PRACTICAL APPLICATION OF THE RIVER STYLES® FRAMEWORK AS A TOOL FOR CATCHMENT-WIDE RIVER MANAGEMENT: A CASE STUDY FROM BEGA CATCHMENT, NEW SOUTH WALES.

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ISBN 1 74138 153 3

ACKNOWLEDGEMENTS

The development, application and teaching of the River Styles® framework began in 1996. Initial funding was provided by the Land and Water Resources Research and Development Corporation (LWRRDC) (now Land and Water Australia, LWA) in Project MQU1 awarded to Gary Brierley. Three Research Officers were supported in the initial development of the framework, Kirstie Fryirs, Tim Cohen and Sharon Cunial. Research in Bega catchment was supported by grants from the Natural Heritage Trust (NHT), Bega Valley Shire, the Far South Coast Catchment Management Committee and Bega Department of Land and Water Conservation (now DNR). This work built on evolutionary research in the Bega catchment completed as part of Honours degrees by Andrew Brooks (1994) and Kirstie Fryirs (1995).

Extensive application of the River Styles® framework has occurred since 1998. Initial endeavours extended work on the South Coast of NSW in Cobargo and Dry River catchments, with support from the South Coast Office of DNR. The next phase of project development entailed completion of a River Styles® report for largely gravel-based rivers in Manning catchment, demonstrating the generic nature of its application. Around this time, significant support was gained for additional applications in northern NSW, in an NHT project co-ordinated by Michael Pitt and Tony Broderick. Rob Ferguson and Guy Lampert undertook River Styles® assessments in 14 catchments across the North Coast region. This work was complemented by externally funded projects in the Bellinger and Hastings catchments (completed primarily by Tim Cohen and Ivars Reinfelds) and the Richmond catchment (completed primarily by Geoff Goldrick), in a project co-ordinated by Linden Bird. This ensured that coverage of River Styles reports extended across all North Coast catchments in New South Wales. In 1999 an equivalent report was completed for the Shoalhaven catchment, and Ian Drummond and Associates (ID&A) completed a commissioned River Styles® report for the Hawkesbury-Nepean catchment.

In conjunction with the initial LWRRDC Grant, and subsequently, numerous River Styles® Short Courses have been presented by Gary Brierley and Kirstie Fryirs.

The Bega case study presented in this book evolved from a pilot study for Stage One of the River Styles® framework by Kirstie Fryirs and Gary Brierley throughout 1997 and 1998. In her PhD thesis, Kirstie Fryirs extended this analysis to assess geomorphic river condition and recovery potential. This work was supported by an Australian Postgraduate Award Scholarship, an Ernest Jackson Memorial Grant (River Basin Management Society) and AINSE Grant 99/155S that supported AMS ^{14}C dating.

Stage Four of the River Styles® framework, which considers management applications, was developed with support from various personnel in the New South Wales state agency (DNR). The research throughout Bega catchment would not have been possible without the support of many individuals and groups. Hundreds of landowners throughout Bega catchment allowed repeated access to their properties over an extended period of time. Field assistance to Kirstie was provided by Rob Ferguson, Emily Cracknell, Sharon Cunial, Tim Cohen and various family members. Support from the Bega office of DNR is much appreciated. The use of air photographs, office space and local knowledge was invaluable. Special mention must be made of Don McPhee, Cliff Massey, Sandra Riddell, Mary Grealy and Justin Gouvernet. Cliff Massey provided significant guidance and information on river conservation and rehabilitation programs being implemented in Bega catchment, building directly on findings generated through application of the River Styles® framework.

The (then) Chair of the Far South Coast Catchment Management Committee, Kerry Pfeiffer, is thanked for promoting the River Styles® pilot study in the Bega catchment. David Outhet, now Principal Geomorphologist in NSW DNR, has provided ongoing support for development of the River Styles® framework, guiding the practical uptake of the work. Erika Klimpsch compiled historical information in the Mitchell Library and State Archives. Paula Crighton and Kahli Macnab manipulated the 25m digital elevation model (DEM) data to construct longitudinal profiles for all the major river courses in the catchment. Kahli also produced various regional setting GIS layers for the catchment using data provided by Tim Dilworth from NSW DNR. The Department of Mineral Resources provided the geology layer. John Jansen provided assistance in applying the Rational Method for discharge determination. Judy Davis (Macquarie University Cartography) and Dean Oliver drafted some of the figures in this book. Cliff Massey (NSW DNR) and Kahli Macnab kindly reviewed this book.

River Styles® is a registered Trademark held by Macquarie University and Land and Water Australia. The trademark is administered through Access Macquarie (formerly MRL). The support provided by various staff at Access Macquarie, in particular Sophie Beauvais, is greatly appreciated.

