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# Estimation of bed roughness from mean velocities measured at two levels near the seabed

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**Abstract**

A new method is developed to estimate the mean bed roughness from time series of mean velocities collected at two levels near the bed. Under the assumption of the law of the wall, the bed roughness is estimated by plotting time series of mean velocities measured at a lower level against those at an upper level. A simple criterion is also derived to censor the velocity data when only some of the data are of logarithmic distribution. This new method is then applied to estimate the bed roughness at three study sites (Site-1, 2, 5) in Moreton Bay, one of the semi-enclosed largest bays in Australia. The mean velocities were measured for 10 min every 30 min at 34 and 100 cm above the seabed at the northern entrance ($h = 16$ m, $\phi_{50} = 0.2$ mm, Site-1), the bay centre ($h = 15$ m, mud, Site-2) and Deception Bay ($h = 6$ m, mud, Site-5) in the Bay. Based on the mean velocities measured for 5 days, the bed roughness is estimated as $k_s = 0.07$, 1.92 and 0.52 cm at Site-1, 2 and 5, and correspondingly, the drag coefficient is $C_D = 1.42 \times 10^{-3}$, $2.96 \times 10^{-3}$ and $2.13 \times 10^{-3}$.


*Keywords:* Bed roughness; Bedform; Tidal current; Wind-waves; Drag coefficient

## 1. Introduction

The bed roughness is an essential parameter in modelling of current circulations, wave height attenuations and sediment transport in estuarine and coastal waters, but it is often unknown and difficult to measure directly in the field. The physical bed roughness generally consists of three roughness components: grain or Nikuradse roughness, bedform roughness, and sediment saltation roughness. The grain roughness is the smallest form of roughness and is commonly taken as $k_s = 2.5d_{50}$. The bedform roughness is generally generated by sand ripples, biogenic mounds, and benthic seagrasses. A great deal of research work has been carried out to estimate the roughness of sand ripples generated by waves (e.g. Nielsen, 1981; Grant and Madsen, 1982). A few studies have also been conducted to evaluate the roughness of sediment saltation (Raudkivi, 1989; You and Nielsen, 1996). The roughness of biogenic

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mounds is often empirically estimated from photographs of the seabed (Grant et al., 1984; Wheatcroft, 1994). Therefore, it is quite difficult to estimate the total roughness of sediment grain, irregular sand ripples, biogenic mounds, benthic seagrasses and sediment saltation in the field.

Alternatively, the total bed roughness may be directly estimated by fitting measured current profiles to the logarithmic distribution, the von Karman–Prandtl velocity equation, in the absence of surface waves. Xu et al. (1994) called this method the mean flow method, but we simply call it the log-fit method in this study. There are two essential conditions required by the log-fit method: (1) simultaneous measurements of mean velocities have to be taken at more than three elevations near the seabed, and (2) the measured mean velocity profile must be logarithmic. The first condition requires that the number of current metres used to measure the current profile should be more than three. This is because the confidence bands on the roughness estimates depends on the number of current metres used (Grant et al., 1984). On the other hand, the number of current metres that can be deployed within the logarithmic lay of 1.0–1.5 m above the seabed is often limited up to four (e.g. Ke et al., 1994). The second condition required by the log-fit method may not be always met in estuarine and coastal waters. For example, Collins et al. (1981) found that the measured mean velocity profiles were not of logarithmic distribution over 44% of the time of rising tides. The bed roughness estimated from individual velocity profile often varies significantly even within one tide cycle, see Fig. 4 of Xu et al. (1994). This implies that the bed roughness estimated by the log-fit method may not be used for general modelling purposes.

In this study, a new method is developed to estimate the bed roughness $k_s$ from time series of mean velocities measured only at two levels near the seabed in Moreton Bay.

## 2. Study sites and instruments

In this study, the seabed roughness in Moreton Bay is estimated at three study sites based on time series of mean velocities measured by two current metres located at 34 and 100 cm above the seabed. Moreton Bay is located at South East Queensland, Australia. The Bay is about 90 km long from the north to south, 30 km in a maximum width, and has a total area of about $1.13 \times 10^5$ ha (see Fig. 1). There are three high offshore islands of North Stradbroke, Moreton and South Stradbroke. These barrier islands consist of massive dune systems, some of which exceed 275 m in height. There is a large opening (14.5 km wide) to the north, and the other three smaller openings are less than 1.6 km wide.

The tides in the Bay are predominantly semi-diurnal with tidal range of about 2 m (You et al., 1998). The tidal currents are strongest at the northern entrance, generally weaker away from the entrance, and are further weakened along the mainland coast. The wave climate in the Bay is generally dominated by fetch-limited local wind-waves. The spatial distribution of wind-wave heights and periods in the Bay was numerically studied by the Bureau of Meteorology (You et al., 1997).

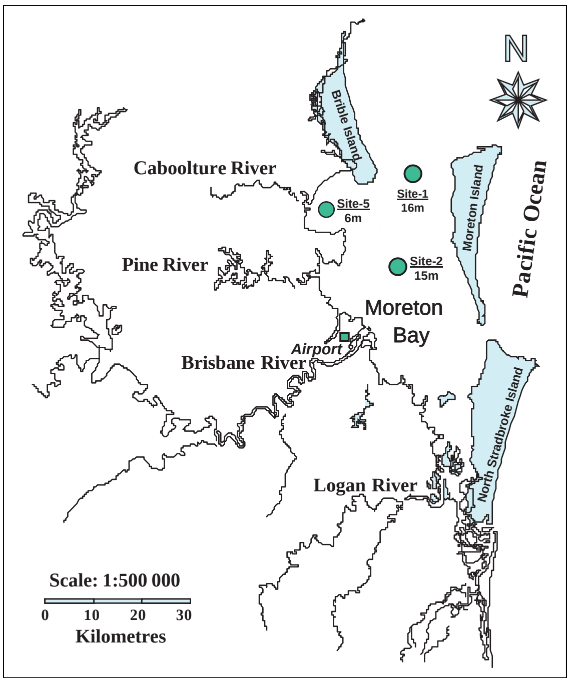


Fig. 1. Locations of three study sites (Site-1, 2, 5) in Moreton Bay.