Introduction: Managing Rivers with Broad Historical Changes and Human Impacts

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Growing concerns over global environmental change, water resources, river restoration, and sustainable river management are focusing attention on the human dimension of fluvial systems. This GSA Special Paper presents a set of studies and interpretations of river-channel change that reflect modern viewpoints of river management in the twenty-first century. It seeks to bridge a rich body of literature borne of late-twentieth-century river studies based in classic concepts of fluvial geomorphology with modern studies of river management and restoration, integrated watershed science, modern fluvial geomorphology, and historical channel-change reconstructions. Collectively, the papers document or recognize extensive changes to fluvial systems over a prolonged period, present analytical methods that can be used to examine and understand fluvial systems, and examine or recommend policies for river management and restoration.

Background

The papers in this Special Paper were drawn from presentations in Topical Session 17 at the annual GSA meeting in Denver, 28–31 October 2007. The title of the topical session was the same as this volume: *Management and Restoration of Fluvial Systems with Broad Historical Changes and Human Impacts.* In addition to inviting selected authors and keynote speakers, the themes and structure of the session were listed by the GSA prior to the meeting, and many authors volunteered papers through this open forum. The favorable response and high level of commitment received from senior scientists and scholars, and the wide range of topics covered, indicate a strong, diverse interest in long-term anthropogenic changes to watersheds and river responses, and rapid growth in the field of river management and restoration. The session drew 34 presentations, including 8 posters and 2 oral paper sessions consisting of 26 papers. The oral papers concluded with a spirited panel discussion.

Panel Discussion

A panel consisting of Peter Downs, Faith Fitzpatrick, Will Graf, Jim Pizzuto, Ellen Wohl, and Bill Renwick made several important points and raised just as many questions concerning long-term human impacts on rivers and the implications for river management. The discussion began with comments by Bill Renwick, Faith Fitzpatrick, Greg Pasternack, Cliff Hupp, Jim Pizzuto, Peter Downs, and others about the importance of impoundments and legacy sediment to sediment regimes and how this factor has changed through time and space. The question of scale is an important aspect of this issue. The importance of large reservoirs to downstream sediment loadings on large rivers has long been recognized. More recently, however, the extensive nature of small headwater impoundments such as farm ponds and mill dams on intermediate-order drainages has come to be recognized. To many environmental scientists—such as those concerned with total daily maximum loads (TMDLs)—all sediment is treated as a pollutant. This perspective is in conflict with the need to introduce sediment to sediment-starved reaches below impoundments or where coarse sediment needs to be recruited to replenish spawning gravels on riffles and bars. This conflicting view toward sediment illustrates the need to recognize unique situations; attempts to prescribe a universal approach (e.g., sediment reduction) to river management may fail to restore needed ecological functions if they do not match specific local or regional geomorphic situations.

The panel discussion next turned to a stimulating dialogue about river-management policy. Robb Jacobson noted how the "democratization" of resource management raises issues of decision making based on limited scientific understanding and may result in policies that treat all rivers alike. Will Graf described a case in which scientists and stakeholders met in two separate groups, then later met together to develop solutions. This procedure took 6 yr to complete, but the result was successful. When discussion shifted to the diversity of goals and philosophies of river restoration, Jack Schmidt pointed out that biologists may regard channel geomorphic features merely as a substrate to support species, whereas geomorphologists see them as a productof dynamic river processes that should be allowed to operate. Pat McDowell indicated that reach-scale restoration projects may not be resilient and are vulnerable to failure over the long term. Much could be learned from the history of ecosystem management, which has long embraced landscape-scale approaches to natural systems. Thus, the conversation turned back again to issues of scale, as Will Graf pointed out how projects of larger extent have a greater difficulty of surviving the budgetary appraisal process. These concepts of developing flexible policy guidelines based on sound science to integrate human impacts over watershed spatial scales and centennial temporal scales formed an appropriate summation of the sessions and a springboard for this volume.

