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Introduction: river confluences, tributaries and the fluvial network

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Introduction

That river systems are networks consisting of links and nodes is one of their most obvious characteristics. Despite the ubiquity of confluences and tributary networks, the first century of modern fluvial geomorphology paid little consistent attention to river junctions and the interactions between tributaries and the main stem (Kennedy, 1984). Important exceptions include classic contributions from Playfair (1802), Lyell (1830) and Sternberg (1875), works on tributary–main-stem interactions (e.g. Krumbein, 1942; Miller, 1958), considerations of junction hydraulics and mixing (e.g. Taylor, 1944; Mackay, 1970) and the seminal works on river network structure (e.g. Horton, 1945; Shreve, 1967). However, the 1980s marked the beginning of a period in which confluence, tributary and network studies developed rapidly. Key contributions were concerned with: confluence morphology, hydraulics and sedimentology (Mosley, 1976; Best, 1986, 1988; Roy et al., 1988), tributary-induced changes in channel form (Richards, 1980; Roy...
and Woldenberg, 1986; Rhoads, 1987) and bed sediments (Church and Kellerhals, 1978; Knighton, 1980), the ecological role of tributaries along unregulated (Bruns et al., 1984) and regulated rivers (Petts, 1984; Petts and Greenwood, 1985), tributaries as repositories of paleoflood information (Kochel and Baker, 1982) and tributary network structure (Abrahams and Campbell, 1976; Flint, 1980; Abrahams and Updegraph, 1987).

Figure 1.1 indicates the rapid increase in the volume of published work on tributaries and confluences in the period since 1980 and illustrates how the initial impetus of the 1980s was consolidated in the 1990s. Ecological interest has lagged behind geomorphology and hydraulics, but it is clear that ecological interest is now growing at the fastest rate. This body of work has demonstrated that river confluences are critical nodes in river systems where tributary fluxes of water and sediment can elicit adjustments in the geomorphology, hydraulics, sedimentology and ecology of the recipient channel. At

![Figure 1.1](image_url)

**Figure 1.1** The growth in research publications that deal with confluences and tributaries. Network research is not included. Because of the cross-disciplinary nature of many papers, the classification into sub-disciplines is imperfect. Searches were made for the period 1980–2007 using the ISI Web of Science, Science Citation Index – Expanded (http://portal.isiknowledge.com/). A primary search was made of titles, abstracts and keywords using the Boolean expression '(confluence* OR tributar*) AND (river* OR channel*)' and subsequent searches explored other likely terms. Results from these searches were then scrutinized and only those papers where tributaries or confluences were the primary subject matter or where they were used explicitly to explain observed phenomena were retained. Large numbers of papers that studied a particular river system including one or more of its tributaries or confluences but which did not focus on the properties or processes of confluences or tributaries were excluded. Because many papers on water chemistry across drainage basins fall into this category, the ‘hydraulics and hydrology’ classification does not include any water quality papers.
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the smallest scales, research at river confluences examined the distinctive flows, morphologies, sedimentary assemblages and habitats that make confluence sites important local features. Most attention has been directed towards understanding flow mixing at junctions (Gaudet and Roy, 1995; Best and Ashworth, 1997; Biron et al., 2004; Rhoads and Sukhodolov, 2004; Ding and Wang, 2006) and relations between sediment transport, morphology and stratigraphy (Biron et al., 1993; Kenworthy and Rhoads, 1995; Ashworth, 1996; Leclair and Roy, 1997; Paola, 1997; Roy and Sinha, 2005; Boyer et al., 2006). The biological attributes of confluences have received some attention (Cellot, 1996; Kupferberg, 1996; Franks et al., 2002; Fernandes et al., 2004; Kreb and Budiono, 2005; Kiffney et al., 2006), as have the dynamics of ice jams at confluences (Prowse, 1986; Ettema et al., 1997; Shen et al., 2000; Ettema and Muste, 2001). At this scale, improved understanding informed, and was informed by, studies of confluences in braided rivers (Ashmore, 1991; Ashworth et al., 1992; Best and Ashworth, 1997), which, arguably, has laid the foundation for recent investigations of the dynamics of river bifurcations (Dargahi, 2004; Federici and Paola, 2003; Khan et al., 2000; Parsons et al., 2007).

