CHAPTER 1

Introduction

Society's ability to maintain and restore the integrity of aquatic ecosystems requires that conservation and management actions be firmly grounded in scientific understanding.

LeRoy Poff, et al., 1997, p. 769

1.1 Concern for river health

Rivers are a much-cherished feature of the natural world. They perform countless vital functions in both societal and ecosystem terms, including personal water consumption, health and sanitation needs, agricultural, navigational, and industrial uses, and various aesthetic, cultural, spiritual, and recreational associations. In many parts of the world, human-induced degradation has profoundly altered the natural functioning of river systems. Sustained abuse has resulted in significant alarm for river health, defined as the ability of a river and its associated ecosystem to perform its natural functions. In a sense, river health is a measure of catchment health, which in turn provides an indication of environmental and societal health. It is increasingly recognized that ecosystem health is integral to human health and unless healthy rivers are maintained through ecologically sustainable practices, societal, cultural, and economic values are threatened and potentially compromised. Viewed in this way, our efforts to sustain healthy, living rivers provide a measure of societal health and our governance of the planet on which we live. It is scarcely surprising that concerns for river condition have been at the forefront of conservation and environmental movements across much of the planet.

In the past, the quest for security and stability to meet human needs largely overlooked the needs of aquatic ecosystems. In many instances, human activities brought about a suite of unintended and largely unconsidered impacts on river health, compromising the natural variability of rivers, their structural integrity and complexity, and the maintenance of functioning aquatic ecosystems. Issues such as habitat loss, degradation, and fragmentation have resulted in significant concerns for ecological integrity, sustainability, and ecosystem health. As awareness and understanding of these issues has improved, society no longer has an excuse not to address concerns brought about by the impacts of human activities on river systems. Shifts in environmental attitudes and practice have transformed outlooks and actions towards revival of aquatic ecosystems. Increasingly, management activities work in harmony with natural processes in an emerging "age of repair," in which contemporary management strategies aim to enhance fluvial environments either by returning rivers, to some degree, to their former character, or by establishing a new, yet functional environment. Notable improvements to river health have been achieved across much of the industrialized world in recent decades. However, significant community and political concern remains over issues such as flow regulation, algal blooms, salinity, loss of habitat and species diversity, erosion and sedimentation problems, and water resource overallocation.

Rivers demonstrate a remarkable diversity of landform patterns, as shown in Figure 1.1. Each of the rivers shown has a distinct set of landforms and its own behavioral regime. Some rivers have significant capacity to adjust their form (e.g., the meandering, anastomosing, and braided river types), while others have a relatively simple geomorphic structure and limited capacity to adjust (e.g., the chain-of-ponds and gorge river types). This variability in geomorphic structure and capacity to adjust, which reflects the array of landscape settings in which these rivers are found, presents signifi-