CHAPTER ONE: INTRODUCTION AND BACKGROUND TO THE RIVER STYLES® FRAMEWORK

1.1 Background to this book

A remarkable transition in Australian land and water management practice has taken place over the past few decades. Accompanying, and in part underpinning, this transition have been changes to the value systems, perspectives and perceptions of landowners, agribusiness interests, environmental practitioners and others involved in land and water management decision-making processes, and the ways in which institutional structures have promoted and facilitated these changes. Despite various trials and tribulations, the emerging approach to river management is characterised by extensive on-the-ground involvement of community groups in land management and rehabilitation practices. Implemented through Catchment Management Authorities, Landcare Groups, Rivercare Groups, etc.. These initiatives have been complemented by core support through programs such as the Natural Heritage Trust, the National River Health Program, and various State Government Agencies. Adoption of participatory rather than regulatory approaches to river management has presented significant opportunity for research, development and incorporation of new ideas into best management practice. These initiatives also provide education and communication tools which can be used by local groups to assist in assessments of how *their* catchment works, emphasising linkages, complexities and the inherent uncertainties of many environmental outcomes, placing site-specific issues within a total catchment context.

Among the many challenges faced by physical/natural scientists in addressing these issues of significant social concern is the need to develop appropriate information bases with which to support this transitional process. This requires the delivery of structured sets of biophysical information, ensuring that 'best available data' are meaningfully inter-linked and communicated in coherent packages. Adoption of adaptive management principles, maintaining a commitment to a 'process of learning', ensures that sufficient consideration is placed on auditing of outcomes, such that lessons can be learnt from past experiences, furthering the enhancement of environmental management and information-delivery processes.

The River Styles® framework has been developed and applied as a tool for catchment-scale information management and communication in light of these social, institutional and intellectual changes. It is a trite but often understated fact that implementation of best management practice requires effective *use* of the best available information. Indeed, any endeavours at notionally *sustainable* environmental management must, by definition, build upon sound insights into the nature of the resource that is being managed. Viewed in this context, it is remarkable to consider how little we actually know about the changing nature of our rivers – their diversity and rarity/uniqueness, their sensitivity to disturbance, measures of their condition/health, their functionality/dynamics and associated patterns and rates of change, and associated physical, ecological, aesthetic, recreational and spiritual values. Working within an ecosystem approach to natural resources management, we recognise explicitly the interconnected nature of these considerations, and the need to convey best available insight into these 'baseline' principles in a structured and coherent manner.

Obviously, any individuals or group of individuals who set out to address these issues are limited by the constraints of their own background experiences and understanding. In addressing questions such as: What are we managing our rivers for?, and What do we want our rivers to be like?, this book has an unashamedly geoecological focus based on a fluvial geomorphology mindset. This viewpoint seeks to explain the diversity of river forms and processes in light of their landscape context, appraising spatial and temporal patterns and rates of change, and highlighting their biophysical linkages and consequences. This mindset also seeks to address underlying causes of river diversity and change, framing 'naturalness' in relation to landscape responses to human disturbance. Such appraisals provide the basis with which to develop notions of 'environmental condition' or 'health', and associated notions of recovery potential.

In its initial manifestation, the River Styles® framework set out to establish an appropriate set of criteria with which to characterise river reaches (Brierley, 1994), showing how geomorphic principles provide core underpinnings for analysis of river 'health' (Brierley and Fryirs, 2005). This perspective reflected a sense of frustration with measures of river condition that had been developed based on macroinvertebrates, fish, water quality or equivalent indices, *independent from* the geomorphic structure of the river reach in which analyses were being performed. Notions from geomorphology were not seen as replacements for these other indices. Rather, it was felt that effective explanation of patterns and trends, and design/implementation of conservation/rehabilitation programs to address these management concerns, could not be developed without geomorphological understanding of the type of river under investigation, its relation to landscape setting and associated sets of catchment linkages, and interpretations of how the river adjusts (in both a contemporary sense, and in terms of likely trajectories of future changes). Over time, these premises emerged into the four key underpinnings of the River Styles® framework, namely:

- Respect diversity
- Work with change
- Work with catchment-scale linkages

- Application of a geomorphic platform to integrate biophysical processes, presenting a coherent physical template for management activities.

Ultimately, we cannot envisage how sustainable river management practices can proceed independent from appropriate information that summarises the landscape context within which each river works, and related insights into river changes that frame likely river futures. Sustainable management strategies must 'work with nature', building on a catchment-framed understanding of river character, behaviour and condition.