Objectives of This Special Paper

Recognition of the complexity, potential anthropogenic contributions, and dynamics of fluvial system change at time scales up to a few centuries is essential to the proper management of river systems. This recognition, along with methods and strategies for managing rivers in this context, is the primary theme of this volume. In many watersheds, long-term anthropogenic changes—such as deforestation, cultivation, fires, urbanization, road construction, and mining—initially resulted in widespread increases in runoff generation, flood magnitudes, erosion, and sedimentation. These changes to watersheds indirectly affect river channels. In addition, direct alterations to channels include dams, levees, channelization, bank protection, instream mining, and removal of vegetation or large woody debris. In many basins, subsequent changes may have initiated relaxation from an earlier period of disruption. For example, reforestation in many regions has reversed the trend away from increased runoff and erosion. In a different sense, dam construction has locally or regionally reversed some effects of increased sediment production by trapping sediment in upstream reaches. In addition to the perturbations and subsequent relaxation from changes, the effects of climate change should be factored into an understanding of watershed processes that drive channel changes.

Several of the studies in this volume are concerned with long-term fluvial changes that recognize the cumulative impacts of human activities over periods that span several generations and up to multiple centuries. Most of the studies are broad in scope and adopt a modern watershed perspective that is both spatially and process integrated. Many also recognize that long-term land-use and land-cover changes, as well as legacy sediment, can be strongly related to modern river processes. These studies provide examples of why attempts to manage or rehabilitate rivers should seek to identify linkages between broad watershed processes and river behavior. Understanding geomorphic and hydrologic changes to surface-water and sediment systems is an essential prerequisite to devising viable management strategies for maintaining stable but dynamic and diverse channels, floodplains, and aquatic ecosystems in a pseudo-natural state, and for anticipating and mitigating further changes. The papers in this volume are divided into three sections related to the implications of historical changes to managing and restoring river systems:

I. Large-Scale, Long-Term Sediment and Geomorphic Changes
II. Hydrologic Considerations for River Restoration
III. River Management and Restoration

The first section emphasizes changes in sediment loadings through time and historical geomorphic changes in rivers. It purveys the extensive nature of changes that characterize many river systems, and how these changes continue to determine modern river processes. The second section is concerned with hydrologic changes and how they may drive river processes, or methods of evaluating them. The final section presents papers that evaluate the success or examine the feasibility of stream restoration. Throughout the volume a recurrent theme of the papers is the pervasive nature of human impacts on river systems and how river management should be keenly sensitive to this legacy.

Divisions between these sections are not absolute, and several of the papers overlap the categories. Although all such classifications have limitations, this structure provides the basis and context from which broader implications can be derived from the papers. The sequence of the sections establishes the background of pervasive change to fluvial systems, followed by examples of hydrologic factors that often drive changes in sediment and geomorphology. Finally, examples of the effectiveness or feasibility of stream restoration provide a reality check for river managers who seek to adopt restoration practices. The brevity of this volume constrains the ability to address all of the topics in detail, and the intent is not to provide a comprehensive treatment of these subjects but a sampling only. The remainder of this introduction briefly describes these three sections of the volume and the papers that are included in them.

Large-Scale, Long-Term Sediment and Geomorphic Changes

The first section presents examples of long-term or broadly extensive changes to watersheds—often human-induced—that drive channel changes in streams and rivers. The emphasis on sediment loads in most of the papers reflects the importance of sediment to geomorphic form, which in turn drives other river functions such as habitat diversity. Sediment dynamics are difficult to measure but have often changed substantially over time and can be critical to proper river management and robust restoration strategies. These papers demonstrate the importance of changing sediment regimes over time, and the need to understand the history of these changes in order to anticipate responses to management policies. The perspective that change is the rule, rather than the exception, is important to most river restoration or management planning. The assumptions that changes in sediment loadings and channel morphology have been minor, and that pristine reference reaches exist that can be emulated to design stable yet "natural" reengineered reaches, should both be critically evaluated on a case-by-case basis. These papers also demonstrate the importance of a watershed-scale analysis sensitive to historical legacies. A disconnection often exists between river management or restoration efforts performed at the river-reach scale and the processes governing fluvial systems that operate at a broader basin scale. Without an understanding of the spatially distributed nature of hydro-geomorphic processes operating over a centennial time scale, local restoration efforts may be prone to failure. The eight papers in this section impart an appreciation for this spatially and temporally broad-scale perspective of substantial change. The importance of interactions between present and historical sediment budgets, channel morphology, and engineering works is made clear in the first paper.