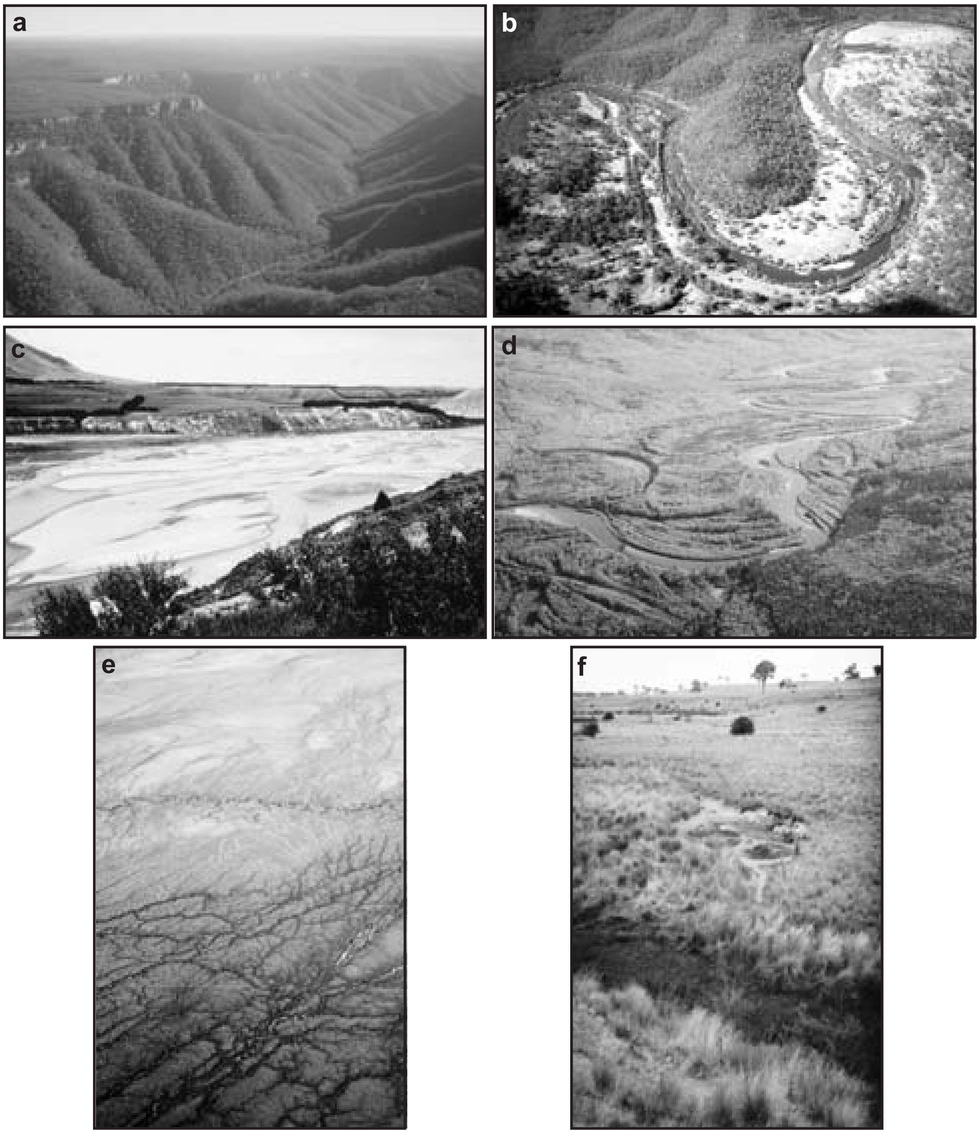

Figure 1.1 The diversity of river morphology
Rivers are characterized by a continuum of morphological diversity, ranging from bedrock controlled variants such as (a) gorges (with imposed sets of landforms), to fully alluvial, self-adjusting rivers such as (c) braided and (d) meandering variants (with various midchannel, bank-attached and floodplain features). Other variants include multichanneled anastomosing rivers that form in wide, low relief plains (e), and rivers with discontinuous floodplain pockets in partly-confined valleys (b). In some settings, channels are discontinuous or absent, as exemplified by chain-of-ponds (f). Each river type has a different capacity to adjust its position on the valley floor. (a) Upper Shoalhaven catchment, New South Wales, Australia, (b) Clarence River, New South Wales, Australia, (c) Rakaia River, New Zealand, (d) British Columbia, Canada, (e) Cooper Creek, central Australia, and (f) Murrumbateman Creek, New South Wales, Australia.

cant diversity in the physical template atop which ecological associations have evolved.

Developing a meaningful framework to recognize, understand, document, and maintain this geodiversity is a core theme of this book. Working within a conservation ethos, emphasis is placed on the need to maintain the inherent diversity of riverscapes and their associated ecological values. Adhering to the precautionary principle, the highest priority in management efforts is placed on looking after good condition remnants of river courses, and seeking to sustain rare or unique reaches of river regardless of their condition.

Just as there is remarkable diversity of river forms and processes in the natural world, so human-induced disturbance to rivers is equally variable (see Figure 1.2). Many of these actions have been intentional, such as dam construction, channelization, urbanization, and gravel or sand extraction. Far more pervasive, however, have

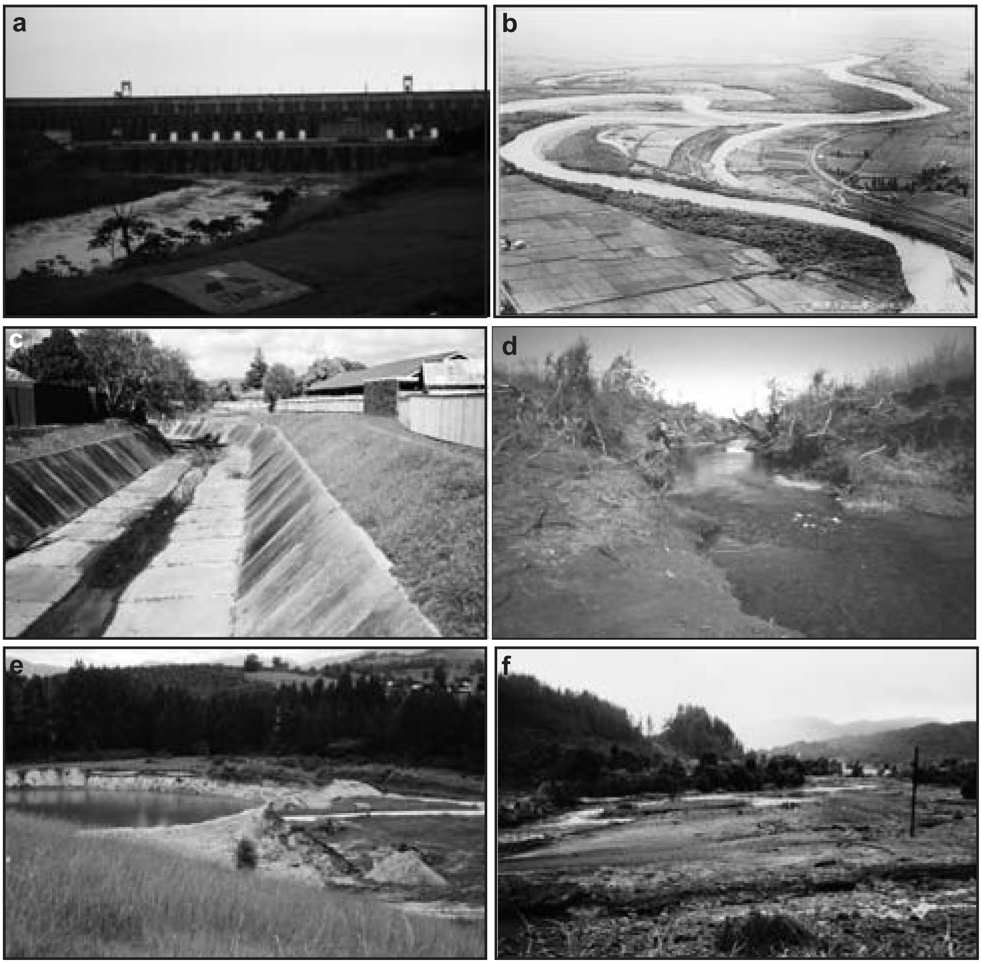

Figure 1.2 Human modifications to river courses
Human modifications to rivers include (a) dams (Itaipu Dam, Brazil), (b) channelization (Ishikari River, Japan), (c) urban stream (Cessnock, New South Wales, Australia), (d) native and exotic vegetation removal (Busby's Creek, Tasmania, Australia), (e) gravel and sand extraction (Nambucca River, New South Wales, Australia), and (f) mine effluent (King River, Tasmania, Australia).

been inadvertent changes brought about through adjustments to flow and sediment transfer regimes associated with land-use changes, clearance of riparian vegetation, etc. Across much of the planet, remarkably few river systems even approximate their pristine condition. Most rivers now operate as part of highly modified landscapes in which human activities are dominant.

