ASCE Manuals and Reports on Engineering Practice No. 110

Sedimentation Engineering

Processes, Measurements, Modeling, and Practice

Edited by Marcelo H. García

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Processes, Measurements, Modeling, and Practice

Edited by Marcelo H. García, Ph.D., P.Eng.

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About the cover: River dunes in the Rio Paraná near Paso de la Patria, Argentina. Bed morphology measurements were made with a multibeam echo sounder in May 2004. Note the ubiquitous superimposition of smaller bedforms on the stoss side of the larger dunes. Image courtesy of Dan Parsons and Jim Best, University of Leeds, U.K.

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FOREWORD

Robert C. MacArthur, Charles R. Neill and Marcelo H. Garcia

It is increasingly evident that global water and soil resources require significantly increasing efforts in management and preservation in order to meet present and future needs for human consumption and ecological balance. In many regions of the world, these resources are adversely affected by water or wind erosion of rocks and soils, by the consequent transport of sediment by streams and rivers, by the deposition of riverborne sediment in lakes, reservoirs, estuaries and seas, and by the incorporation or concentration of contaminants and toxic substances in sediments. This series of processes is often referred to briefly as *sedimentation*. Their investigation, evaluation and treatment in the context of civil engineering and public works facilities is commonly referred to as *sedimentation engineering*.

As distinct from articles and reports on specific aspects of sedimentation, one of the first English-language books to attempt a comprehensive treatment in a civil engineering context was ASCE's Manual 54, *Sedimentation Engineering*, edited by the late Professor Vito Vanoni with a long list of contributors, and published in 1975 after more than a decade of preparatory work. The 1975 manual describes and analyzes soil erosion and sediment yields, properties of sediment, sediment transport under the action of water and wind, techniques of sediment measurement, methods of sediment control in engineering works, and economic and legal aspects of sedimentation engineering. Manual 54 remains an important and reliable reference on many aspects of sedimentation engineering, but in other aspects it has become out-dated by advances in knowledge and by the emergence of new problems, issues and methods for assessing them. In terms of key issues at the beginning of the twenty-first century, perhaps the most notable missing material in the 1975 Sedimentation Engineering Manual relates to environmental and ecological problems associated with sedimentation and other significant topics such as river restoration and reservoir sedimentation. This is not surprising since most sediment-related environmental concerns were in their early stages at the time the original manual was being prepared.

Since the publication of Manual 54, extensive advances have been made in methods of investigation, measurement and analysis, including the extensive use of computer modeling procedures that are becoming increasingly more reliable to simulate sediment transport dynamics. Today more is known about fluvial transport of coarse sediment mixtures, erosion of cohesive and semi-cohesive materials, bridge-pier scour, reservoir sedimentation, river morphodynamics and about sedimentation hazards including debris torrents, mudflows and hyper-concentrated flows. Multidisciplinary research has expanded the understanding of linkages between fluvial processes and ecological responses, while sediment engineering studies are increasingly accepted and relied upon as necessary input to schemes for water resource development and for environmental restoration or enhancement. Perhaps most significant of all, the ecology and morphology of streams and the transport of contaminants has emerged as a major rationale for many sediment studies and are now essential considerations in project planning, design and permit consideration.

Moves towards the present publication began with the formation in 1991 of a *Task Committee to Expand and Update ASCE Manual 54* under the formulation and leadership of Dr. Robert MacArthur, then with the Corps of Engineers' Hydrologic Engineering Center in Davis, CA. In 1999, by which time initial drafts had been prepared for ten chapters, Professor Marcelo Garcia of the University of Illinois at Urbana-Champaign was appointed as Chief Editor, with the vision of a new volume of the Manual that would utilize state-of-the-art information published in ASCE's *Journal of Hydraulic Engineering* and other internationally recognized sources such as the IAHR Journal of Hydraulic Research. Realizing the monumental effort required to prepare a complete revision of the original Manual 54, it was decided that the new publication should be treated as a companion to its progenitor, which would be made available again through a new printing to be known as the Classic Edition (Vanoni, 2006).

This companion volume, designated Manual of Practice 110, *Sedimentation Engineering: Processes, Measurements, Modeling, and Practice,* consists of 23 chapters and 6 appendices covering selected topics — generally, those where important advances have been made since 1975, or topics that were not addressed at that time. The list of topics covered is not necessarily comprehensive, having been limited by constraints on the availability and time of writers. Significant matters that are not addressed include wind-induced erosion and transport and sediment transport in pipes (treated in Manual 54) and the field of coastal erosion and sedimentation (not addressed in Manual 54 or Manual 110).

This Manual 110 includes contributions from internationally recognized experts in various fields of sedimentation science and engineering. Lists of persons involved in preparing and writing this Manual are provided below. All parts of the manual have been subjected to extensive review and technical editing, and all writers and reviewers have operated either on a voluntary basis or with the support of their employing organizations.