In addressing these various concerns, the River Styles® framework presents a coherent, tightly structured package of geomorphologically-based insights that is applied at the catchment-scale. Over time the framework evolved from a characterisation procedure (similar to the Stream Reconnaissance Handbook, Thorne, 1998) towards an interpretative set of guidelines with which to approach river classification. In moving towards the latter, we never set out to create an Australian-based alternative to the Rosgen (1996) procedure, which has received widespread management application in the United States. Rather, the River Styles® framework provides a set of procedures that guides management practices in a manner that 'works with' the changing nature of river character and behaviour throughout a catchment. This learning tool presents an approach to constructing reality that provides a meaningful basis for river description, an explanatory basis with which to assess how rivers behave, and a predictive framework to interpret how rivers are likely to adjust in the future. The framework provides a physical basis to compare like with like, summarising baseline information on the character, behaviour, distribution and condition of river types across a catchment. It does NOT pigeon-hole reality based on static assessments of river morphology. It endeavours to move beyond prescriptive strategies that manage rivers to some 'type' or 'norm'. The generic, open-ended nature of the River Styles® framework allows new variants of rivers to be added as they are characterised, viewing each river reach in terms of its behaviour and associated landscape/catchment linkages.

In the River Styles® framework, assessments of river character and behaviour are framed in terms of their environmental setting, appraising the nature, range and rate of geomorphic adjustments. Interpretation of catchment-specific biophysical interactions frames analysis of reach-scale adjustments in the future. Applications of the framework generate catchment-specific understanding of river forms and processes, their linkages, and system dynamic. Such insights can be extended to identify regional-scale patterns with which to appraise the uniqueness, rarity and representativeness of river types. It is only with this information in hand that comprehensive planning programs for conservation/rehabilitation can be developed in a way that respects the inherent diversity of river systems, tied to appraisals of their condition (and associated 'remnant' status). If we wish to maintain a truly 'natural' river character, with naturally adapted flora and fauna, target conditions in management programs must replicate the natural variability and changing nature of river structure and flow inherent to the landscape setting.

The River Styles® framework operates as a flexible 'learning package', whereby sets of questions are posed to develop a system-wide set of information. Just as individual catchments may have 'unique' types of rivers, the distribution of river types in any one catchment and their patterns/rates of responses to human disturbance are almost certainly unique. Understanding these catchment-specific responses, and associated perspectives on future trajectories of change, are considered to be prerequisites for effective management programs. Applications of the River Styles framework prompt river practitioners to focus attention on the underlying causes of problems associated with river changes, rather than their symptoms. To achieve this, investigators apply a systematic process of enquiry to evaluate and interpret their own river system. The underlying catchcry in applications of the River Styles framework is "KNOW YOUR CATCHMENT".

The various components of the River Styles framework have been presented at various local, regional, national and international workshops and conferences, and have been published in the internationally refereed literature and as a book (Brierley and Fryirs, 2005). However, to date, these components have yet to be pulled together in a catchment-scale synthesis. This book applies the package of intellectual constructs developed under the auspices of the River Styles® framework in their entirety, documenting the application of all four stages of the framework in the Bega Catchment, on the South Coast of New South Wales.

Completion of all four stages of the River Styles® framework in the Bega Catchment has been facilitated by extensive catchment scale research into river character, behaviour and evolution. There are many examples across Australia in which more detailed analyses have been completed for specific reaches, but all too often these analyses cannot be placed within a meaningful catchment context. Indeed, the limited availability of baseline information on river character and behaviour at the catchment scale presents enormous constraints in the application of supposedly sustainable management practices! Without being unduly cynical, we contend that it is difficult to effectively manage a resource without appropriate information on the resource to be managed!

We must confess, at the outset, that we cannot envisage the depth of analysis presented in this book being applied in many other significantly-sized catchments. In completing this work, one of the authors (KF) walked virtually the entire length of the studied river courses in Bega catchment. However, this application was intimately tied to the development of the framework itself, and subsequent analyses will be much less demanding (in general terms). Indeed, the various procedures documented here can be extended or modified in applications to any catchment. For example, with appropriate modifications, the 'way of thinking' highlighted in this book can be extended to regulated or urbanised catchments, adding additional layers of information that relate to direct human modifications along river courses. Herein lies one of the innate strengths of the River Styles® framework, in that a basic set of principles can be readily extended to new situations, without undermining the integrity of the approach. The approach promotes practitioner-based understanding of individual systems, such that management programs fit that particular system – not some 'text book' example or some preconceived 'norm' that has been derived elsewhere. Just as fine-grained meandering river reaches may demonstrate an array of behavioural attributes depending on their within-catchment position and what's upstream, so the nature of modified urban streams in, say, Sydney, Melbourne, Brisbane, Adelaide and Perth will demonstrate differing sets of biophysical interactions because of the very different topographic, lithological, and climatic settings in which they are set (as well as primary differences in urban planning and design). The same principle could equally be applied to record the diversity of rivers in regulated systems.

