Sand Waves at the Mouth of San Francisco Bay, California

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Background

A multibeam bathymetric survey that produced unprecedented high-resolution images of the mouth of San Francisco Bay was conducted in 2004 and 2005. The survey, performed over forty days by the Seafloor Mapping Lab at California State University, Monterey Bay, consisted of 1,396 track lines, 1.1 billion soundings, and covered an area of 154 km² (200 ft²). The goals of this survey were to analyze sediment transport pathways at the mouth of San Francisco Bay and to calculate bathymetric change since the last survey was completed in 1958. The survey showed significant bathymetric changes that occurred over the past 50 years. It also revealed the only continuous sand waves that are among the largest and best developed in the world.

Bedform Diversity

The complex temporal and spatial variations in wave and tidal current interactions at the mouth of San Francisco Bay result in a diverse array of bedforms, eddies, and sediment transport pathways (Gammon and others, 2006). Strong tidal currents peak at over 2 m/s (6.6 ft/s) and rocky headlands and embayments help to create strong eddies and reverse flows, all of which combine to form highly variable bottom features.

Massive Sand Waves

Some of the largest sand waves in the world are located just west of the Golden Gate Bridge—these waves have been formed by abundant sediment and extremely powerful tidal currents. The data are shown in the figure below as perspective-viewed shaded relief images. This massive sand wave field covers an area of approximately 4 km² (1.5 m²) in water depths ranging from 30 m (98 ft) to 108 m (348 ft). More than 40 distinct sand waves were identified; the waves have an average wavelength of 82 m (269 ft) and an average height of 6 m (20 ft). The maximum wavelength and height are 220 m (722 ft) and 10 m (33 ft), respectively. Perpendicular to the largest crest is a slow downwind migration rate, when averaged over an entire year, is just 7 m (23 ft), or less than 2 cm/day (0.7 in/day). These data show that strong tidal fluctuations repeatedly as frequently as 24 hours (figure 4) showed that crests shifted as much as 3 m (10 ft), whereas over the entire 13-day sampling period the tide forces 2 billion m³ (528 billion gallons) of water through the Golden Gate—that’s the equivalent of the volume of water required to fill 660,000 Olympic-sized swimming pools! The resulting strong currents sweep large volumes of sediment between the narrow rocky headlands, spun by the Golden Gate Bridge, onto the Bay shore during the ebb tide.

Sand Wave Migration

Multiple surveys of a 2.5 km (1.6 mi) track line through the center of the massive sand wave field were completed in 2004 and 2005. Analysis of these surveys yields the calculation of above- and below-tide longshore sediment transport rates. In 2004, surveys repeated as frequently as 24 hours (figure 5) showed that crests shifted in much as 3 m (10 ft), whereas over the entire 13-day sampling period the average migration of each sand wave was 6.4 m (21 ft). The wave-Militia Channel. The 2005 survey indicates that the net migration rate, when averaged over an entire year, is just 7 m (23 ft), or less than 2 cm/day (0.7 in/day). Several trends show that strong tidal fluctuations can daily lead to small migrations that are equivalent to the gravi-