Jacobson et al. (this volume) note the influence of dams and bank protection on spatial patterns of sedimentation, suspended sediment loads, and channel morphology in the Lower Missouri River. The history of channel engineering in the Lower Missouri River includes construction of the largest reservoir storage system in North America and bank stabilization and channelization projects between 1930 and 1960. Altered sediment regimes below dams impose constraints on river restoration and management options, and the ability to manage dam releases to compensate for those altered regimes is severely limited. The reservoir system has reduced downstream flow variability and sediment loads, and reservoir operation policies aimed at managing sediment must contend with uncertainty in how channels will respond. This uncertainty calls for a better understanding of present and historical sediment fluxes.

Using observed fluxes on the mainstem of the Lower Missouri River, Jacobson et al. compute suspended sediment budgets that reveal distinct temporal and spatial changes. At Yankton, South Dakota, below Gavins Point Dam, post-dam suspended sediment loads (1994–2006) were only 0.2% of pre-dam values. This proportion increased downstream to 11% at Omaha, Nebraska, and 17% at Hermann, Missouri. Tributaries are key contributors to mainstem sediment loads below the dams. The amount of sediment contributed by tributaries decreased between 1948 and 1952 and 1994 and 2006 owing largely to improved land-conservation practices in tributary watersheds. Bank stabilization (1930–1960) reduced channel top widths by two-thirds, the sequestering of sediment preferentially removed sand from the suspended load, and commercial channel mining continues to remove much sand. Textures of the active load, therefore, have fined downstream and through time. Most channels responded to reduced sediment loads with bed incision, which decreased lateral connectivity between channels and floodplains. Aquatic habitat restoration—active since 1984—was stimulated in 2003 by mandates to restore and increase shallow-water habitats (SWH) and emergent sandbars. Naturalized reservoir releases with periodic high flows will be used to laterally connect channels with floodplains, build emergent sandbars, and increase SWH. Pulsed reservoir releases are constrained by flood risks in low-lying lands below Omaha where channels have not incised. Sandy sediment derived from excavations and placed in the channel to improve SWH will contribute ~34 Mg y^{-1} to the main channel over the next 15 yr; i.e., ~62% of the 1994–2006 suspended sediment budget. This planned project raises questions of the capacity of the river to carry the increased load. Given the complexities and constraints of the Lower Missouri system, the authors recommend concentrating restoration efforts in zones where they will be most effective with regard to costs and sustainable benefits.

Fitzpatrick et al. (this volume) demonstrate the pervasive nature of change to fluvial and wetland systems brought about by sedimentation derived from agricultural forest clearance and engineering works in an upper Midwestern watershed over the past 160 yr. The study was initiated to identify restoration alternatives. It demonstrates the need to understand the history and geomorphic evolution of a system rather than simply basing restoration strategies on channel morphology that was fundamentally changed from low to high banks by human-induced sedimentation. They cite sediment cores, geochemical dating, historical aerial photographs, and other evidence to constrain sedimentation rates and locations. Peak volumetric overbank sedimentation rates to the marsh occurred from 1919 to 1936, owing primarily to agricultural practices. These rates were seven times greater than modern rates (1994–2006), which are, in turn, more than four times rates during the early settlement period from 1846 to 1885. A full understanding of sedimentation and channel morphologic change requires knowledge of the history of levees, railroad embankments, dams, and channelization in the area.

Madej and Ozaki (this volume) emphasize the longevity of geomorphic impacts of massive sedimentation events in the gravel-bed Redwood Creek, California, caused by a series of ~25-yr flood events in the 1950s through 1975. Based on a data set collected over the past 30 yr, they examine the effects of a 1997 10-yr flood event on channels recovering from the earlier sedimentation. Comprehensive field measurements are used to document protracted sediment reworking after three decades. Over the long term, channel incision is characterized by decelerating rates of bed lowering that define an exponential decay rate from progressive bed armoring. Spatial patterns of recovery are nonuniform in the basin; sediment evacuation in the upper basin has been relatively rapid compared with that downstream. Pool depths and frequencies increased through time until they were partially refilled by the 1997 flood. Little is known about how quickly gravel-bed rivers in mountainous forested basins recover from episodic sedimentation. The observed pattern of punctuated recovery of the channel system is important, therefore, to river managers and restoration scientists, who should consider the feasibility of passive restoration; i.e., letting nature do the work.