In this book, geomorphic information is used to provide a baseline template for river management in Stage 4 of the River Styles® framework. These insights have been supplemented in Bega Catchment through additional layers of information on habitat availability, water allocation procedures, and sediment and vegetation management plans. These collective insights have been used to frame river conservation and rehabilitation strategies within a catchment plan (see Chapter 7).

1.2 What is the River Styles framework?

River Styles record the character and behaviour of a river, providing a geomorphic appraisal of what a river system looks like, how it behaves, and how it has adjusted over time (Brierley and Fryirs, 2005). As the capacity for river adjustment varies for each River Style, management issues and associated rehabilitation programs differ for different River Styles. Catchment scale appraisal of geomorphic river condition and recovery potential, framed in terms of the evolutionary pathways of differing River Styles®., provide a coherent platform for decision-making for a suite of river management activities. As individual catchments comprise unique patterns of River Styles®, in which reaches have differing condition and recovery potential, planning for river conservation and rehabilitation is a catchment-specific exercise, though the guiding principles outlined in this book are generic.

Building on the practical set of objective criteria used in river reach analysis by Kellerhals et al. (1976), and the nested hierarchical framework proposed by Frissell et al. (1986), the River Styles® framework provides a physical basis by which to describe <u>and</u> explain the within-catchment distribution of river structure and function, and predict likely future river behaviour. The nested hierarchical basis of the framework differentiates among five scales: catchments, landscape units, River Styles (reach-scale), geomorphic units and hydraulic units. Catchment-scale conditions dictate the type and configuration of landscape units (i.e. topography), which in turn control the range of River Styles formed along river courses. River Styles are characterised for differing valley-settings. Distinction is made among confined (no floodplain), partly-confined (discontinuous floodplain) and laterally-unconfined (continuous floodplain) valley-settings. Nested within these valley-settings, River Styles are defined at the reach scale (*sensu* Kellerhals et al., 1976), whereby boundary conditions are sufficiently uniform along a stretch of river (i.e. there is no significant change in the imposed discharge or sediment load) such that the river maintains a near-consistent geomorphic structure. River Styles comprise assemblages of geomorphic units (i.e. channel and floodplain landforms such as pools, riffle, levees, backswamps, etc.). Analysis of these landforms is used to interpret the behaviour of each River Style. Hydraulic units, which are areas of homogenous substrate and flow type, are nested within instream geomorphic units.

In applications of the River Styles® framework, spatial and temporal linkages of biophysical processes are appraised in terms of linkages between differing reaches and between tributary streams and the trunk stream. Downstream patterns of River Styles are explained. Morphodynamic perspectives on the geomorphic make-up of catchments are tied to appraisal of system evolution to provide a predictive context with which to interpret how changes in one part of the catchment have impacted elsewhere, over what time frame, and what the likely future river condition will be. This provides an appropriate context with which to frame management responses to future catchment disturbance. Key attributes of the River Styles framework are summarised in **Table 1.1.**

Table 1.1 Key attributes of the River Styles Framework (from Brierley and Fryirs, 2005)

The River Styles framework:

- Works with the ***natural diversity*** of river forms and processes. Due recognition is given to the continuum of river morphology, extending from bedrock-imposed conditions to fully alluvial variants (some of which may comprise unincised valley floors). The River Styles framework can be applied in any environmental setting.

- Is framed in terms of ***generic, open-ended*** procedures that are applied in a catchment-specific manner. Reaches are not 'pigeon-holed' into rigid categories; rather, new variants are added to the existing range of River Styles based on a set of discrete attributes (i.e. the valley setting, geomorphic unit assemblage, channel planform, and bed material texture).

- Evaluates ***river behaviour***, indicating how a river adjusts within its valley setting. This is achieved through appraisal of the form-process associations of geomorphic units that make up each River Style. Assessment of these building blocks of rivers, in both channel and floodplain zones, guides interpretation of the range of behaviour within any reach. As geomorphic units include both erosional and depositional forms, and characterise ALL riverscapes, they provide an inclusive and integrative tool for classification exercises.

- Provides a ***catchment-framed*** baseline survey of river character and behaviour. Application of a nested hierarchical arrangement enables the integrity of site-specific information to be retained in analyses applied at catchment or regional levels. Downstream patterns and connections among reaches are examined, demonstrating how disturbance impacts in one part of a catchment are manifest elsewhere over differing timeframes. Controls on river character and behaviour, and downstream patterns of River Styles, are explained in terms of their physical setting and prevailing biophysical fluxes.

