

Floodplain Classification and its Relevance to Stream Management

J. C. Croke *

ABSTRACT: *Part of effective stream management is to integrate available knowledge on river behaviour from a wide range of locations, and apply this to the local problem. Classification schemes have an important role to play in this process by providing a logical framework in which to integrate our knowledge. To be of greatest benefit a river classification scheme needs to represent the physical processes that control river behaviour but remain simple enough for wide application. A floodplain classification is proposed here based upon the concept of stream power in relation to the resistance of the floodplain and channel sediment. The classification uses a hierarchy of floodplain types and orders, and the scheme is applicable to a wide range of floodplains, at all river scales. It is proposed that rivers move predictably from one type to another on the basis of changes to stream power or resistance, which can be modified by management.*

1.0 INTRODUCTION

Recent reports on the 'health' of Australian rivers suggest significant changes have occurred in catchments and streams throughout a very large part of the country (CSIRO, 1992). Major areas of concern include the morphological and ecological impacts of river regulation, bank erosion, changes to the stream substrate and channel siltation. While it is now generally agreed that these problems must be addressed at the catchment scale, within the framework of some Total Catchment Management (TCM) strategy, there is a lack of consensus on how this is to be achieved, and at what spatial scale. It is clear that there is insufficient data (quantitative or qualitative) available to characterise our river systems and consequently, the development of national, state or even local strategies and future management directions is virtually impossible. This task is further complicated by the problems of scale and time. Small and large catchments are likely to manifest and respond to change differently and therefore require management strategies which reflect this (CSIRO, 1992). Likewise, the state of a particular river as it exists today must be evaluated within the context of its propensity to change in the future and what the magnitude of this change is likely to be. For example, there is little point in recommending the restoration of riparian vegetation along a highly mobile river or reach of river where the dominant processes are lateral migration and/or channel avulsion. It is crucial, therefore, that river management strategies incorporate the concept of 'dynamic equilibrium' (Chorley, Shumm and Sugden, 1984).

Floodplains are important features in the landscape and it is important that their development and characteristics are understood and integrated into river management strategies for a number of reasons. Firstly, floodplains provide a major source for river sediments, and the physical and chemical characteristics of these materials may impact considerably on water quality. Secondly, floodplains which are inundated at high flow become part of the surface flow system. Even at low water, groundwater returns can be a significant component of the baseflow of river discharge. Surface forms that affect the passage of floodwaters and how they change over time are therefore important to our understanding of flood hydrology. Likewise, a knowledge of subsurface floodplain materials that affect groundwater storage, flow and quality is important. Thirdly, because floodplains are genetically associated with the river channel, they preserve a detailed record of past river activity. Understanding how river channels have changed is vital if restoration strategies which are both morphologically stable and ecologically desirable are to be developed. The purpose of this paper is to outline a relatively simple process-based classification of rivers and floodplains that can be used as a the basis for planning stream management strategies.

2.0 THE NEED FOR AND ROLE OF CLASSIFICATION

There is a need for a river classification scheme which extrapolate between sites as well as putting local sites into the broader context of riverine evolution. Determination of the position of any riverine system within the spectrum of floodplain types should make it possible to predict potential changes for the system. All river systems, at any spatial scale, expend energy; their very form and shape reflect the balance between the force of the flow and the resistance of the stream's boundary materials (Fig. 1). The location of a river within any catchment, together with the nature of its discharge, sediment load and flow characteristics are all determinants of the amount of energy available to a given river system. Australian rivers often display different and, in some cases unique processes, such as catastrophic stripping, prominent benches and pronounced levees, chains of ponds, downstream reductions in channel width/depth. There are a huge range of distinctive forms which may not appear to be related, but they can be placed in a framework of force versus resistance and over time change position predictably in this framework.

* CRC for Catchment Hydrology, CSIRO Division of Water Resources, GPO Box 1666, ACT 2601
Telephone: (06) 246 5788 Fax: (06) 246 5845 Email: jacky@cbr.dwr.csiro.au

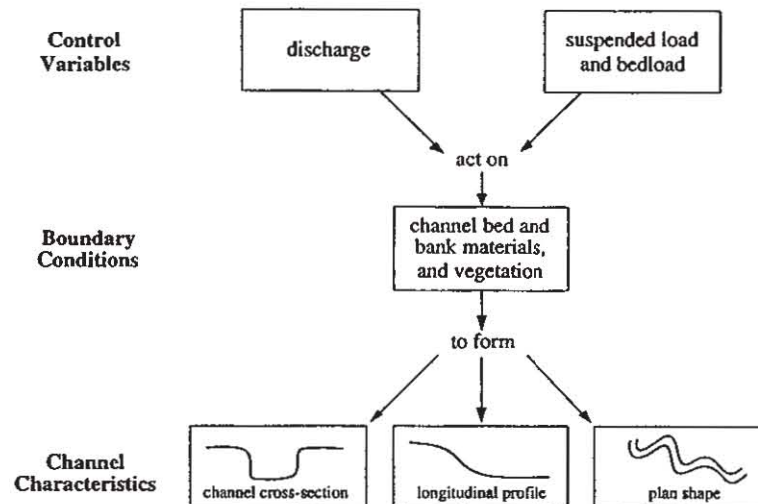


Figure 1. Equilibrium Concept for Eroding Channels (after Schumm, 1969)

