79,300 lbs (353 kN).

2. **Maximum velocity at propeller.** The initial jet velocity is given by:

   $$V_2 = 1.13/D_o\ (\text{thrust}/\rho)^{0.5} \qquad (2)$$

   where

   thrust = thrust per propeller,
   $D_o$ = jet diameter and is equal to $D_p$ for a Kort nozzle propeller, and
   $\rho$ = water density.

For this tug, $V_2$ is 7.8 m/s.

3. **Maximum jet velocity in Zone 1.** The maximum velocity for a single propeller in Zone 1 as a function of distance behind the propeller is:

$$V(xp)_{max} = 1.45\ V_2\ (xp/D_p)^{-0.524} \qquad (3)$$

where

xp = the distance from the propeller.

4. **Jet deflection by rudder.** The vertical distance from the propeller shaft to the location of maximum velocity within the jet is:

$$CJ = -[\tan(12°)(xp\text{-}SETBACK / 2) - C_{para}\ g(xp - SETBACK/2)^2/(V_2^2 \cos^2(12°))] \qquad (4)$$

where

CJ = vertical distance from the propeller shaft to the location of maximum velocity within the jet,

SETBACK = horizontal distance from the propeller to the stern of the towboat (assumed to be 2 m for this analysis), and

$C_{para}$ = an empirical coefficient equal to 0.04 for Kort nozzle propellers.

5. **Radial velocity decay.** The velocity decays radially from each propeller using the jet equation for fully developed flow from Verhey (1983):

$$V_{x,r} = V(xp)_{max} \exp[-r^2/(2C^2xp^2)] \qquad (5)$$

with C = 0.18 from Verhey (1983) and r measured from the position of the jet maximum as defined by CJ. The bottom velocity is calculated by setting r equal to distance between the maximum velocity position (as determined by CJ) and the bottom.

6. **Superimpose two velocity fields.** The lateral distribution of jet velocity from each propeller is combined using superposition.

Zone 2 is represented by a single jet whose maximum velocity is at the surface. It begins at $X_p/D_p$ = 10 and can extend for hundreds of meters. The velocity in Zone 2 is determined as follows:

7. **Maximum jet velocity in Zone 2.** The jet is treated as single jet whose maximum velocity is at the surface. The maximum near surface velocity is decayed away from the vessel according to:

$$V(xp)_{max}/V_2 = C_{exp} \exp(-0.0178\ xp/D_p) \quad (6)$$

where the empirical coefficient $C_{exp}$ is 0.85 for Kort nozzle propellers.

8. **Decay velocity in vertical direction.** The velocity decays in the vertical direction according to:

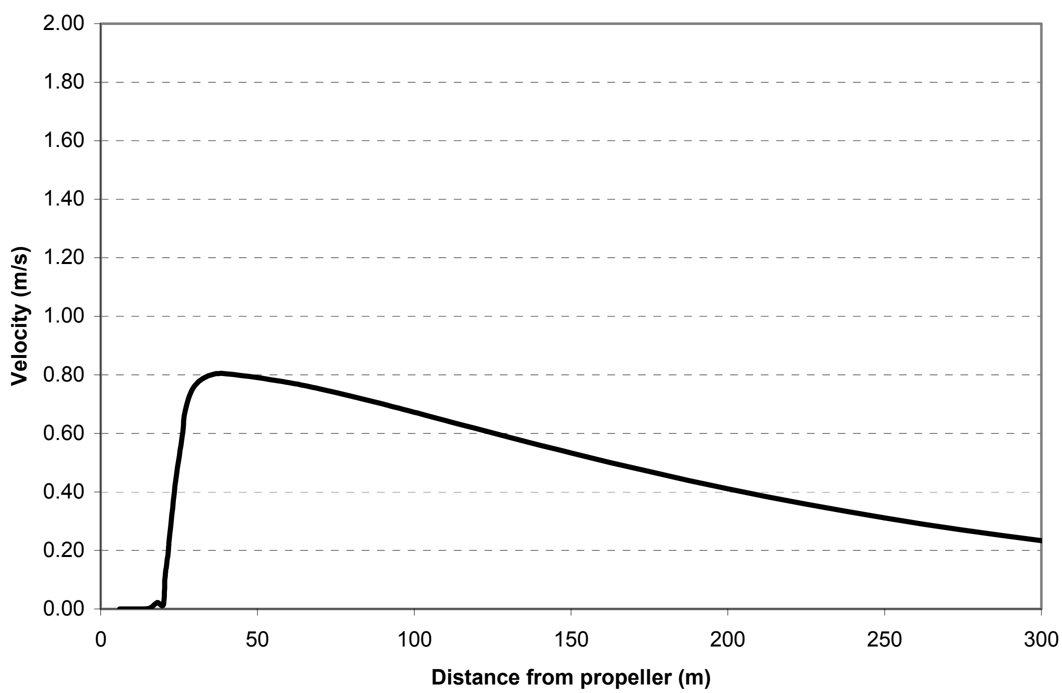
$$V_{bot}/V_{surf} = 0.34(D_p/H_p)^{0.93}\ (xp/D_p)^{0.24} \quad (7)$$

where $V_{surf}$ is the velocity from equation (5) using

$C = C_{z2} = 0.84(xp/D_p)^{-0.62}$.

The solutions for the Zone 1 and Zone 2 bottom velocities were blended between xp = 7.5 to 10 $D_p$ to provide a smooth transition. The resulting calculated bottom velocity versus distance behind the propeller is presented in Figure 1.

**Figure 1 Calculated bottom velocity versus distance behind propeller.**




The maximum velocity is 0.8 m/s, which occurs about 40 m behind the propeller. Although the tug creates a high velocity propwash jet (7.8 m/s) immediately behind the vessel, the results shown in Figure 1 show that the velocities decay substantially before reaching the river bottom. The velocity slowly trends down to about 0.4 m/s at 200 m and 0.2 m/s at 300 m. The distance between the Daniel Island shoreline and the edge of the navigation channel near the terminal varies between 130 m at the south end of the terminal and 230 m at the north end of the terminal. Therefore, the propwash generated by a tug at the edge of the navigation channel can affect current velocities in the vicinity of the Daniel Island shoreline. Although the velocities shown in Figure 1 between 130 m and 230 m are between 0.6 m/s and 0.35 m/s, it should be noted that the calculations shown in Figure 1 are based on the navigation channel water depth of 14.9 m MLW, and the propwash velocities would be greater than these values as the jet enters shallower water as it approaches the shoreline.

These velocities are within the range of typical tidal currents that occur in this area, and therefore the propwash alone would not be expected to cause significant erosion of the river bottom near the Daniel Island shoreline. However, the effect would be additive to the tidal currents, and if the tug operates at peak tidal current conditions, it would potentially cause additional erosion beyond that typically occurring in the area from tidal currents.

Both the duration and frequency of the events should be considered in weighing the magnitude of these potential effects on erosion. At a given point near the Daniel Island shoreline, a propwash event from a tug would occur over a relatively short period of time (seconds or minutes) in contrast to the tidal currents that occur over periods of hours. At full operation of the proposed terminal, about 1.8 container ships per day would require tug assistance for turning maneuvers. However, the ships will be turned at different locations in the turning basin, and therefore, the tugs will not always operate at the same location. Therefore, a given point near the Daniel Island shoreline would be affected less often than 1.8 times per day. In contrast, peak tidal currents affect this area four times per day. Given the relative short duration and infrequency of the propwash events, it is expected that the tug operations would not cause measurable erosion of the Daniel Island shoreline.

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