The innate diversity of river courses is a source of inspiration, but it presents many perplexing challenges in the design and implementation of sustainable management practices. Unless management programs respect the inherent diversity of the natural world, are based on an understanding of controls on the nature and rate of landscape change, and consider how alterations to one part of an ecosystem affect other parts of that system, efforts to improve environmental condition are likely to be compromised. River management programs that work with natural processes will likely yield the most effective outcomes, in environmental, societal, and economic terms. Striving to meet these challenges, truly multifunctional, holistic, catchment-scale river management programs have emerged in recent decades (e.g., Gardiner, 1988; Newson, 1992a; Hillman and Brierley, in press). Procedures outlined in this book can be used to determine realistic goals for river restoration and rehabilitation programs, recognizing the constraints imposed by the nature and condition of river systems and the cultural, institutional, and legal frameworks within which these practices must be applied.

1.2 Geomorphic perspectives on ecosystem approaches to river management

Rivers are continuously changing ecosystems that interact with the surrounding atmosphere (climatic and hydrological factors), biosphere (biotic factors), and earth (terrestrial or geological factors). Increasing recognition that ecosystems are open, nondeterministic, heterogeneous, and often in nonequilibrium states, is prompting a shift in management away from maintaining stable systems for particular species to a whole-of-system approach which emphasizes diversity and flux across temporal and spatial scales (Rogers, 2002). Working within an ecosystem approach to natural resources management, river rehabilitation programs apply multidisciplinary thinking to address concerns for biodiversity and ecosystem integrity (Sparks, 1995). Inevitably, the ultimate goals of these applications are guided by attempts to balance social, economic, and environmental needs, and they are constrained by the existing hydrological, water quality, and sediment transport regimes of any given system (Petts, 1996). Ultimately, however, biophysical considerations constrain what can be achieved in river management. If river structure and function are undermined, such that the ecological integrity of a river is compromised, what is left? River rehabilitation programs framed in terms of ecological integrity must build on principles of landscape ecology. The landscape context, manifest through the geomorphic structure and function of river systems, provides a coherent template upon which these aspirations must be grounded. The challenge presented to geomorphologists is to construct a framework with which to meaningfully describe, explain, and predict the character and behavior of aquatic ecosystems.

Biological integrity refers to a system's wholeness, including presence of all appropriate biotic elements and occurrence of all processes and interactions at appropriate scales and rates (Angermeier and Karr, 1994). This records a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes. Ecosystem integrity requires the maintenance of both physico-chemical and biological integrity, maintaining an appropriate level of connectivity between hydrological, geomorphic, and biotic processes. While loss of biological diversity is tragic, loss of biological integrity includes loss of diversity and breakdown in the processes necessary to generate future diversity (Angermeier and Karr, 1994). Endeavors to protect ecological integrity require increased reliance on preventive rather than reactive management, and a focus on landscapes rather than populations.

In riparian landscapes, aquatic, amphibious, and terrestrial species have adapted to a shifting mosaic of habitats, exploiting the heterogeneity that results from natural disturbance regimes (Junk et al., 1989; Petts and Amoros, 1996; Naiman and Decamps, 1997; Ward et al., 2002). This mosaic includes surface waters, alluvial aquifers, riparian vegetation associations, and geomorphic features

(Tockner et al., 2002). Because different organisms have different movement capacities and different habitat ranges, their responses to landscape heterogeneity differ (Wiens, 2002). Fish diversity, for example, may peak in highly connected habitats, whereas amphibian diversity tends to be highest in habitats with low connectivity (Tockner et al., 1998). Other groups attain maximum species richness between these two extremes. The resulting pattern is a series of overlapping species diversity peaks along the connectivity gradient (Ward et al., 2002). Given the mutual interactions among species at differing levels in the food chain, ecosystem functioning reflects the range of habitats in any one setting and their connectivity.

Landscape ecology examines the influence of spatial pattern on ecological processes, considering the ecological consequences of where things are located in space, where they are relative to other things, and how these relationships and their consequences are contingent on the characteristics of the surrounding landscape mosaic. The pattern of a landscape is derived from its composition (the kinds of elements it contains), its structure (how they are arranged in space), and its behavior (how it adjusts over time; Wiens, 2002). A landscape approach to analysis of aquatic ecosystems offers an appropriate framework to elucidate the links between pattern and process across scales, to integrate spatial and temporal phenomena, to quantify fluxes of matter and energy across environmental gradients, to study complex phenomena such as succession, connectivity, biodiversity, and disturbance, and to link research with management (Townsend, 1996; Tockner et al., 2002; Ward et al., 2002; Wiens, 2002).

Principles from fluvial geomorphology provide a physical template with which to ground landscape perspectives that underpin the ecological integrity of river systems. Although landscape forms and processes, in themselves, cannot address all concerns for ecological sustainability and biodiversity management, these concerns cannot be meaningfully managed independent from geomorphological considerations. Working from the premise that concerns for ecological integrity are the cornerstone of river management practice, and that landscape considerations underpin these endeavors, interpretation of the diversity, patterns, and changing nature of river character and behavior across a catchment is integral to proactive river management. This book outlines a generic set of procedures by which this understanding can be achieved.

Rehabilitation activities must be realistically achievable. Most riverscapes have deviated some way from their pristine, predisturbance condition. Hence, practical management must appraise what is the best that can be achieved to improve the health of a system, given the prevailing boundary conditions under which it operates. In instances where human changes to river ecosystems are irreversible or only partially reversible, a pragmatic definition of ecological integrity refers to the maintenance of a best achievable condition that contains the community structure and function that is characteristic of a particular locale, or a condition that is deemed satisfactory to society (Cairns, 1995). Specification of the goals of river management, in general, and river restoration, in particular, has provoked considerable discussion, as highlighted in the following section.

1.3 What is river restoration?

The nature and extent of river responses to human disturbance, and the future trajectory of change, constrain what can realistically be achieved in river management (Figure 1.3; Boon, 1992). At one extreme, *conservation* goals reflect the desire to preserve remnants of natural or near-intact systems. Far more common, however, are endeavors to rectify and repair some (or all) of the damage to river ecosystems brought about by human activities. Various terms used to describe these goals and activities can be summarized using the umbrella term "restoration."