River and floodplain classifications have been criticised in the past for their simplification of a complex and highly variable landform, for their resultant loss of useful information and/or for their static approach. While it is true that some classification schemes can induce unnecessary pigeon-holing, this is primarily caused by selecting criteria which are not process-based and therefore cannot reflect the natural variability of river/floodplain systems in space or time. A simple classification based solely on the morphology of the channel planform (ie meandering, braided etc) provides useful information on processes, but it provides little on where the river sits within a dynamic continuum of potential change over time. The River Murray in planform looks, and is often perceived to be, a highly mobile and active river as evidenced by the numerous scroll bars, meander cutoffs and oxbow lakes. However, over the past one hundred years or so the Murray has remained relatively stable because the present energy of the river is insufficient to mobilise the meanders (Rutherford, 1990). Furthermore, our understanding of the processes of channel sedimentation and hence floodplain formation have expanded considerably over the past twenty years or so. The reported dominance of a single process, namely lateral point-bar accretion, has been superseded in the literature by the identification of additional processes including overbank vertical-accretion; braided-channel accretion; oblique accretion; counterpoint accretion and abandoned channel accretion (see Nanson and Croke, 1992 for descriptions). Many of these processes are well illustrated in Australian fluvial systems.

3.0 FLOODPLAIN CLASSIFICATION

3.1 The Energy:Resistance Concept

A review of river and floodplain classifications and the principals underlying the energy:resistance concept are described in detail in Nanson and Croke (1992). In

brief, the energy:resistance concept attempts to characterise the channels ability to do work, or more specifically, to entrain and transport sediment and the resistance of the channel boundary to erosion. Three categories of specific stream power are used to distinguish High, Medium and Low-energy dominated floodplains (Table 1). Specific stream power (W/m^2) is defined as $w=gQS/W$, where g is specific weight of water, Q is bankfull discharge, S is channel slope and W is bankfull flow width. Bank resistance is more difficult to quantify due to the typically unquantified control of sediment cohesion and vegetation on bank stability. Bank resistance is classified according to the size of sediment within the bank; sand and gravel banks are classified as non-cohesive and silt and clay as cohesive (Table 1). The resultant scheme produces a tripartite division of river floodplains; High-energy non-cohesive floodplains (A1-A4); Medium-energy non-cohesive floodplains (B1-B3d) and low-energy cohesive floodplains (C1-C2b). On the basis of additional geomorphological processes, for example, the presence or absence of scroll bars, counterpoint sedimentation, organic backswamp deposits, and valley confinement, a total of thirteen orders and suborders were recognised from examples reported in the literature and personal observations.

There are a number of aspects of the energy:resistance classification scheme which may be appropriate to the characterisation of Australian river/floodplain systems.

- The classification scheme is process based and can be used to characterise the energy:resistance relationship of river systems at any spatial scale, including entire river systems, reaches or specific sites.
- Stream power is an effective measure of the stream's

| Floodplain Type | Order | Energy: Resistance estimate W/m^{-2} | Description |
|---|--|--|--|
| Class A: High-energy Non-cohesive Floodplain | A1: Confined coarse textured floodplains. | $> 1000 W / m^{-2}$ | Disequilibrium floodplains which erode in response to extreme events. Typically located in steep headwater reaches where channel migration is prevented by valley confinement. |
| | A2: Confined vertical accretion floodplains. | 300-1000 | |
| | A3: Unconfined vertical accretion sandy floodplains. | 300-600 | |
| | A4: Cut and fill floodplains. | 300 | |
| Class B: Medium-energy Non-cohesive Floodplain. | B1: Braided river floodplains. | 50-300 | Equilibrium floodplains formed by regular flow events in relatively unconfined valleys. |
| | B2: Wandering gravel-bed river floodplains. | 30-200(?) | |
| | B3: Meandering river, lateral migration floodplains. (There are 4 suborders within category B3.) | 10-60 | |
| Class C: Low-energy Cohesive Floodplains | C1: Laterally stable single-channel floodplains | $< 10 W / m^{-2}$ | Floodplains formed by regular flow-events along laterally stable single-thread or anastomosing low-gradient channels. |
| | C2: Anastomosing river floodplains. (There are 2 suborders of Category C2.) | | |

Table 1. Summary of Major Floodplain, Orders and Energy Classes from Nanson and Croke (1992)

energy under *bankfull* conditions, a state when the potential for stream bank erosion is often most likely. Ordering stream channels according to their bankfull energy capacity provides a useful guide to the force available to that river or river reach at this magnitude of flow.

- Quantifiable values of stream power and bank stability can be collected for a range of river environments and can be then used to construct an 'inventory' of river systems at the local, state or even national scale. River systems can be placed within this energy continuum and appropriate management strategies can be devised for the specific requirements of river/floodplain type. For example, the management strategies appropriate to high energy river and floodplain systems are likely to be entirely different to those required of low energy cohesive systems.

