Chapter 1
Introduction

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by
Chih Ted Yang

1.1 Background and Needs

Surface erosion, sediment transport, scour, and deposition have been the subjects of study by engineers and geologists for centuries, due to their importance to economic and cultural development. Most ancient civilizations existed along rivers in order to use the water supply for irrigation and navigation. All rivers carry sediments, due to surface erosion from watersheds and bank erosion along the river. Our understanding of the dynamic equilibrium between sediment supply from upstream and a river's sediment transport capability is important to the success of river engineering design, operation, and maintenance.

Engineers built levees along rivers for flood control purposes. Reservoirs are built to ensure water supply and flood control. Canals are built for water supply and navigation. Sustainable use of these hydraulic structures depends on our understanding of the erosion and sedimentation processes and how to apply them to hydraulic designs. For example, soil conservation practice, check dams, sediment bypass devices, and sluicing are often used to reduce sediment inflow or remove sediments from a reservoir to prolong the useful life of a reservoir. The dynamic equilibrium, or regime, concept was used in the design of stable regime canals in India and Pakistan. More recently, computer models have been developed to simulate and predict the erosion and sediment transport, scour, and deposition processes.

There are many sediment transport books, such as those by Graf (1971), Yalin (1972), Simons and Sentürk (1977), Chang (1988), Julien (1995), and Yang (1996). These books were written mainly as university textbooks for teaching and research purposes. There is a gap between engineering and academic needs. Engineers often find it is difficult to apply erosion and sediment transport theories they have learned from the classroom to solve river engineering design problems. The American Society of Civil Engineers published the *Manuals and Reports of Engineering Practice No. 54 – Sedimentation Engineering* in 1935 (Vanoni, 1975). The erosion and sedimentation literature and methods summarized in that manual do not include those developed and used in the past thirty years. There is a need to develop and publish an erosion and sedimentation manual to summarize what we have learned in the past thirty years for the benefit of practicing engineers and geologists.

1.2 Objectives

Engineers in the Bureau of Reclamation's Sedimentation and River Hydraulics Group provide technical assistance and conduct studies to meet the needs of other Reclamation offices and of domestic and international water resources agencies. In addition to using the latest state-of-theart technology, engineers in the Sedimentation and River Hydraulics Group often have to develop new technology, methods, and computer programs for solving erosion, sedimentation, and river hydraulic problems. All the authors of the *Erosion and Sedimentation Manual* are members of the Sedimentation and River Hydraulics Group. Information, computer programs, and materials included in the manual are based on proven technology existing in the literature and some of them were developed by the authors for solving practical engineering problems. The objectives of writing this manual are twofold: to summarize the authors' experience and knowledge and to share with the public what they have learned and used in solving erosion and sedimentation problems. The Erosion and Sedimentation Manual is intended for engineers with basic background and knowledge in open channel hydraulics, sediment transport, and river morphology. The manual can also be used as a reference book for university professors, graduate students, and researchers for solving practical engineering problems.

1.3 Manual Organization

This manual contains nine chapters and three appendices. Each chapter is self-contained, with an introduction, summary, and a list of references. Cross references are made to avoid duplications of materials in different chapters. Basic theories, concepts, and approaches in erosion, sediment transport, river morphology, computer modeling, and field survey are reviewed and summarized in the manual. Examples are used to illustrate how to use the methods and programs contained in the manual. Materials contained in each chapter and appendix are briefly summarized as follows.

Chapter 1 - Introduction

Chapter 1 describes the background, needs, and objectives of preparing and publishing this manual.

Chapter 2 - Erosion and Reservoir Sedimentation

Chapter 2 describes and evaluates empirical approaches based on the universal soil loss equation and its modified versions and the determination of sediment yield as a function of drainage area, drainage classification, or from direct measurements. The physically based approach is derived from the unit stream power theory for erosion and sediment transport and the minimum unit stream power or minimum stream power theory governing the river morphologic processes. Field data were used to compare the accuracy and applicability of the empirical and physically based approaches. The concept and approach used in developing the Generalized Sediment Transport model for Alluvial River Simulation (GSTARS) computer models GSTARS 2.1, GSTARS3, and GSTAR-W are summarized. It shows how a systematic approach based on consistent theories can be used to develop a model to simulate and predict the erosion and sediment transport, scour, and deposition processes in rivers and reservoirs in a watershed. This chapter ends with a summary of technology used in the determination of reservoir sediment trap efficiency, sediment density, and sediment distribution in a reservoir using conventional methods and the minimum unit stream power or minimum stream power methods.

Chapter 3: Noncohesive Sediment Transport

This chapter starts with the subject of incipient motion, followed by sediment transport functions based on regime, regression, probabilistic approaches, and deterministic approaches. Most of the commonly used sediment transport equations are summarized and compared. In addition to the conventional approaches, stream power, unit stream power, power balance, and gravitational power theories are summarized and compared. To address the impacts of fine sediment or wash load on sediment transport, the subject of nonequilibrium sediment transport is also included. This chapter ends with recommendations for selecting appropriate equations under different hydraulic and sediment conditions.