Restoration means different things to different people, the specific details of which may promote considerable debate and frustration (Hobbs and Norton, 1996). Although the term has been applied to a wide range of management processes/activities, its precise meaning entails the uptake of measures to return the structure and function of a system to a previous state (an unimpaired, pristine, or healthy condition), such that previous attributes and/or values are regained (Bradshaw, 1996; Higgs, 2003). In general, reference is made to predisturbance functions and related physical,

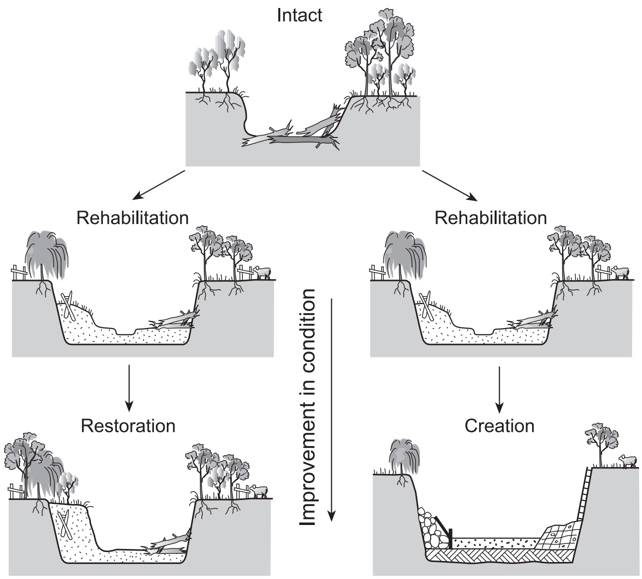

Figure 1.3 Framing realistic management options – what can be realistically achieved? Determination of river rehabilitation goals is constrained primarily by what it is realistically possible to achieve. This reflects system responses to human disturbance, the prevailing set of boundary conditions, and the likely future trajectory of change (as determined by limiting factors and pressures operating within the catchment and societal goals). Maintenance of an intact condition is a conservation goal. If a return to a predisturbance state is possible and desirable, rehabilitation activities can apply recovery principles to work towards a restoration goal. In many instances, adoption of a creation goal, which refers to a new condition that previously did not exist at the site, is the only realistic option.

chemical, and biological characteristics (e.g., Cairns, 1991; Jackson et al., 1995; Middleton, 1999).

The few studies that have documented geomorphic attributes of relatively intact or notionally pristine rivers (e.g., Collins and Montgomery, 2001; Brooks and Brierley, 2002), and countless studies that have provided detailed reconstructions of river evolution over timescales of decades, centuries, or longer, indicate just how profound human-induced changes to river forms and processes have been across most of the planet. It is important to remember the nonrepresentative nature of the quirks of history that have avoided the profound imprint of human disturbance. Intact reaches typically lie in relatively inaccessible areas. They are seldom representative of the areas in which management efforts aim to improve river health. However, it is in these reaches, and adjacent good condition reaches, that efforts at restoration can meaningfully endeavor to attain something akin to the pure definition of the word.

Viewed in a more general sense, restoration refers to a management process that provides a means to communicate notions of ecosystem recovery (Higgs, 2003). For example, the Society for Ecological Restoration (SERI, 2002) state that restoration refers to the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. The notion of recovery describes the process of bringing something back.

Endeavors that assist a system to adjust towards a less stressed state, such that there is an improvement in condition, are more accurately referred to as river *rehabilitation*. Rehabilitation can mean the process of returning to a previous condition or status along a restoration pathway, or *creation* of a new ecosystem that previously did not exist (Fryirs and Brierley, 2000; Figure 1.3). In landscapes subjected to profound human disturbance, such as urban, industrial, or intensively irrigated areas, management activities inevitably work towards creation goals. Both restoration and creation goals require rehabilitation strategies that strive to improve river condition, applying recovery notions to work towards the best attainable ecosystem values given the prevailing boundary conditions. The essential difference between restoration and creation goals lies in the perspective of regenerating the "old" or creating a "new" system (Higgs, 2003).

Various other terms have been used to characterize practices where the goals are not necessarily framed in ecosystem terms. For example, *reclamation* refers to returning a river to a useful or proper state, such that it is rescued from an undesirable condition (Higgs, 2003). In its original sense, reclamation referred to making land fit for cultivation, turning marginal land into productive acreage. Alternatively, *remediation* refers to the process of repairing ecological damage in a manner that does not focus on ecological integrity and is typically applied without reference to historical conditions (Higgs, 2003). Reclamation and remediation are quick-fix solutions to environmental problems that address concerns for human values, viewed separately from their ecosystem context.

The purpose and motivation behind any rehabilitation activity are integral to the goal sought. Specification of conservation, restoration, or creation goals provides an indication of the level and type of intervention that is required to improve riverine environments.

1.4 Determination of realistic goals in river rehabilitation practice

The process of river rehabilitation begins with a judgment that an ecosystem damaged by human activities will not regain its former characteristic properties in the near term, and that continued degradation may occur (Jackson et al., 1995). Approaches to repair river systems may focus on rehabilitating "products" (species or ecosystems) directly, or on "processes" which generate the desired products (Neimi et al., 1990; Richards et al., 2002). However, unless activities emphasize concerns for the rehabilitation of fundamental processes by which ecosystems work, notions of ecosystem integrity and related measures of biodiversity may be compromised (Cairns, 1988).

The goal of increasing heterogeneity across the spectrum of river diversity represents a flawed perception of ecological diversity and integrity. In some cases, the "natural" range of habitat structure may be very simple. Hence, heterogeneity or geomorphic complexity does not provide an appropriate measure of river health (see Fairweather, 1999). Simplistic goals framed in expressions such as "more is better" should be avoided (Richards et al., 2002). Use of integrity as a primary management goal avoids the pitfalls associated with assumptions that greater diversity or productivity is preferred.