- The classifying criteria are not static- ie if channel characteristics change this will be reflected in the energy capacity of the stream and hence floodplain type. Floodplains and channels can therefore move from high to low energy classes due to a corresponding decrease in slope, discharge and/or channel dimension etc.

3.2 Disturbing the Energy:Resistance Balance

Many of the problems encountered in our river systems today reflect the streams response to some alteration of the energy:resistance balance. Bank erosion, increased sediment and nutrient delivery to the streams, stream aggradation/degradation, and avulsion, for example, reflect the rivers disequilibrium between the amount of energy available and the resistance of the channel boundary materials. Laterally stable, single channel floodplains (C1) for example, changed to wandering gravel-bed river floodplains (B2). This followed an

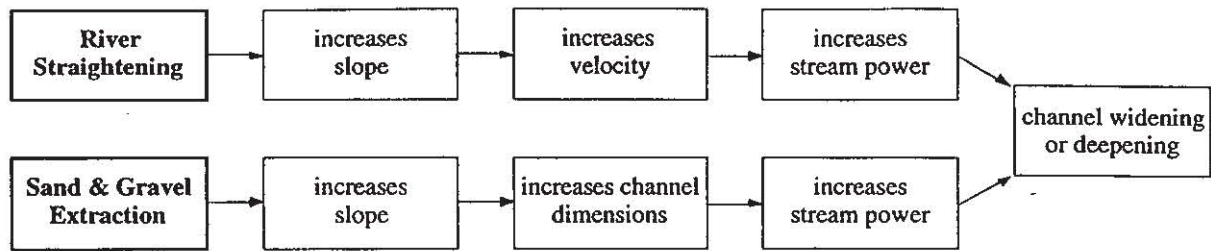


Figure 2. Adjustments to channel variables due to disturbances

increase in coarse sediment delivery in response to historic heavy metal mining (Croke, 1994). Sand and gravel extraction is likely to increase channel dimension (hence flow capacity), increase the slope of the bed and ultimately increase the available stream power (Fig. 2). This in turn is likely to increase sediment transport rates and channel bank erosion. Weir and dam impoundment will also alter the slope of the channel and the stream power / bank resistance relationship will in turn be affected (Fig. 2). Attempts to improve bank stability by artificial embankments etc may result in this available energy being applied to the channel bed, promoting increased channel incision and sediment transport. It is important to recognise the predictability of the dynamic changes within a river system.

Fundamental to the genetic classification proposed by Nanson and Croke (1992) is the recognition that a channel and floodplain will change in response to environmental factors that affect the channel. With additional data on both the range of stream powers for selected river types and bank resistance, it may be possible to identify 'thresholds' of instability for given channel and floodplain types. These can then be used in the development of management strategies appropriate for different energy classes of rivers and floodplains. It is important, therefore, that stream management strategies evaluate the potential impact of a particular disturbance within the context of the variables which will affect the energy:resistance balance of the stream.

4.0 CONCLUSIONS

Current problems in stream management highlight the sensitive balance between the channels erosive power and the resistance of its boundary materials. This energy:resistance concept of river behaviour provides a useful classification which can be used at a range of spatial scales. This variable may be particularly useful in providing a common link for river inventories and in producing a state wide or national river classification scheme. The advantages of this scheme are that it is process oriented and therefore can predict what happens through time. Furthermore, it only requires simple parameters which can be easily gathered for all rivers.

It incorporates a wide range of scale of rivers and scale is important in determining appropriate management strategies; minor adjustments to resistance, for example, will have little impact on a high energy river. Further work in obtaining estimates of stream power for a greater range of river and floodplain environments, in addition to developing a quantifiable estimate of bank resistance, will contribute to the application of this scheme to river management purposes.

5.0 ACKNOWLEDGEMENTS

The author would like to thank Ian Prosser, Eugene Wallensky and Kent Rich for their assistance in the preparation of this paper.

6.0 REFERENCES

- Chorley, R. J., Schumm, S. A. and Sugden, D. E. (1984). 'Geomorphology' Methuen, London.
- Croke, J.C. (1994). Floodplain variability in the Glenmalure Valley, SE Leinster Ireland'. Irish Geography, 13, 1-12.
- CSIRO (1992). Towards Healthy Rivers: A Report to the Honourable Ross Kelly, Minister for Arts, Sport, the Environment and Territories'. CSIRO Division of Water Resources, Consultancy Report No. 92/44.
- Nanson, G.C. and Croke, J. C. (1992). 'A Genetic Classification of Floodplains'. Geomorphology, 4, 459-486.
- Rutherford, I. (1990). 'Ancient River- Young Nation', In: Mackay, N. and Eastburn, D. (Eds.) 'The Murray', Murray Darling Basin Commission, Canberra, 17-38.
- Schumm, S. A. (1969). River Metamorphosis. Journal of the Hydraulics Division, American Society of Civil Engineers 95, 255-73.