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Stream Restoration in Dynamic Fluvial Systems

Scientific Approaches, Analyses, and Tools

Andrew Simon, Sean J. Bennett,
and Janine M. Castro
Editors

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Cover Image: Time series photographs (1997 and 2009) of a meander bend on Goodwin Creek, Mississippi, before and 2 years after restoration. This successful project is described in the book. Photographs by Andrew Simon and David Derrick.

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PREFACE

Stream restoration is a catchall term for modifications to streams and adjacent riparian zones undertaken to improve geomorphic and/or ecologic function, structure, and integrity of river corridors, and it has become a multibillion dollar industry worldwide. A vigorous debate currently exists in research and professional communities regarding the approaches, applications, and tools most effective in designing, implementing, and assessing stream restoration strategies given a multitude of goals, objectives, stakeholders, and boundary conditions. More importantly, stream restoration as a research-oriented academic discipline is, at present, lagging stream restoration as a rapidly evolving, practitioner-centric endeavor.

Our initial discussions for an edited volume on stream restoration led to a preliminary list of potential contributors assembled by the editors and Colin Thorne. Our approach for soliciting contributions to the volume was simple: we extended invitations to as many leading stream restoration scholars and practitioners as possible (though initially limited to 25). In addition, we made a concerted effort to have a diversified group of contributors. On the basis of the comments from the proposal peer reviewers, the editors altered a few of the contributions in consultation with select authors and solicited a few additional papers to achieve parity in both scope and content as suggested.

The final product of these efforts is a volume that brings together leading experts in both the science and practice of stream restoration, providing a comprehensive, integrative, and interdisciplinary synthesis of process-based approaches, tools, and techniques currently in use, as well as their philosophical foundations. Here nearly 70 researchers from North America, Europe, and Australia contribute papers divided into six broad categories: (1) general approaches, (2) stream hydrology and hydraulics, (3) habitat essentials, (4) sediment transport issues, (5) structural approaches, and (6) model applications. The result is a concise, up-to-date treatise addressing key issues in stream restoration, stressing scientifically defensible approaches and applications from a wide range of perspectives and geographic regions. Most importantly, the volume furthers the ongoing dialogue among researchers and practitioners.

We should like to extend our appreciation to those who made this publication possible. We thank the authors who contributed to the volume, and those individuals who provided constructive and timely reviews of these papers (listed below). We thank Colin Thorne for offering many helpful suggestions in preparing the book proposal. Finally, we gratefully acknowledge the continued support of the University at Buffalo, the U.S. Fish and Wildlife Service, and the Agricultural Research Service of the U.S. Department of Agriculture.

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Section I

Introduction

The Evolving Science of Stream Restoration

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Stream restoration is a general term used for the wide range of actions undertaken to improve the geomorphic and ecologic function, structure, and integrity of river corridors. While the practice of stream restoration is not new to geomorphic, ecologic, or engineering communities, the number of restoration activities and their associated costs has increased dramatically over the last few decades because of government policies intended to protect and restore water quality and aquatic species and their habitats. The goals and objectives, tools and technologies, approaches and applications, and assessment and monitoring standards promoted and employed in stream restoration are rapidly evolving in response to this increased focus and funding. Because technology transfer is an important activity in scientific discourse, this volume provides a comprehensive, integrative, and interdisciplinary synthesis of process-based approaches, tools, and techniques currently used in stream restoration, as well as their philosophical and conceptual foundations. This introductory paper provides a brief summary of the history and evolving science of stream restoration and emerging areas relevant to the stream restoration community.