Unlike many biotic characteristics, physical habitat is directly amenable to management through implementation of rehabilitation programs (Jacobson et al., 2001). Hence, many management initiatives focus on physical habitat creation and maintenance, recognizing that geomorphic river structure and function and vegetation associations must be appropriately reconstructed before sympathetic rehabilitation of riverine ecology will occur (Newbury and Gaboury, 1993; Barinaga, 1996). Getting the geomorphological structure of rivers right maximizes the ecological potential of a reach, in the hope that improvements in biological integrity will follow (i.e., the "field of dreams" hypothesis; Palmer et al., 1997). The simplest procedure with which to determine a suitable geomorphic structure and function is to replicate the natural character of "healthy" rivers of the same "type," analyzed in equivalent landscape settings.

In any management endeavor, it is imperative to identify, justify, and communicate underlying goals, ensuring that the tasks and plan of action are visionary yet attainable. Although setting goals for rehabilitation is one of the most important steps in designing and implementing a project, it is often either overlooked entirely or not done very well (Hobbs, 2003). Success can only be measured if a definitive sense is provided of what it will look like. Unfortunately, however, there is a tendency to jump straight to the "doing" part of a project without clearly articulating the reasons why things are being done and what the outcome should be (Hobbs, 1994, 2003).

While sophisticated methodologies and techniques have arisen in the rapidly growing field of rehabilitation management, the conceptual foundations of much of this work remain vague (Ebersole et al., 1997). The pressure of timeframes, tangible results, and political objectives has lead to a preponderance of short-term, transitory rehabilitation projects that ignore the underlying capacities and developmental histories of the systems under consideration, and seldom place the study/treatment reach in its catchment context (Ebersole et al., 1997; Lake, 2001a, b). Unfortunately, many of these small-scale aquatic habitat enhancement projects have failed, or have proven to be ineffective (e.g., Frissell and Nawa, 1992).

Ensuring that goals are both explicit enough to be meaningful and realistic enough to be achievable is a key to the development of successful projects. Ideally, goals are decided inclusively, so that everyone with an interest in the outcomes of the project agrees with them (Hobbs, 2003). Scoping the future and generating a realistic vision of the desired river system are critical components of the planning process. The vision should be set over a 50 year timeframe (i.e., 1–2 generations; Jackson et al., 1995), such that ownership of outcomes can be achieved. A vision must be based on the best available information on the character, behavior, and evolution of the system, providing a basis to interpret the condition and trajectory of change from which desired future conditions can be established (Brierley and Fryirs, 2001). These concepts must be tied to analysis of biophysical linkages across a range of scales, enabling off-site impacts and lagged responses to disturbance events and/or rehabilitation treatments to be appraised (Boon, 1998).

To maximize effectiveness, rehabilitation efforts should incorporate spatiotemporal scales that are large enough to maintain the full range of habitats and biophysical linkages necessary for the biota to persist under the expected disturbance regime or prevailing boundary conditions. Although emphasis may be placed on a particular component or attribute, ultimate aims of long-term projects should focus on the whole system at the catchment scale (Bradshaw, 1996). Desired conditions for each reach should be specified as conservation, restoration, or creation goals, indicating how they fit within the overall catchment vision. Appropriate reference conditions should be specified for each reach.

Defining what is "natural" for a given type of river that operates under a certain set of prevailing boundary conditions provides an important step in identification of appropriate reference conditions against which to measure the geoecological integrity of a system and to identify target conditions for river rehabilitation. A "natural" river is defined here as "a dynamically adjusting system that behaves within a given range of variability that is appropriate for the river type and the boundary conditions under which it operates." Within this definition, two points of clarification are worth noting. First, a "natural" condition displays the full range of expected or appropriate structures and processes for that type of river under prevailing catchment boundary conditions. This does not necessarily equate to a predisturbance state, as human impacts may have altered the nature, rate, and extent of river adjustments (Cairns, 1989). Second, a dynamically adjusted reach does not necessarily equate to an equilibrium state. Rather, the river adjusts to disturbance via flow, sediment, and vegetation interactions that fall within the natural range of variability that is deemed appropriate for the type of river under investigation.

Determination of appropriate reference conditions, whether a fixed historical point in time or a suite of geoecological conditions, represents a critical challenge in rehabilitation practice (Higgs, 2003). Systems in pristine condition serve as a point of reference rather than a prospective goal for river rehabilitation projects, although attributes of this ideal condition may be helpful in rehabilitation design. Identification of reference conditions aids interpretation of the rehabilitation potential of sites, thereby providing a basis to measure the success of rehabilitation activities.

Reference conditions can be determined on the basis of historical data (paleo-references), data derived from actual situations elsewhere, knowledge about system structure and functioning in general (theoretical insights), or a combination of these sources (Petts and Amoros, 1996; Jungwirth et al., 2002; Leuven and Poudevigne, 2002). The morphological configuration and functional attributes of a reference reach must be compatible with prevailing biophysical fluxes, such that they closely equate to a "natural" condition for the river type. Ideally, reference reaches are located in a similar position in the catchment and have near equivalent channel gradient, hydraulic, and hydrologic conditions (Kondolf and Downs, 1996). Unfortunately, it is often difficult to find appropriate reference conditions for many types of river, as "natural" or minimally impacted reaches no longer exist (Henry and Amoros, 1995; Ward et al., 2001). In the absence of good condition remnants, reference conditions can be constructed from historical inferences drawn from evolutionary sequences that indicate how a river has adjusted over an interval of time during which boundary conditions have remained relatively uniform. Selection of the most appropriate reference condition is situated within this sequence. Alternatively, a suite of desirability criteria derived for each type of river can be used to define a natural reference condition against which to compare other reaches (Fryirs, 2003). These criteria must encapsulate the forms and processes that are "expected" or "appropriate" for the river type. They draw on system-specific and process-based knowledge, along with findings from analysis of river history and assessment of available analogs. This approach provides a guiding image, or *Leitbild*, of the channel form that would naturally occur at the site, adjusted to account for irreversible changes to controlling factors (such as runoff regime) and for considerations based on cultural ecology (such as preservation of existing land uses or creation of habitat for endangered species; Kern, 1992; Jungwirth et al., 2002; Kondolf et al., 2003). *Leitbilds* can be used to provide a reference network of sites of high ecological status for each river type, as required by the European Union Water Framework Directive.