James et al. (this volume) contrast styles of channel change and recovery between two rivers that were managed by distinctly different policies beginning in the late nineteenth century. Historical reconstructions of the lower Yuba and Feather Rivers—severely impacted by hydraulic mining sedimentation—are based on evaluations of a large number of historical maps and aerial photographs and high-resolution 1999 LiDAR-SONAR composite topographic data. Both the timing and styles of geomorphic responses were markedly dissimilar in the two rivers owing to contrasting engineering strategies practiced from the 1880s through the mid-twentieth century. These watersheds represent the earliest example of federally sponsored river-basin management west of the Mississippi River, so this post-project evaluation documents the consequences of one of the longest-running river-engineering experiments in the western USA.

Surian et al. (this volume) present a European perspective of long-term anthropogenic channel morphological changes in the context of Italian rivers. They use historical maps, aerial photographs, and field survey data to examine changes in dimensionless channel width (W/W_{max}) and bed elevation over the past 200 yr in 12 rivers, seven heading in the Alps and five in the Apennines. Changing sediment loads were the primary causes of channel change, but this relationship was driven by factors that varied within and between watersheds and through time. Most channels underwent a long period of incision and narrowing that began in the late nineteenth century and lasted well into the twentieth century. This incision was driven largely by human activities, beginning with levees, followed by bank protection and reforestation. Incision intensified from 1950 to the 1980s with dam construction and gravel mining. The incision processes have reversed or stabilized over the past 15 to 20 yr in most rivers. In light of the extreme changes to these rivers, the authors do not recommend trying to use channel conditions prior to human disturbances as a reference for restoration. They call for a focus on sediment management in severely impacted fluvial systems such as these.

Hupp et al. (this volume) present measurements of modern bank erosion and floodplain sedimentation rates in the Roanoke River, on the Coastal Plain of North Carolina, USA. They use erosion pins, repeated transects, clay pads, and other techniques to evaluate bank stability and floodplain deposition, and for development of a sediment budget for 153 km of the river downstream of two dams built in 1953 and 1963. Channel widening (net bank erosion) occurred on 90 transects, whereas only 12 transects display narrowing (net deposition). The zone of most rapid overall bank retreat has apparently progressed downstream through the upper reaches near the dams. Bank retreat is now greatest in the middle reaches of the study area, where mean annual rates on transects were found to be 63 mm yr^{-1} compared with 44 mm yr^{-1} upstream near the dams, and 24 mm yr^{-1} farther downstream (not including mass wasting events). High low-flow river stages after dam construction have concentrated fluvial bank erosion on the lower banks. This bank undercutting has encouraged mass wasting of mid- and upper banks composed largely of historical alluvium. Bank mass wasting, which was not well represented in the sediment budget, is suggested as an explanation for a large sediment surplus—deposition on lower Roanoke floodplains in excess of bank erosion—of approximately 2.8 10^6 m^3 yr^{-1}.

Güneralp and Rhoads (this volume) demonstrate a multi-methodological approach, including the use of a variety of geospatial methods, to compute stream powers, map lateral migration locations, estimate migration rates, and evaluate bank stabilization and stream restoration potential. They analyze channel planform changes over a 60-yr period in seven 5- to 10-km stream reaches in the Kishwaukee River watershed in northern Illinois, using a GIS-based channel-change detection with historical aerial photographs. Cross-sectional stream power (total power per unit flow width) correlates with lateral migration rates. None of the reaches had mean bankfull mean stream powers as high as 35 W m^{-2}, the threshold for meander recovery often noted in the literature. Local stream powers were also less than the threshold except in one steep headwater watershed, where they were as high as 63 W m^{-2}. In spite of stream powers below the threshold for meander recovery, most reaches underwent substantial lateral planation, and spatial patterns of channel migration were strongly related to stream power. The authors conclude that historical evaluations of channel change and computations of stream power provide important river-management tools.