Chapter 4 - Cohesive Sediment Transport

The current level of understanding on cohesive sediment transport of fine matters is relatively primitive when compared with that of noncohesive sediment transport. This does not mean cohesive sediment transport is of less importance. Most pollutants are attached to and transported with fine sediments. The U.S. Environmental Protection Agency (2001) has identified sediment as the number one pollutant in the United States. This chapter summarizes cohesive sediment transport theories and experimental methods for determining erosion parameters. Computer models, especially the GSTARS3 and GSTAR-1D models, can be used to simulate the transport processes of cohesive sediments.

Chapter 5 - Sediment Modeling for Rivers and Reservoirs

This chapter starts with the numerical modeling cycle, followed by basic equations used in one-, two-, and three-dimensional models. Numerical solution methods, such as finite difference, finite element, and finite volume methods are introduced and compared. The stream tube concept and minimum total stream power theory are used in the development of the GSTARS. Examples of application of GSTARS 2.1 and GSTARS3 computer models are included to illustrate how the models can be applied to simulate and predict the sedimentation processes in rivers and reservoirs.

Chapter 6 – Sustainable Development and Use of Reservoirs

Sedimentation is a sure way to shorten the useful life of reservoirs. Due to environmental, political, social, economic, and geological considerations, sustainable development and use of reservoirs must be considered in the planning, design, construction, and operation of new reservoirs. For existing reservoirs, engineering methods should be developed and applied to prolong their useful life. This chapter provides a brief description of the planning process and design considerations for hydraulic structures to reduce sediment inflow to a reservoir and to sluicing sediment from a reservoir. Sediment management methods for large and small reservoirs are described and compared. Reservoir operation rules for different types of reservoirs are recommended, and sedimentation and prevention costs are included for engineers to consider.

GSTARS 2.1, GSTARS3, GSTAR-1D, GSTAR-W, and economic models are introduced as technical tools that are available for engineers to apply for analyzing and solving sedimentation problems.

Chapter 7 – River Processes and Restoration

A river is a dynamic system. Engineers must understand factors and principles governing river processes. Engineering design and construction of hydraulic structures without taking these factors and principles into consideration may not last long and may not serve the basic functions of rivers. Many existing hydraulic structures have been redesigned or modified in recent years to restore a river's basic functions. This chapter describes the geomorphic processes and possible disturbances affecting the river corridor. Analytical approaches for hydrologic, hydraulic, and sediment transport studies are summarized. Restoration options and treatments using structural and nonstructural measures are discussed and included in this chapter.

Chapter 8 – Dam Decommissioning and Sediment Management

More than 76,000 dams that are at least 6 feet high exist in the United States. While the great majority of these dams still provide beneficial use and function to the society, some of the dams may need to be decommissioned. Reasons for decommissioning include, but are not limited to, economics, dam safety and security, legal and financial liability, ecosystem restoration, and recreation considerations. This chapter describes reservoir sediment management problems and engineering considerations of dam decommissioning. Sediment management alternatives include no action, sediment removal by river erosion and by mechanical means, and stabilization. Special attention is paid to analysis methods for river erosion of reservoir sediments and their impacts on downstream river reaches.

Chapter 9 –Reservoir Survey and Data Analysis

Reservoir sedimentation is an ongoing natural depositional process that can remain below water and out of sight for a significant portion of the reservoir life, but lack of visual evidence does not reduce the potential impact. Reservoir sediment models have been developed for analyzing and solving sediment problems. Calibration and confirmation of these models can be achieved with accurate field data. This chapter presents methodology to measure reservoir bathymetry or topography with the goal of accurately updating reservoir sedimentation and storage capacity information in a timely and cost-efficient matter. Reclamation's Sedimentation and River Hydraulics Group continuously upgrades their technical procedures to reflect ever-changing technology, and the majority of the techniques provided are from experience gained. This chapter provides guidelines, techniques, and information for planning, collecting, analyzing, and reporting reservoir and river survey studies with the ultimate goals of preservation of the information and uniformity of collection and analysis.

Appendix I - Notation

Appendix II - Conversion Factors

Appendix III – Physical Properties of Water

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1.4 Summary

The *Erosion and Sedimentation Manual* provides a comprehensive coverage of subjects in nine chapters (i.e., introduction, erosion and reservoir sedimentation, noncohesive sediment transport, cohesive sediment transport, sediment modeling for rivers and reservoirs, sustainable development and use of reservoirs, river processes and restoration, dam decommissioning and sediment management, and reservoir surveys and data analysis). Each chapter is self-contained, with cross references of subjects that are discussed in different chapters of this manual. The manual also includes a list of commonly used notations used in the erosion and sedimentation literature, conversion factors between the Imperial and metric units, physical properties of water, and author and subject indexes for easy reference. Each chapter has a list of references for readers who would like to seek out more detailed information on specific subjects. The manual should serve as a useful book for researchers, university professors and graduate students, and engineers in solving erosion and sedimentation problems.

1.5 References

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