1.5 Managing river recovery processes in river rehabilitation practice

Exactly what is required in any rehabilitation initiative will depend on what is wrong. Options may range from limited intervention and a leave-alone policy, to mitigation or significant intervention, depending on how far desired outcomes are from the present condition. In some instances, sensitive, critical, or refuge habitats, and the stressors or constraints that limit desirable habitat, must be identified, and efforts made to relieve these stressors or constraints (Ebersole et al., 1997). Controlling factors that will not ameliorate naturally must be identified, and addressed first. Elsewhere, rehabilitation may involve the reduction, if not elimination, of biota such as successful invaders, in the hope of favoring native biota (Bradshaw, 1996). For a multitude of reasons, ranging from notions of naturalness that strive to preserve "wilderness," to abject frustration at the inordinate cost and limited likelihood of success in adopted measures (sometimes referred to as basket cases, or "raising the *Titanic*"; Rutherfurd et al., 1999), it is sometimes advisable to pursue a passive approach to rehabilitation. This strategy, often referred to as the "do nothing option," allows the river to self-adjust (cf., Hooke, 1999; Fryirs and Brierley, 2000; Parsons and Gilvear, 2002; Simon and Darby, 2002). Although these measures entail minimal intervention and cost, managers have negligible control over the characteristics and functioning of habitats (Jacobson et al., 2001).

In general terms, however, most contemporary approaches to river rehabilitation endeavor to "heal" river systems by enhancing natural recovery processes (Gore, 1985). Assessment of geomorphic river recovery is a predictive process that is based on the trajectory of change of a system in response to disturbance events. Recovery enhancement involves directing reach development along a desired trajectory to improve its geomorphic condition over a 50–100 year timeframe (Hobbs and Norton, 1996; Fryirs and Brierley 2000; Brierley et al., 2002). To achieve this goal, river rehabilitation activities must build on an understanding of the stage and direction of river degradation and/or recovery, determining whether the geomorphic condition of the river is improving, or continuing to deteriorate.

Assessment of geomorphic river condition measures whether the processes that shape river morphology are appropriate for the given setting, such that deviations from an expected set of attributes can be appraised (Figure 1.4; Kondolf and Larson, 1995; Maddock, 1999). Key consideration must be given to whether changes to the boundary conditions under which the river operates have brought about irreversible changes to river structure and function (Fryirs, 2003). Identification of good condition reaches provides a basis for their conservation. Elsewhere, critical forms and processes may be missing, accelerated, or anomalous, impacting on measures of geoecological functioning.

Understanding of geomorphic processes and their direction of change underpins rehabilitation strategies that embrace a philosophy of recovery enhancement (Gore, 1985; Heede and Rinne, 1990; Milner, 1994). Helping a river to help itself presents an appealing strategy for river rehabilitation activities because they cost nothing in themselves (although they may cost something to initiate), they are likely to be self-sustaining because they originate from within nature (although they may need nurturing in some situations), and they can be applied on a large scale (Bradshaw, 1996). Design

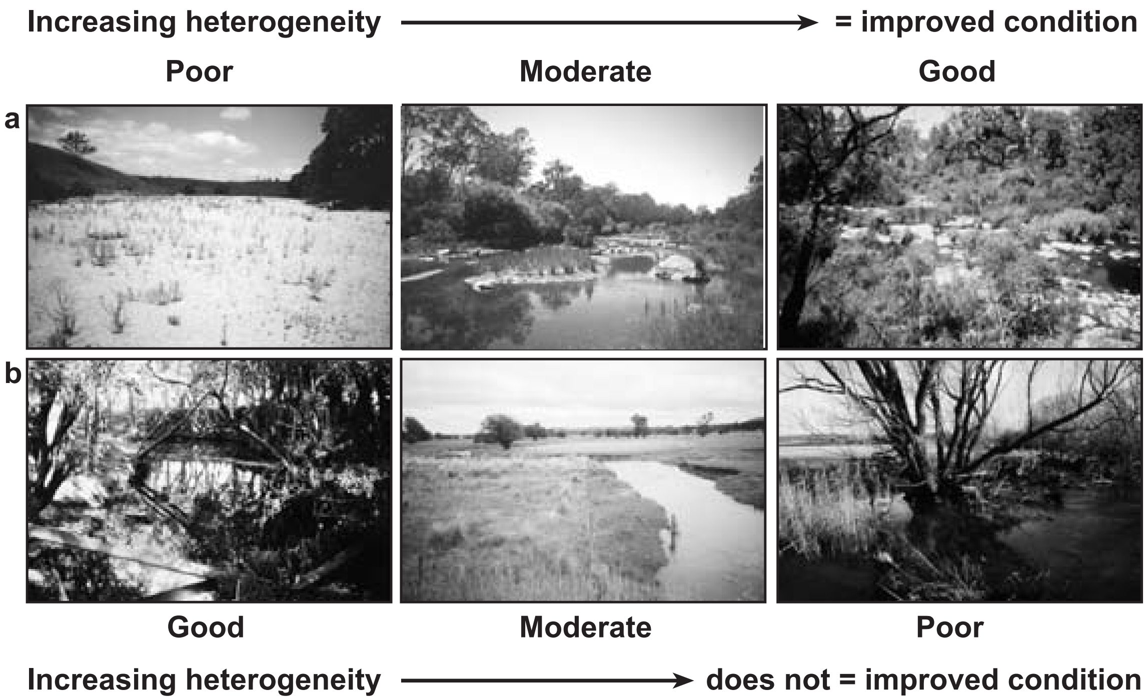

Figure 1.4 Habitat diversity for good, moderate, and poor condition variants of the same river type
Natural or expected character and behavior varies for differing types of river. Some may be relatively complex, others are relatively simple. Natural species adaptations have adapted to these conditions. Assessments of geomorphic river condition must take this into account, determining whether rehabilitation activities should increase (a) or decrease (b) the geomorphic heterogeneity of the type of river under investigation. Increasing geomorphic heterogeneity is not an appropriate goal for all types of river, and may have undesirable ecological outcomes. More appropriate strategies *work with* natural diversity and river change.

and implementation of appropriate monitoring procedures are integral in gauging the success of these strategies.

