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THE CONCEPT OF SEDIMENT TRANSPORT AND HOW IT AFFECTS COASTAL AREAS.

Concept of sediment transport

Much of what we understand concerning sediment transport is based on a series of fundamental concepts in fluid mechanics. These reflect ideas explored in the seventeenth and eighteenth centuries that were advanced significantly during the late nineteenth and early twentieth centuries. A particular subset of advances that is believed to be of special relevance to modern geomorphologists concerned with, especially, sand transport. These include important developments by William Froude (1866: the Froude number); Osborne Reynolds (1883: the Reynolds number); Theodore von Ka´rma´n and Ludwig Prandtl (early twentieth century: boundary-layer theory and the law of the wall); Johann Nikuradse (1933: equivalent sand grain roughness); and Hunter Rouse (1938: the Rouse number).

William Froude (1810–1879) was an English hydrodynamicist and naval architect with a degree in mathematics from Oxford. His major contribution to the study of sediment transport in geomorphology lies in the dimensionless number that bears his name, although the relation was proposed earlier by Jean-Baptiste Be´langer (Chanson, 2009). The Froude number (Fr) can be expressed in several forms, but most generally as:

where V is a characteristic velocity, g is the gravitational constant, and L is a characteristic length (Graf, 1984). The Froude number can be interpreted as the ratio of inertial to gravitational forces, or as the ratio of mean flow velocity to the celerity of a shallow water surface wave.

In the context of open channel flow, V represents the flow averaged over the entire channel cross-section and L is the hydraulic depth (the cross-sectional channel area divided by the surface width). In rivers, the Froude number provides one approach to distinguish between flow regimes. A Froude number <1 indicates subcritical or tranquil flow. In this state, flow velocity is smaller than that of a wave propagating on the surface and gravitational forces are dominant. For Fr >1, the flow is termed supercritical or rapid, and the inertial forces are dominant. The Froude number is also useful in establishing similitude between model and prototype in laboratory studies.

The Reynolds Number Osborne Reynolds (1842–1912) was an Irish-born, Cambridge educated mathematician and engineer. Virtually, his entire professional career was spent as a Professor of Engineering at Owens College. The author of more than 70 scholarly publications on topics ranging from fluid mechanics to naval architecture, and from thermodynamics to civil engineering, Reynolds’ many achievements led him to be elected a fellow of the Royal Society in 1877 (Jackson, 1995). Reynolds’ accomplishments in the realm of fluid mechanics include development of the useful concept that has come to be known as ‘Reynolds-averaging,’ in which turbulent flows are characterized through decomposition into mean and fluctuating components. But he is best known for his studies of flow in pipes and the quantification of conditions associated with the transition from laminar to turbulent flow, as characterized by the well-known Reynolds number (Re):

where v is kinematic viscosity (Reynolds, 1883). This dimensionless number represents the ratio of inertial to viscous forces. At small values (Re <2300 in pipe flow), viscosity is dominant and flow will be laminar. At high values (Re >4000 for pipe flow), stronger inertial forces will produce turbulent flows. A transitional zone exists between the laminar and turbulent regimes in which either flow condition may prevail depending on additional factors like surface roughness. In the original studies, the characteristic length scale (L) was the pipe diameter, but in later practice, it varied with application. In the case of open channel flow, for example, hydraulic depth is generally used. For particles settling in a fluid, the particle diameter is used for L (and the resulting quantity is termed the particle Reynolds number). Along with the Froude number, the Reynolds number provides a key tool for determining whether dynamic similitude exists between model and prototype flows (e.g., Middleton and Wilcock, 1994).

Prandtl’s momentum–transport theory

(Prandtl, 1926, as cited in Vennard and Street, 1982):

where t is shear stress and p is the fluid density. He also noted that l is a function of distance from the bound density l=ky, with k an empirical constant.

Theodore von Ka´rma´n (1881–1963) was a student of Prandtl at the University of Göttingen, and his PhD, written about the behaviour of solids, was awarded in 1908.

How sediment transport affects coastal areas

1. It results in the formation of characteristic coastal landforms such as [beaches](https://en.wikipedia.org/wiki/Beach), [barrier islands](https://en.wikipedia.org/wiki/Barrier_islands), and capes.
2. It takes place in near-shore environments due to the motions of waves and currents.
3. In coastal waters, sediment transport processes are strongly affected by high-frequency waves introducing oscillatory motions acting on the particles. The high-frequency (short) waves generally act as sediment stirring agents; net sediment transport is due to the mean current.