Preface

Sediment transport is an important and classical research topic in environmental science and hydrodynamics, and it also plays an important role in contaminant hydrology, hydraulic engineering and marine science. Despite substantial efforts have been made over past centuries, our ability to estimate sediment transport in a turbulent system remains inadequate. Errors in estimation and prediction sometimes are unacceptable in both suspension and bed-load transport where the measured transport rates often differ by one to two orders of magnitude with calculations by using the standard formulae. One of the major obstacles is the poor understanding of the effect of turbulent flow and complex riverbed structure on sediment transport. For example, turbulence structures usually exhibit fractal characteristics, which cause anomalous diffusion or path-dependent random motion of suspension particles. Cluster structures are often observed on riverbeds composed of particles with a wide range of size distributions that may significantly alter bed-load transport rates and yield sub-diffusion behavior.

To better understand the physical mechanism of anomalous sediment transport and further provide accurate description and prediction, it is necessary to conduct theoretical and numerical analysis together with experimental study of sediment transport in turbulence and/or heterogenous riverbed structures. Previous investigations have clearly shown that the time series of particle velocity in turbulence follows a stretched-Gaussian distribution, which correspondingly produces anomalous diffusion of sediment suspensions. While the riverbed structure may block sediment particle and slow down the movement, turbulent flow may also form preferential flow paths to accelerate particle movement. So, how to quantify the influence of turbulent flow and riverbed structure on sediment transport is a critical issue for accurate description and prediction.

This book attempts to systematically investigate anomalous sediment transport, including experiments, physical analysis, stochastic models, and field application. The laboratory experiments and field measurements of the vertical velocity distribution, riverbed structure, and sediment concentration have been carried out to explore the physical mechanism of anomalous transport. Several new mathematical physical approaches (including a fractional derivative model, the continuous-time random walk method and Hausdorff derivative model) were introduced to accurately characterize anomalous sediment transport in turbulent flow. The aim is to offer readers a better understanding of anomalous sediment transport.

The book is structured in nine chapters. Chapter 1 presents basic theories and research methods for sediment transport and anomalous diffusion in turbulence. Chapter 2 provides physical analysis of particle movement in turbulence and the mechanism of anomalous sediment transport. Chapter 3 mainly discusses the theoretical models, especially the fractional derivative model, for vertical distribution of suspended sediment under steady flow. Chapter 4 introduces the Hausdorff fractal derivative model for suspended sediment transport in steady flow, based on the multi-fractal property

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of turbulence structure. Chapter 5 describes the nonlocal bed-load transport by using a fractional derivative model and the peridynamic differential-operator regional nonlocal model. Chapter 6 employs a continuous-time random-walk model to explore the physical mechanism of anomalous diffusion in bed-load transport, and also offers an accurate description of bed-load transport. Chapter 7 makes an attempt to use a simple Hausdorff fractal derivative model to simulate bed-load transport. Chapter 8 investigates the relationship between anomalous diffusion and fractal structure, especially concerning how to determine the parameters for nonlocal models. Finally, some future perspectives are given in Chapter 9.

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