The process of river rehabilitation is a learning experience that requires ongoing and effective monitoring in order to evaluate and respond to findings. Measuring success must include the possibility of measuring failure, enabling midcourse corrections, or even complete changes in direction (Hobbs, 2003). If effectively documented, each project can be considered as an experiment, so that failure can be just as valuable to science as success, provided lessons are learnt. Goals or performance targets must be related to ecological outcomes and be measurable in terms such as increases in health indicators (e.g., increasing similarity of species or structure with the reference community), or decreases in indicators of degradation (e.g., active erosion, salinity extent or impact, nonnative plant cover). The choice of parameters to be monitored must go hand in hand with the setting of goals, ensuring that they are relevant to the type of river under consideration, so that changes in condition can be meaningfully captured. Baseline data are required to evaluate changes induced by the project, including a detailed historical study (Downs and Kondolf, 2002). Monitoring should be applied over an extensive period, at least a decade, with surveys conducted after each flood above a predetermined threshold (Kondolf and Micheli, 1995). These various components are integral parts of effective river rehabilitation practice.

1.6 Overview of the River Styles framework

Best practice in natural resources management requires appropriate understanding of the resource that is being managed, and effective use of the best available information. In river management terms, catchment-scale information on the character, behavior, distribution, and condition of different river types is required if management strategies are to "work with nature." Given that rivers demonstrate remarkably different character, behavior, and evolutionary traits, both between- and within-catchments, individual catchments need to be managed in a flexible manner, recognizing what forms and processes occur where, why, how often, and how these processes have changed over time. The key challenge is to understand why rivers are the way they are, how they have changed, and how they are likely to look and behave in the future. Such insights are fundamental to our efforts at rehabilitation, guiding what can be achieved and the best way to get there.

This book presents a coherent set of procedural guidelines, termed the River Styles framework, with which to document the geomorphic structure and function of rivers, and appraise patterns of river types and their biophysical linkages in a catchment context. Meaningful and effective *description* of river character and behavior are tied to *explanation* of controls on why rivers are the way they are, how they have evolved, and the causes of change. These insights are used to *predict* likely river futures, framed in terms of the contemporary condition, evolution, and recovery potential of any given reach, and understanding of its trajectory of change (Figure 1.5).

The River Styles framework is a rigorous yet flexible scheme with which to structure observations and interpretations of geomorphic forms and processes. A structured basis of enquiry is applied to develop a catchment-wide package of physical information with which to frame management activities (Figure 1.6). This package guides insights into the type of river character and behavior that is expected for any given field setting and the type of adjustments that may be experienced by that type of river. A catchment-framed nested hierarchical arrangement is used to analyze landscapes in terms of their constituent parts. Reach-scale forms and processes are viewed in context of catchment-

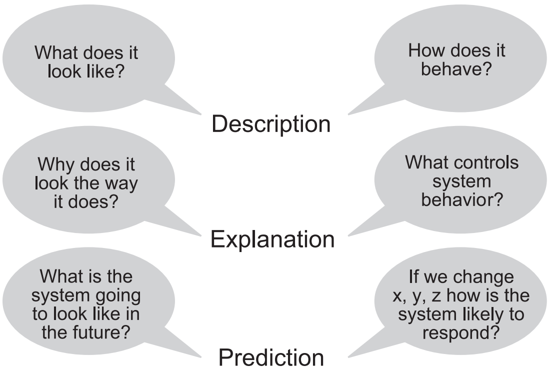

Figure 1.5 Routes to description, explanation, and prediction

scale patterns and rates of biophysical fluxes. Separate layers of information are derived to appraise river character and behavior, geomorphic condition, and recovery. Definition of ongoing adjustments around a characteristic state(s) enables differentiation of the behavioral regime of a given river type from river change. Analysis of system evolution is undertaken to appraise geomorphic river condition in context of "expected attributes" of river character and behavior given the reach setting. Interpretation of catchment-specific linkages of biophysical processes provides a basis with which to assess likely future patterns of adjustment and the geomorphic recovery potential of each reach. The capacity, type, and rate of recovery response of any given type of river are dependent on the nature and extent of disturbance, the inherent sensitivity of the river type, and the operation of biophysical fluxes (both now and into the future) at any given point in the landscape. When these notions are combined with interpretations of limiting factors to recovery and appraisal of ongoing and likely future pressures that will shape river forms and processes, a basis is provided to assess likely future river condition, identify sensitive reaches and associated off-site impacts, and determine the degree/rate of propagating impacts throughout a catchment.

The strategy outlined in this book emphasizes the need to understand individual systems, their idiosyncrasies of forms and processes, and evolutionary traits and biophysical linkages, as a basis to

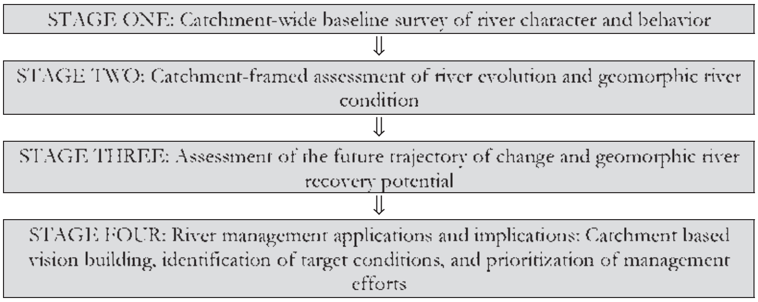

Figure 1.6 **Stages of the River Styles framework**

determine options for management – in planning, policy, and design terms. System configuration and history ensure that each catchment is unique. In making inferences from system-specific information, cross-reference is made to theoretical and empirical relationships to explain system behavior and predict likely future conditions. Principles outlined in this book provide a conceptual tool with which to read and interpret landscapes, rather than a quantitative approach to analysis of river forms and processes. Application of these procedures provides the groundwork for more detailed site- or reach-specific investigations.