- Evaluates recent river changes in context of longer-term landscape ***evolution***, framing river responses to human disturbance in context of the 'capacity for adjustment' of each River Style. Identification of reference conditions provides the basis to determine how far from its 'natural' condition the contemporary river sits and interpret why the river has changed. Analysis of reaches at differening stages of geomorphic adjustment at differing localities (ie space-time transformation or ergodic reasoning) is applied to interpret evolutionary pathways for reaches of the same type.

- Provides a meaningful basis to compare type-with-type. From this, the contemporary ***geomorphic condition*** of the river is assessed. Analysis of downstream patterns of River Styles and their changes throughout a catchment, provides key insights with which to determine geomorphic ***river recovery potential***. This assessment, in turn, provides a physical basis to predict likely future river structure and function.

The River Styles framework comprises four stages (see **Figure 1.1**).

Figure 1.1 Stages and steps in the River Styles Framework (Brierley and Fryirs, 2005)

STAGE ONE: Catchment-wide baseline survey of river character and behaviour

Stage One, Step One: Assess regional and catchment setting controls
Stage One, Step Two: Define and map River Styles across the catchment
Stage One, Step Three: Interpret controls on the character, behaviour and downstream patterns of River Styles

STAGE TWO: Catchment-framed assessment of river evolution and geomorphic river condition

Stage Two, Step One: Determine the capacity for adjustment of the River Style
Stage Two, Step Two: Assess river evolution as a basis to identify irreversible geomorphic change and a reference condition
Stage Two, Step Three: Determine and explain the geomorphic condition of the reach

STAGE THREE: Assessment of the future trajectory of change and geomorphic river recovery potential

Stage Three, Step One: Determine the trajectory of river change
Stage Three, Step Two: Assess river recovery potential: Place reaches in their catchment context and assess limiting factors to recovery

STAGE FOUR: River management applications and implications: Catchment based vision building, identification of target conditions and prioritisation of management efforts

Stage Four, Step One: Develop a catchment-framed physical vision
Stage Four, Step Two: Identify target conditions for river rehabilitation and determine the level of intervention required
Stage Four, Step Three: Prioritise efforts based on geomorphic river condition and recovery potential
Stage Four, Step Four: Monitor and audit improvement in geomorphic river condition

Stage 1 of the River Styles framework entails identification, interpretation and mapping of River Styles throughout a catchment. This provides a baseline survey of river character and behaviour. Each River Style is characterised by a distinctive set of attributes, analysed in terms of river planform, the geomorphic units that make a river reach, and bed material texture. Interpretation of geomorphic units provides insight into the range of formative processes that reflect the range of behaviour of a River Style (see Brierley and Fryirs, 2000, 2005). Each River Style is then placed in context of the downstream pattern of River Styles found in different subcatchments.

Assessments of geomorphic character and behaviour must appreciate system dynamic, the ongoing patterns and rates of adjustment, and their linkages within a catchment. These are critical underpinnings of the River Styles framework, wherein contemporary river forms and processes (**Stage 1**) are assessed in context of system evolution (**Stage 2**). From the latter component, assessment is made of how these changes have impacted on the contemporary geomorphic condition of rivers (see Fryirs, 2003; Brierley and Fryirs, 2005).

When assessed within their catchment context, analyses of river evolution and geomorphic condition provide a basis to predict the pathway of likely future river adjustment (see Fryirs and Brierley, 2000, 2001; Brierley and Fryirs, 2005). In **Stage 3** of the River Styles framework these insights are used to analyse the recovery potential of each reach of each River Style. Assessment of the likelihood of future improvement or deterioration of river condition provides a critical perspective for planning activities, based on interpretations of what is realistically achievable for any given reach.

Management applications of the River Styles framework include establishment of a catchment-wide vision and development of 'target conditions' for each reach that fit within this vision (**Stage 4**). Less impacted sections of a River Style are used to guide the target conditions for river structure in more degraded reaches of river which operate under a similar set of controls, replicating the 'natural' character of rivers for equivalent landscape settings. This maximises the potential for rivers to self-adjust in a 'natural' manner, reducing the need for ongoing reactive management. Using this baseline information, a physically-based prioritisation framework is applied to determine catchment-framed river conservation and rehabilitation strategies (see Brierley and Fryirs, 2001, 2005; Brierley et al., 2002). This provides a rational basis with which to structure and implement conservation and rehabilitation programs. Management applications of the framework are summarised in **Table 1.2**.