Gran et al. (this volume) examine sediment loads in the Le Sueur River, an agriculture-dominated tributary to the Minnesota River, in the upper Midwest, USA. They take a long-term perspective by comparing mean Holocene production rates of suspended sediment in the watershed with modern low-turbidity management goals. Sediment production in the Le Sueur River is strongly influenced by the geomorphic history of the basin. Deep knickpoints were initiated by regional post-glacial base-level lowering associated with the catastrophic drainage of glacial Lake Agassiz. These knickpoints have eroded headward 30 to 35 km over ~11,500 yr and are now located in the lower reaches of all three main tributaries of the Le Sueur. Calculations of Holocene sediment production rates, based on topographic analyses of post–glacial valley formation using high-resolution LiDAR data, indicate that modern sediment loads are 1.3 to 3.4 times higher than the average load over the past 11,500 yr BP. These modern rates compare with a tenfold increase in regional post-European-settlement production rates based on sedimentation in Lake Pepin. The watershed can be divided into agricultural uplands above the knickpoints, and a lower incised zone dominated by steep bluffs and ravines that contributes from 61% to 74% of the total basin sediment. The watershed now contributes a disproportionate amount of sediment to the Minnesota River and Lake Pepin largely from sediment produced in the deeply incised channels. Total suspended solid (TSS) loads are an order of magnitude greater than regulatory standards, so this spatial knowledge is important for targeting remedial measures.

Hydrologic Considerations for River Restoration

The three studies in this section provide examples of the importance of hydrology to river systems. Hydrologic influences are key to many watershed problems, and methods of analyzing hydrologic inputs and outputs are welcome additions to most river managers' tool boxes. Hydrology may drive biogeomorphic factors through flow frequencies or connectivity and may govern sediment loads, channel morphology, water quality, and aquatic ecology. The first paper begins with a broad consideration of channel changes in semiarid streams that are largely influenced by flow regulation and diversions. It includes a case study of refuge pools in headwater streams that can be linked to groundwater during low-flow periods. The second paper proposes a method for determining appropriate flow releases from reservoirs. The third paper utilizes a method of analyzing annual maximum flow data to detect spatial and temporal change. The first two papers are concerned with providing guidance for management of river environments, whereas the third paper is more concerned with demonstrating hydrologic change and a method for quantifying this change.

Wohl et al. (this volume) review historical fluvial changes in the Great Plains. They demonstrate the need to study rivers as spatially heterogeneous systems rather than as disjunct reaches. The paper considers a broad array of management factors and implications of low flows, such as water allocation, water-table fluctuations, biology, and riparian vegetation composition. The authors place emphasis on the seasonal lack of longitudinal connectivity on small intermittent headwater streams that have received less attention than larger, perennial Great Plains rivers. These pools are essential to the fragile ecosystems of small ephemeral rivers. Regionally, intensive groundwater withdrawals have reduced the volume and longitudinal connectivity of refuge pools that provide important habitat for native aquatic species. A case study within Pawnee National Grasslands illustrates the challenges of preserving refuge pools as an integral part of the riverscape of the western Great Plains. A lack of statistical correlations between biological activity and most physical pool characteristics or location within the drainage network leads the authors to recommend that programs aimed at sustaining ecological systems should concentrate on pool size. They suggest that management strategies should focus on protecting larger pools from consumptive water use.

Rathburn et al. (this volume) develop a four-step method for identifying appropriate environmental flows needed to control sediment transport and vegetation. The method is aimed at integrating dam-operating policies with river management to ensure environmental flows that meet conservation targets. Flows along the North Fork Cache La Poudre River in north-central Colorado are characterized using a method that links sediment-transporting events and riparian vegetation composition and structure to specific flow recurrence intervals. Results of a hydrologic analysis, coupled with the sediment and riparian vegetation data, quantify the in-channel and overbank flows necessary to maintain channel processes and ecologically healthy riparian areas. Developing rational dam-operating policies that ensure appropriate environmental flows is an example of the emerging science of active river management for restoration purposes. Environmental flow standards developed by interdisciplinary teams of scientists can quantify the complex system processes responsible for maintaining ecological health within fluvial systems. These efforts to quantitatively link river flow to conservation priorities as a means of managing riverine ecosystems represent a turning point in how societies view and value regulated rivers.

Galster (this volume) uses extensive U.S. Geological Survey (USGS) gauging data from U.S. rivers to evaluate the rate at which peak annual discharge increases downstream with drainage area. Most of the studied rivers flow out of the Appalachian Mountains in the eastern USA. The discharge-area relationship is often assumed to be linear; i.e., a log-log (power function) relationship in which the exponent is approximately equal to 1.0. Results of this study, however, indicate a nonlinear or secular trend in time with most of the basins. Many rivers had exponents <0.75, indicating greater runoff generation and conveyance in tributaries than in larger rivers downstream. Many other rivers demonstrated substantial changes in discharge-area relationships through time primarily from dams, urbanization, and other land-use changes. Documenting linkages between the instrumental hydrologic record and channel morphology has been a prominent enterprise in fluvial geomorphology for several generations. These findings and the method of analysis have important implications for river management and policy, particularly given the limited flow data for most watersheds. Drainage area is often used as a proxy for discharge in hydrologic models, flood-hazard analyses, channel-stability computations, ecological-habitat evaluations, and other planning tools, but assuming a linear relationship between discharge and drainage area should be done with caution.