Marcelo H. García
Editor of Manual of Practice 110
Past Chair, ASCE Sedimentation Committee

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DEDICATION

Vito A. Vanoni (1904–1999)

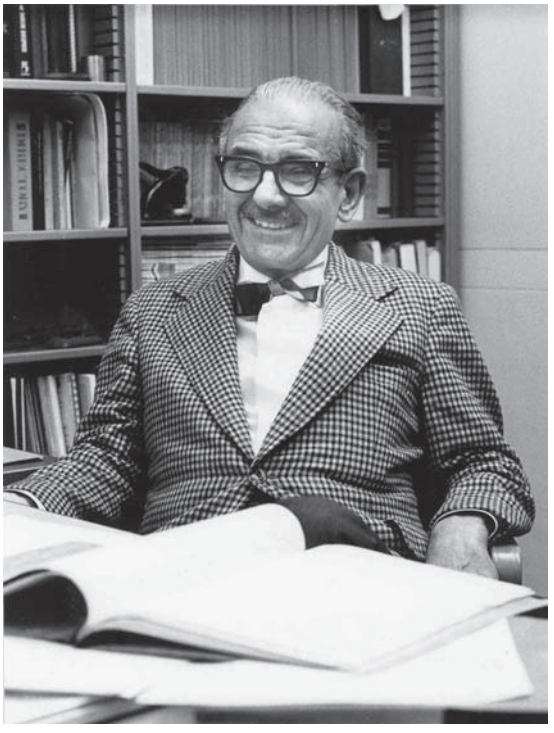


Fig. 1. Prof. Vito A. Vanoni in his office, 1974. (Photo credit: Caltech)

This updated edition of Sedimentation Engineering (ASCE Manuals and Reports on Engineering Practice No. 110) is dedicated to Professor Vito A. Vanoni, an internationally recognized professor of Civil, Hydraulic, and Sedimentation Engineering at the California Institute of Technology from 1942 to 1999. Professor Vanoni was an insightful researcher, an energetic and inspirational teacher, and the visionary editor and a contributing author of the original volume of *Sedimentation Engineering* (ASCE Manuals and Reports on Engineering Practice No. 54) published in 1975. Manual 54 is a classic reference used by professionals and academics around the world. Professor Vanoni was the recipient of numerous professional honors and awards; however, he always displayed a humble and sincere interest in all of his students, his family, his profession, and his colleagues at Caltech. He encouraged fundamental research on sediment transport using modern fluid mechanics, and recognized the need for much more graduate level education to support the advances in research and applications of sedimentation engineering. The profession and science of sedimentation engineering was greatly advanced by the research, teachings and publications produced by Professor Vanoni during his career.[1] Therefore, the ASCE Task Committee to Expand and Update ASCE Manual 54 dedicates this edition of *Sedimentation Engineering* to Vito A. Vanoni for the significant contributions he made to the profession of sedimentation engineering and mobile boundary hydraulics during his career. We miss his charm, intellect, enthusiasm, insightfulness, and friendship.

[1] Brooks, N. H. (2001). "Vito Vanoni (1904–1999): A leader in sedimentation engineering." *Journal of Hydraulic Engineering,* ASCE, 127(3), 175–179. Reprinted in this volume, page 1107.

CHAPTER 1

Overview of Sedimentation Engineering

Robert C. MacArthur, Charles R. Neill, Brad R. Hall, Vic J. Galay, and Andrey B. Shvidchenko

1.1 INTRODUCTION

1.1.1 General

Sedimentation engineering embraces the identification, planning, analysis, and remediation, principally in the context of civil and hydraulic engineering practice, of projects or technical investigations to avoid and/or mitigate problems caused by sedimentation processes. These processes include erosion, entrainment, transport, deposition, and compaction of sediment. External agents and forces driving these processes may include water, wind, gravity, and ice. Human activities also affect sedimentation processes. This volume of *Sedimentation Engineering*, referred to herein as Manual 110, focuses primarily on physical processes, measurements, modeling, and the practice of sedimentation engineering, mainly in the context of rivers and inland water bodies. (Chapter 4, however, addresses fine sediments topics, including those found in coastal and estuarine environments.)

The original ASCE Manual 54 *Sedimentation Engineering,* edited by Vito A. Vanoni (1975), represents a 10-year effort by the Task Committee for the Preparation of a Manual on Sedimentation under the coordination of the Sedimentation Committee of the Hydraulics Division of ASCE. Professor Vanoni and the Task Committee assembled and organized state-of-the-art information on sediment mechanics and sedimentation engineering available at the time. Since then, awareness of the importance, scope, and potential consequences of sedimentation processes in relation to civil engineering works, human activities, and the environment has greatly increased. Also greatly expanded are the scientific and engineering understanding and knowledge of underlying processes related to sedimentation engineering. Manual 110 is designed to update selected topics in the original manual and to present recent advances and new topics in sedimentation engineering as a complement to the original Manual 54. Manual 110 is intended to supplement rather than replace the original manual, which contains a wealth of fundamental information that has not lost its validity. Together, both manuals document the evolution of the specialized field of sedimentation engineering over a 50-year period.

1.1.2 Global Aspects and Changing Roles

As awareness of sedimentation processes and the consequences of poor sediment-management practices has increased among civil engineers and other water resources professionals, it has increasingly been realized that a multidisciplinary approach to problem identification, quantification, and management is often required to deal with the interrelated effects of geomorphologic, environmental, and engineering issues. This type of comprehensive systems approach is also demanded by more stringent legal and regulatory requirements regarding sediment and hydraulic processes in water bodies.

Factors that have resulted in increased public awareness and greater potential impacts to water resources and the environment include the following:

- Growing global populations place increasing pressures on land and water resources. As forest and farmlands become subject to increased soil erosion (Fig. 1-1), reservoirs designed for centuries of useful life may fill with sediment in a few decades, and water supply, irrigation systems, and critical aquatic habitat areas may become clogged with sediment deposits, while poorly managed forests and farmlands decline in function and productivity.
- Human settlements have increasingly occupied areas more vulnerable to erosion and sedimentation, thus aggravating runoff, soil erosion, and gullying (Fig. 1-2). Poor land use planning, management, and maintenance