Table 1.2 Key management applications of the River Styles Framework (from Brierley and Fryirs, 2005)

The River Styles framework:
• Provides a basis to ***order a nested hierarchy of physical information*** in a consistent, coherent, and integrative manner. From this, information gaps, and the need for more detailed assessments of biophysical information, can be determined.
• Shows how the physical structure of rivers throughout a catchment provides a ***template*** to evaluate interactions of biophysical processes. A consistent basis is provided to appraise issues of uniqueness, rarity, naturalness, geodiversity, and representativeness.
• Helps to develop ***proactive***, rather than reactive, management strategies that 'work with nature', ensuring that site-specific strategies are linked within a reach and catchment-based ***'vision'***.
• Determines realistic '***target conditions'*** for river rehabilitation, focusing management attention on underlying causes of 'problems', rather than the symptoms of change. This enables the most appropriate river rehabilitation treatment to be selected (or designed).
• Can be used to more effectively ***prioritise*** resource allocation to management issues, balancing efforts at river conservation and rehabilitation. This requires differentiation of reaches of high conservation value (in terms of the geodiversity and/or rarity of River Styles) and degraded or stressed rivers. Priorities can be determined within- and between-catchments, presenting an open and transparent physical basis for decision-making.
• Can be used to select representative or reference sites across the range of River Styles in programs to ***monitor*** river condition and audit the effectiveness of river management strategies. These benchmarking and monitoring procedures can be applied at scales ranging from within-catchment programs through to regional, State or even National river management programs. For example, classification of wild and scenic rivers can be undertaken to determine the 'best remaining reaches' of different types of rivers, providing an appraisal of which components of diversity and functioning have been compromised and whether these trends can be reversed.

1.3 How we hope this book will be used

The River Styles® framework presents a structured 'way of thinking' about rivers, providing a logical and coherent way to break down reality. It presents a catchment-scale application of principles outlined in the companion book "*Geomorphology and River Management: Applications of the River Styles Framework*" published by Blackwell (Brierley and Fryirs, 2005). This book demonstrates how principles of fluvial geomorphology and the River Styles® framework provide a geomorphic template for river management.

The thinking expressed here can be expanded to relate to additional biophysical considerations. For example, an ecosystem approach to river management that relates geomorphic insights to concerns for water quality or ecological values.

Uptake of rehabilitation programs that strive to heal river systems, 'working with' natural recovery processes, has been facilitated by extensive involvement and leadership from the small group of professional geomorphologists in Australia. A significant collection of tools and techniques for river rehabilitation has been provided through initiatives such as the National Stream Rehabilitation Guide (Rutherfurd et al., 2000), the National Stream Restoration Framework (Koehn et al., 2001), and various National Stream Management Conferences (Rutherfurd and Walker, 1996; Rutherfurd and Bartley, 1999; Rutherfurd et al., 2001; Rutherfurd et al., 2005). The River Styles® framework directly complements the conceptual component of the first volume of the National Stream Rehabilitation Guide (Rutherfurd et al., 2000), and practical rehabilitation design options outlined in the second volume of Rutherfurd et al. (2000). In general terms there is remarkable uniformity of perspective in these various documents and approaches.

1.4 Communicating the River Styles framework: a comment on terminology

The intended target audience for this book extends across the range of river practitioners. Given the diverse array of potential end-users, all endeavours have been made to present this case-study in a user-friendly and easily communicable manner. Various key terms used in this book are defined in **Table 1.3**. We apologise in advance to others who note inconsistency in cross-disciplinary use of terms, or duplication of other terms in the literature.

Table 1.3 Definition of terms used in the River Styles framework (Brierley and Fryirs, 2005)