River Management and Restoration

The papers in this section provide scientific findings relevant to river management and restoration policy. Few post-project studies have been conducted of restored river reaches, so much is to be learned about which restoration methods are most appropriate, and which river reaches are most likely to be geomorphically durable or ecologically viable. The first two papers in this section provide detailed examinations of restored river reaches that should be a welcomed addition to the restoration literature. The third paper provides clear insights into the reasoning involved in selecting reference reaches and viable sites for restoration. Collectively, these three papers provide much-needed information about the relatively young science of river restoration.

Elliot and Capesius (this volume) analyze geomorphic changes along high-gradient rivers at sites on three "reclaimed" reaches in Colorado monitored for the USGS *Reconfigured-Channel Monitoring and Assessment Program* (RCMAP). Repeated cross-section surveys in these gravel-bed rivers document changes to banks, bars, and channels and constructed boulder and log structures following 4- and 6-yr floods at two of the sites. The authors provide quantitative hydraulic information about flow environments and grain size. Boundary shear stresses for floods are computed using the HEC-RAS model, and critical shear stresses for median sediment size are computed using Shield's criteria. The ratio of these values (τ_o/τ_c) is used to estimate the sediment-entrainment potential for a given cross section. Use of this ratio and recognition of areas with excessive flood boundary shear stress, relative to the resistive force of the sediment, often explain the spatial patterns of bank erosion and streambed deposition and scour observed at the monitored sites. The quantitative approach, coupled with abundant field data and thorough documentation, makes this paper a valuable contribution to stream restoration science.

Chin et al. (this volume) examine two small step-pool stream channels in California as unique case studies evaluating the ecological potential of step-pool restoration. The two streams, restored in 1996 and 2003, were examined for geomorphic stability of the step-pool systems and characteristics of benthic macroinvertebrates present. Geomorphic stability has been maintained through storms exceeding 14- to 20-yr recurrence intervals. The biological effectiveness of restoration by artificially manipulating step-pool systems was assessed through monitoring percentages of sensitive taxa to determine if ecologically viable environments were created. Comparisons were made across habitat types, to identify the most beneficial habitat, and across watersheds including a reference reach. Five to 12 yr after restoration the reference reach was found to have healthier ecological conditions and biological indicators than in the restored reaches, which were not significantly different than in unrestored reaches above or below the restored reaches.

Smith et al. (this volume) evaluate the effects on low-gradient rivers of extensive watershed disturbance in western Tennessee. Excessive sedimentation generated by deforestation and agricultural erosion on sandy uplands has induced complex channel and valley-bottom responses, including formation and growth of valley plugs, upstream migration of the zone of aggradation, and widespread flooding. Reformation of meanders owing to avulsions around plugs—sometimes reoccupying former channels—is identified as a form of passive self-restoration. Long-standing policies that promote extensive channelization and canal maintenance conflict with mandates to protect wetlands and restore streams. The authors' descriptions of river restoration efforts in this highly altered hydrologic setting, and the role of beaver and unmanaged channel avulsions in restoring natural conditions, provide lessons that should lead to more sustainable management programs.

Concluding Remarks

From the breadth of papers included in this volume, it is evident that many scientists are working on diverse fluvial systems to address timely questions relevant to river management and restoration. These studies reflect growing interests in environmental resources, ecological sustainability, and anthropogenic change that are driving modern movements in aquatic restoration and sustainable river management. The papers in this volume provide a repository of information that demonstrates the complexities of managing river systems that are responding to legacy conditions and that may have been highly altered by human activities. We hope this body of knowledge will benefit others by elucidating the historical and spatial dimensions of watershed processes that should be understood for decision making to be well informed. The challenge to river scientists is the need for continuing to assess the broad historical changes to fluvial systems brought on by human and nonhuman factors in order to develop practical solutions and policies for sound management of river resources.