At a slightly larger scale, the confluence zone has been recognized as an important site of storage and staging for clastic and organic materials in fans and terraces (Albertson and Patrick, 1996; Brierley and Fryirs, 1999; Florsheim et al., 2001; May and Gresswell, 2004; Gomez-Villar et al., 2006). Ecological research at this scale suggests that tributary channels in the vicinity of confluences can provide important biological resources including, for example, refugia from high water temperatures (Bramblett et al., 2002; Cairns et al., 2005) and main-stem predators (e.g. Fraser et al., 1995). It has been proposed that such factors, along with enhanced morphological heterogeneity in this confluence zone, may create hotspots of elevated biodiversity (Benda et al., 2004a). At the larger, reach scale, main-stem adjustments to tributary fluxes of water, sediment and organic materials have been shown to structure the longitudinal operation of various abiotic and biotic processes leading to step-changes or gradient shifts in, for example, bed material grain size (Dawson, 1988; Rice and Church, 1998), longitudinal profile (Rice and Church, 2001; Hanks and Webb, 2006) and macroinvertebrate ecology (Perry and Schaeffer, 1987; Rice et al., 2001). Earlier work on tributary influences has been extended to investigate what controls the magnitude of tributary impacts (Rice, 1998; Benda et al., 2004b; Ferguson et al., 2006; Rice et al., 2006).

Understanding confluence dynamics and tributary impacts at these various scales is crucial for scaling-up knowledge of river processes to the drainage network scale: understanding the operation of the nodes in a network is necessary in order to develop network-scale models and tools. Indeed, there is increasing awareness that river system science requires a better integration of process knowledge across a range of spatial scales and particular emphasis is being placed on understanding network-scale functions (e.g. Paola et al., 2006). Building on early work that focused on the topological properties of river networks (see Abrahams, 1984, for a review), a large body of research over the past 30 years has focused on the fractal properties and scaling relations of networks
and the way in which these properties and relations are connected to basin hydrological response (see Rodríguez-Iturbe and Rinaldo, 1997). This line of research has matured into the investigation and modelling of process dynamics at river network scales, for example in geomorphology (Gasparini et al., 1999; Binnie et al., 2006; Sklar et al., 2006; Bigelow et al., 2007) and lotic ecology (Poole, 2002; Power and Dietrich, 2002; Benda et al., 2004a; Grant et al., 2007; Thorp et al., 2006; Bertuzzo et al., 2007). Other emerging topics include the role of network structure in pollutant dispersion and the relation of channel networks on other planets to those on Earth – topics that are covered in the latter section of this volume.

Key aims of the book

Work on confluence dynamics, tributary impacts and network-scale functions is, then, alive and well and involves experimental work in the field and laboratory, numerical modelling and large-scale empirical field investigations. This endeavour is frequently cross-disciplinary, challenging traditional boundaries between ecology, engineering, geomorphology, hydrology and sedimentology and emphasizing that river network form and functions control the spatio-temporal patterns of many physical, chemical and biotic processes at the Earth’s surface (Paola et al., 2006). At the onset of the second century of modern fluvial studies, our key aim in this book is to present a multidisciplinary, multiscale perspective on confluences, tributaries and river networks. Our intention is that by bringing together work on confluence dynamics and tributary–main stem interactions with network-scale perspectives, the reader will be better positioned to explore the links between processes across these scales. We have tried to draw out these linkages explicitly wherever possible. We hope that the book will provide a foundation upon which integrative effort can be built so that a truly network-scale understanding of river systems can be developed. A recurrent theme, raised by numerous authors, is the need for the continued collection of field and experimental data with which to develop and test our models of confluence, tributary and network processes, and we hope that the areas for further investigation highlighted herein will direct this effort. Also, by presenting the material here in book form, we hope to maximize the involvement of the wider community and facilitate the incorporation of new confluence, tributary and network understanding into the management of river processes and services.

Sections of the book

The book is organized into three parts: (I) River Channel Confluences, (II) Tributary–Main-stem Interactions and (III) Channel Networks. Each section begins with a short
introductions essay that includes an overview of the papers in that section, so we refrain from providing such an overview here. Individual chapters focus on the core themes of research and knowledge as well as some topics that have received less attention (e.g. confluence and tributary management). Each chapter provides a review of current understanding, presents new research and considers where future efforts should be directed. We do not claim that the volume is comprehensive, and some topics, such as the structure and dynamics of distributary drainage networks, are not covered here. We do feel, however, that the book has sufficient scope to introduce the novice and scholar alike to many important issues at the forefront of research on river confluences, tributaries and networks. It is hoped that the book as a whole will provide a timely synthesis of a rapidly growing and important field of study but will also bring forward new and stimulating ideas that will shape a coherent and fruitful vision for future work.

References


CH 1 INTRODUCTION: RIVER CONFLUENCES, TRIBUTARIES AND THE FLUVIAL NETWORK


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