1. INTRODUCTION

Stream restoration is a catchall term used to describe a wide range of management actions and as such is difficult to define. The definition of stream restoration can vary with the perspective or discipline of the practitioner or with the temporal and spatial scale under consideration. For example, to environmental engineers, stream restoration could mean the return of a degraded ecosystem to a close approximation of its remaining natural potential [*Shields et al.*, 2003], while geomorphologists and hydrologists might define restoration as improving hydrologic, geomorphic, and ecological processes in degraded watershed systems and replacing lost, damaged, or compromised elements of those natural systems [*Wohl et al.*, 2005]. Ecologists further note that restoration of rivers should result in a watershed's improved capacity to provide clean water, consumable fish, wildlife habitat, and healthier coastal waters [*Palmer and Bernhardt*, 2006]. Any of these definitions could include a spectrum of management activities, from replanting riparian trees to full-scale redesign of river channels [*Bernhardt et al.*, 2007]. The wide range of definitions used for stream restoration, and its variation in time, is summarized by *Dufour and Piégay* [2009].

The primary focus of stream restoration has, not surprisingly, been on corridors impaired or degraded by anthropogenic activities. These activities include channelization and hydromodification, alteration of land use and land cover, the discharge of pollutants and contaminants into surface and ground waters, and the introduction of new aquatic species [*Wohl et al.*, 2005; *Palmer and Bernhardt*, 2006]. On the basis of recent reports, leading causes of water quality impairment in U.S. rivers include water quality, habitat alterations, impaired biota, nutrients, and sediment [*U.S. Environmental Protection Agency (U.S. EPA)*, 2009]. The majority of low-order U.S. streams, which constitute 90% of all stream miles, have some level of biological impairment, and the most frequent stressors include nutrient loadings, riparian disturbance, and streambed sediment [*U.S. EPA*, 2006]. The most commonly stated goals for river restoration in the United States are to enhance water quality, to manage riparian zones, to improve in-stream habitat, to provide for fish passage, and for bank stabilization [*Bernhardt et al.*, 2005].

The objectives of this introductory paper are to provide a brief history of stream management, to summarize the evolving science of stream restoration, and to identify emerging areas relevant to the stream restoration community. While the emerging areas identified here are not intended to be all inclusive, they do represent the continually changing issues and challenges surrounding stream restoration research and practice and include the following: (1) conflicts within the stream restoration community, (2) the communication of “failure” or lack of success, (3) policy, uncertainty, and practice, (4) landscape trajectories and rise of the social dimension, (5) the future of flow redirection techniques, and (6) the role of models. Finally, the intended goals and thematic focus of this edited volume are presented and contextualized.

2. A BRIEF HISTORY

While "stream restoration" has been vigorously debated from theoretical and philosophical bases over the past few decades, the implementation of stream restoration projects has grown into a multibillion dollar industry. The term "stream restoration" is fairly recent in our river management lexicon, yet the practice of modifying channels for benefit is not.

Early stream management efforts were aimed at bringing water to settlements, reducing the ravages of floods, and irrigating croplands [*Hodge*, 2000, 2002]. The oldest known artificial watercourses were irrigation canals, built in Mesopotamia circa 4000 B.C., in the area of modern day Iraq and Syria. In what is now Jordan and Egypt, the earliest known dams were constructed between 3000 and 2600 B.C. The Indus Valley civilization in Pakistan and north India (circa 2600 B.C.) developed sophisticated irrigation and storage systems, including the reservoirs built at Girnar in 3000 B.C. [*Rodda and Ubertini*, 2004]. In Egypt, canals date back to 2300 B.C. when one was built to bypass the cataract on the Nile near Aswan [*Hadfield*, 1986], while construction of embankments and drainage ditches took place in Italy and Britain 2000 years ago during Roman rule [*Brookes*, 1988; *Billi et al.*, 1997]. Greek engineers were the first to use canal locks, which regulated water flow in the ancient Suez Canal as early as the third century B.C. [*Moore*, 1950; *Froriep*, 1986; *Schörner*, 2000].

By the nineteenth century, large-scale agricultural development associated with European settlement in North America, Australia, and India led to the clearing of large tracts of land and alteration of rainfall-runoff relations. Poor soil conservation practices led to massive erosion of fields and upland areas [*Ireland et al.*, 1939], causing infilling of channels and increasing the magnitude and extent of