Term	Definition in the River Styles framework
River Style – River Styles are classified at the scale of river reaches in a catchment-specific and scalar independent manner. A River Style is defined as a section of river whereby boundary conditions are sufficiently uniform along a reach of river (i.e. there is no change in the imposed flow or sediment load) such that the river maintains a near consistent structure. Individual River Styles have diagnostic features or unique combinations of features (assessed in terms of channel planform, the assemblage of geomorphic units, and bed material texture).	
Landscape unit	Different compartments of similar topography are referred to as 'landscape units'. These topographic features comprise a characteristic pattern of landforms. Landscape units are differentiated on the basis of relief, elevation, topography, geology and position (e.g. upland versus lowland settings). Examples include tablelands, uplands, escarpment, base of escarpment, rounded foothills and lowland plains. Landscape units generally form a characteristic downstream sequence. The extent and character of relief variability, manifest primarily through the imposed slope and confinement of the valley floor trough, are key determinants of the *valley-setting* in which a river is formed.
Geomorphic unit	Geomorphic units are the building blocks of river systems. These landforms represent specific associations between landscape morphology and the set of processes that produce that form. Geomorphic units are differentiated into instream (erosional and depositional) and floodplain types. Analysis of the morphology, bounding surface and sedimentology of geomorphic units, along with interpretation of their distribution and genetic associations with adjacent features, provides a basis to interpret river behaviour.
Hydraulic unit	Patches of relatively homogeneous flow and substrate character, nested within geomorphic units. Hydraulic units are identified on the basis of surface flow type and dominant substrate composition (Thomson et al., 2001) and are considered to be critical habitat units.
Valley-setting	Relief variability, manifest primarily through the slope and confinement of the valley floor, is a key determinant of a valley-setting. The ***confined valley-setting*** has no floodplain or isolated pockets of floodplain. Over 90% of the channel margin abuts the valley margin. The ***partly-confined valley-setting*** contains discrete but discontinuous floodplain pockets that can alternate in a downstream direction. Between 10-90% of the channel abuts the valley margin. The ***laterally-***

<table>
<tr><td></td><td>unconfined valley-setting is characterised by rivers with continuous floodplains along both channel banks. Less then 10% of the channel margin abuts the valley margin.</td></tr>
<tr><td>Imposed and flux boundary conditions (catchment boundary conditions)</td><td>Analysis of ongoing system responses to disturbance is framed in terms of the imposed boundary conditions within which rivers operate (i.e. the catchment and landscape unit scale controls) and the flux boundary conditions that reflect the flow/sediment balance along a reach (and related vegetation associations). Imposed and flux boundary conditions are used to explain controls on river character and behaviour, providing the foundations for predicting likely future river adjustments.</td></tr>
<tr><td colspan="2">River condition - A measure of the capacity of a river to perform functions is appraised are expected for that river within the valley-setting that it occupies. The contemporary geomorphic state of a reach relative to a ‘natural’ or ‘expected’ reference condition of the same type of river. Assessment of river condition requires an understanding of:
➢ the spatial distribution of river types
➢ how those rivers behave (ie. river dynamics/evolution), and
➢ forms, extent and impact of human disturbance, including an appraisal of whether change has been irreversible.</td></tr>
<tr><td>Capacity for adjustment</td><td>Morphological adjustments brought about by the changing nature of biophysical fluxes that do not record a wholesale change in river type.</td></tr>
<tr><td>Degrees of freedom</td><td>The ability of differing components of a river system to adjust, measured in terms of bed character, channel attributes and planform attributes.</td></tr>
<tr><td>Relevant geoindicators</td><td>Parameters used to interpret and explain system structure, function and condition for each degree of freedom. ‘Relevant geoindicators’ provide a reliable and relevant signal about the condition of a reach. The geoindicators measured are River Style specific.</td></tr>
<tr><td>Desirability criteria</td><td>Assessment of the appropriateness of each relevant geoindicator for each River Style. A question is posed for each geoindicator to produce a set of desirability criteria to identify a reference condition and assess geomorphic condition of a reach.</td></tr>
<tr><td>Natural river (Natural reference condition)</td><td>A ‘natural’ river is dynamically adjusted so that geomorphic structure and function operate within a capacity for adjustment that is appropriate for that type of river, given the prevailing boundary conditions. A ‘natural reference condition’ is considered to be a river that is operating in the absence of human-disturbance. Changes to this ‘Intact’ or ‘pre-disturbance’ condition are considered to be reversible.</td></tr>
<tr><td>Expected reference condition</td><td>A pre-human disturbance reference condition is largely irrelevant for many river systems. Hence, expected reference conditions are identified against which the geomorphic condition of a reach is assessed. Three types of expected reference condition differentiate among situations in which the reach has been:
➢ reversibly altered by human disturbance,
➢ irreversibly altered by indirect human disturbance, or
➢ irreversibly altered by direct human disturbance.</td></tr>
<tr><td>Irreversible geomorphic change</td><td>A wholesale shift in the geomorphic unit structure, planform and bed material texture, such that the river operates in a fundamentally different manner to its former state with no prospect of return over a 50-100 year timeframe. This transition in the behavioural regime marks the adoption of a different type of river.</td></tr>
<tr><td>Good condition</td><td>River character and behaviour are appropriate for the River Style given the valley-setting and within-catchment position. Geomorphic structures are in the right place and operate as expected for the River Style. These reaches have a near-natural potential for ecological diversity and associated vegetation associations.</td></tr>
<tr><td>Moderate condition</td><td>Certain characteristics are out-of-balance or inappropriate for the River Style. Localised degradation of river character and behaviour is typically marked by modified patterns of geomorphic units. Key geomorphic structures are in the wrong places. Locally anomalous processes occur. In general, these reaches have poor vegetation associations and/or cover.</td></tr>
<tr><td>Poor condition</td><td>River character is divergent from the natural reference condition. Abnormal or accelerated geomorphic behaviour occurs. Key geomorphic units are located inappropriately along the reach, and processes are out-of-balance or anomalous. These reaches generally have low levels of bank vegetation and/or are weed infested. If fundamental threshold conditions are breached, irreversible geomorphic change would transform the reach to a different River Style.</td></tr>
<tr><td colspan="2">River recovery – Post-human disturbance trajectory of change towards an improved condition. River recovery is not simply the reverse of river degradation.</td></tr>
<tr><td colspan="2">Trajectory of change – the pathway along which a reach adjusts following disturbance. Three trajectories are identified in the River Styles framework, degradation, restoration and creation.</td></tr>
<tr><td colspan="2">Recovery potential –the likelihood of a reach recovering towards its reference condition in the next 50-100 years. Restoration (return to pre-disturbance condition) or creation (development of a new condition) can occur. Determination of river recovery potential requires an understanding of the linkages of geomorphic processes, off-site impacts and limiting factors within a catchment.</td></tr>
<tr><td>Intact</td><td>A river that operates in the absence of human-disturbance such that geomorphic characteristics and behavioural attributes are consistent with the pre-disturbance state. These reaches are often sufficiently</td></tr>
</table>