However, application of geomorphic principles in the determination of sustainable river management practices is far from a simple task. The need for system-specific knowledge and appropriate skills with which to interpret river evolution and the changing nature of biophysical linkages (and their consequences) ensure that such exercises cannot be meaningfully undertaken using a prescriptive cook-book approach. The cautious, data intensive measures applied in this book are considered to present a far better perspective than managing rivers to some norm! Hopefully, lessons have been learnt from the homogenization of river courses under former management regimes.

Management applications of the River Styles framework focus on the derivation of a catchment-scale vision for conservation and rehabilitation, identification of reach-specific target conditions that fit into the bigger-picture vision, and application of a geomorphologically based prioritization procedure which outlines the sequencing of actions that best underpins the likelihood of management success. The framework does not provide direct guidance into river rehabilitation design and selection of the most appropriate technique. Rather, emphasis is placed on the need to appraise each field situation separately, viewed within its catchment context and evolutionary history. The underlying catchcry in applications of the River Styles framework is "KNOW YOUR CATCHMENT."

1.7 Layout and structure of the book

This book comprises four parts (Figure 1.7). Part A outlines the geoecological basis for river management. Chapter 2 documents the use of geomorphology as a *physical template* for integrating biophysical processes, *working with linkages* of biophysical processes within a catchment framework, and the need to *respect diversity* (work with nature). Chapter 3 outlines how geomorphic principles provide a basis for river management programs to *work with change* through understanding of controls on river character and behavior and prediction of likely future adjustments.

Geomorphic principles that underpin applications of the River Styles framework are documented in Part B. Pertinent literature is reviewed to assess river character (Chapter 4), interpret river behavior (Chapter 5), analyze river evolution and change (Chapter 6), and appraise river responses to human disturbance (Chapter 7).

The River Styles framework is presented in Part C. An overview of the framework in Chapter 8 is followed by a brief summary of practical and logistical issues that should be resolved prior to its application. Chapter 9 presents the step-by-step procedure used to classify and interpret river character and behavior in Stage One of the framework.

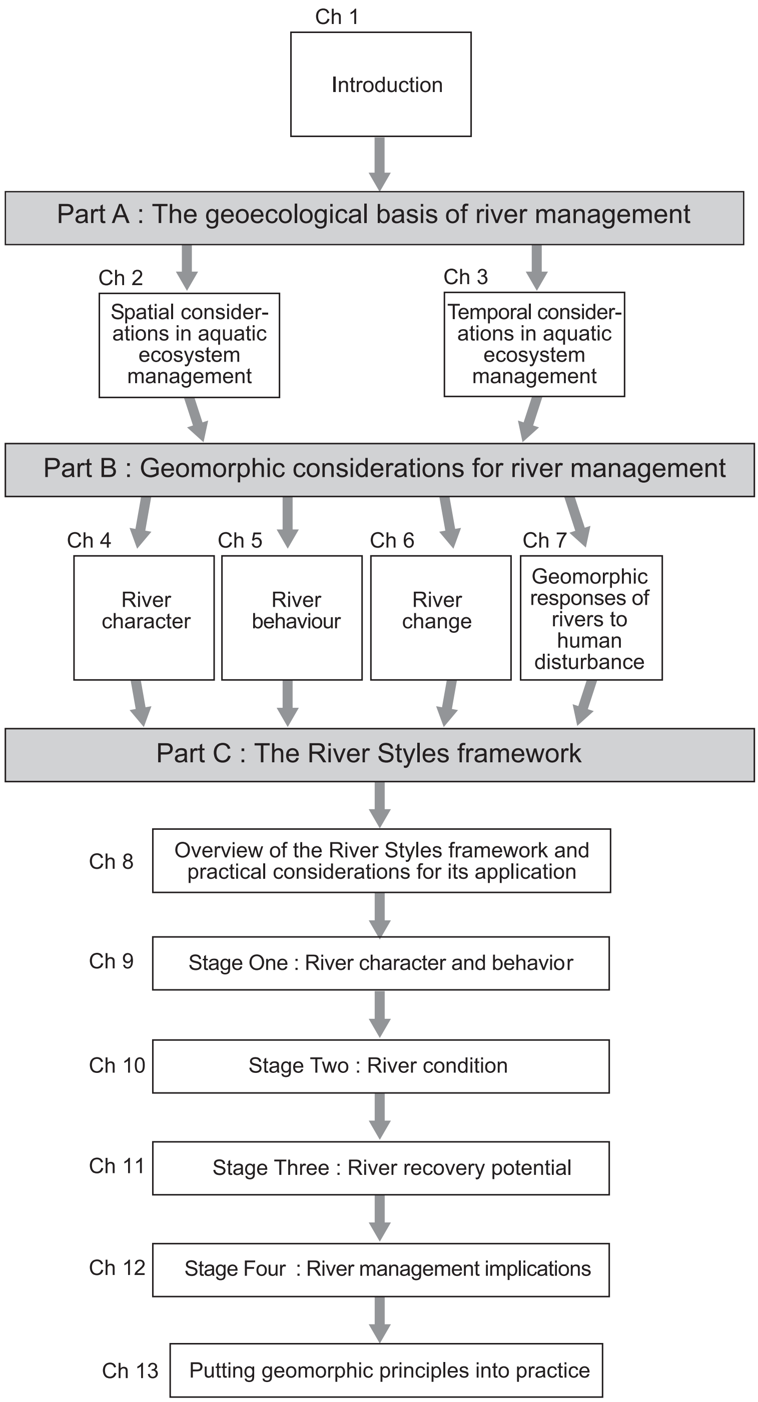

Figure 1.7 **Structure of the book**

Procedures used to assess geomorphic condition of rivers in Stage Two of the framework are presented in Chapter 10. Evolutionary insights are used to interpret the future trajectory and recovery potential of rivers in Stage Three of the framework (Chapter 11). Finally, Chapter 12 outlines Stage Four of the River Styles framework, which can be used to develop catchment-framed visions for management, identify target conditions for river rehabilitation, and prioritize where conservation and rehabilitation should take place.

The concluding chapter, in Part D, outlines an optimistic (aspirational) perspective on future river management practices and outcomes (Chapter 13).