	robust to ‘bounce back’ to their intact condition following disturbances.
Degraded	A reach that has moved away significantly from its intact condition, and has not commenced along a recovery pathway. The river continues to adjust to disturbance, and form-process associations are out of balance.
Turning point	A transitional stage, used to describe a bifurcation in the reach’s evolution that marks a transition from degradation to recovery. Future river adjustments may push the river in one of three directions: on the continuing path of degradation, onto the restoration pathway, or onto the creation pathway. In many instances, these reaches show initial signs of recovery.
Restoration	Reversible geomorphic change has occurred and recovery towards a pre-disturbance state follows disturbance. Ultimately, these reaches have the potential to regain a near-intact condition.
Creation	Recovery towards a new alternative state that did not previously exist at the site. The character and behaviour of these reaches does not equate to a pre-disturbance state. Rather, the river is adjusting towards the best attainable state given the prevailing flux boundary conditions. All rivers that have experienced irreversible geomorphic change are recovering along a creation pathway.
River rehabilitation – A process that is undertaken to help a river adapt to a new environment by improving the condition and enhancing the recovery of the system through manipulation of its structure and function.	
Catchment-based vision	Set of goals that outline a realistic sense of what is achievable in river rehabilitation terms throughout a catchment.
Recovery goal	A defined state (either restoration or creation) that provides a long term goal for river rehabilitation.
Target condition	A good or moderate condition state that provides a short-medium term goal for the rehabilitation of reaches in poor geomorphic condition. Target conditions are the stepping stones towards the recovery goal.

1.5 Layout and structure of this book

Following this introductory chapter, practical considerations that must be resolved prior to application of the River Styles framework are summarised in Chapter 2. Chapter 3 reviews the methods adopted in application of the River Styles framework in Bega catchment. Chapters 4-7 of this book sequentially present findings from application of Stages 1-4 of the River Styles framework in Bega catchment. Chapter 4 assesses the character and behaviour of River Styles and assesses controls on their character and behaviour. This is presented for each of the downstream patterns of River Styles identified. An accompanying pdf file contains the River Styles proformas for each of the River Styles in Bega catchment. Chapter 5 presents the analysis of geomorphic river condition throughout the catchment, including assessment of the capacity for adjustment and evolutionary sequences for each River Style. The geomorphic condition of each reach of each River Style in the catchment is explained. Chapter 6 assesses the geomorphic recovery potential of each reach of each River Style in Bega catchment. Emphasis is placed on how downstream transfer of sediments, related to the position of reaches of differing River Styles within the catchment, dictates the likely future trajectory of change and the recovery potential of each reach. Chapter 7 outlines a catchment-based physical vision framed over an interval of 50-100 years. The information base developed in Stages One-Three of the framework is then used to identify target conditions for river rehabilitation throughout the catchment. From this, a physical basis to prioritise efforts at conservation and rehabilitation is applied. This procedure recognises the linkages of geomorphic processes throughout the catchment, highlighting those reaches that demonstrate the greatest likelihood of success. Finally, practical uptake of findings from the case study for ongoing river management practice in Bega catchment is outlined in the concluding chapter (Chapter 8), highlighting potential implications of this work.