Emerging issues in flood plain research

GERALD C. NANSON
School of Geosciences, University of Wollongong, New South Wales 2522, Australia
e-mail: gnanson@uow.edu.au

JACKY C. CROKE
Department of Geography and Oceanography, University of New South Wales at ADFA, Canberra, Australian Capital Territory 2601, Australia

Abstract Flood plain research is now considered crucial to the study of whole catchment ecosystems, from the perspective of material fluxes, contaminant storage, and riverine ecology. Papers submitted to this theme clearly reflect the growing diversity and relevance of flood plain research. In this brief overview, we highlight some of the emerging issues that may contribute to an appreciation of future research directions. These issues are concerned primarily with: flood plain formation processes; flood plain destabilization and changes in flood plain "state"; scale and the need for continuing research in the world's large flood plains; the role of vegetation in flood plain systems; flood plains in interdisciplinary research; and advances in techniques for flood plain research.
Key words flood plains; processes; interdisciplinary research; vegetation

INTRODUCTION

Flood plains have been extensively used and exploited over millennia as important locations for settlement and agriculture, and in many of today's landscapes this remains their primary function. In terms of scientific and applied research, flood plains have gained recognition as vital components of the fluvial ecosystem. Flood plain research is now considered crucial to the study of whole catchment ecosystems, from the perspective of material fluxes, contaminant storage, and riverine ecology. Their role in carbon cycling and storage has only recently been appreciated (Robertson *et al*., 1999) but this too is likely to extend the relevance of these landforms to flood plain research.

In many respects, papers in this volume reflect the growing diversity and the increasing relevance of, flood plain research. These papers, and our review of the recent literature, raise some interesting issues regarding the future application and direction of flood plain research both from a scientific and applied perspective. Rather than attempt a detailed literature review in such a short space we present a brief discussion of selected but emerging issues that may contribute to an appreciation of future research directions. These issues are primarily concerned with:

- the emergence of non-point bar, within-channel deposition as a dominant mechanism in flood plain development;
- recognition of some flood plains as non-equilibrium landforms;
- the role of vegetation in flood plain development;
- accurate representation of large-scale flood plain processes;
- flood plains in interdisciplinary research;
- the application of new techniques to flood plain studies.

Recent collections of papers and contributions by Carling & Petts (1992), Anderson *et al.* (1996), Alexander & Marriott (1999) and Tockner *et al*. (2002) provide more detail with regard to specific aspects of flood plains.

WITHIN-CHANNEL DEPOSITION—THE NEW DOMINANT PROCESS IN FLOOD PLAIN FORMATION?

Over the past 20 years, advances in our understanding of the relative contribution of both lateral and vertical accretion processes in flood plain formation suggests that there is no single, dominant model of flood plain formation. A significant advance in the past few years has been the recognition that lateral accretion does not have to consist predominantly of point-bar accretion. Recent research suggests that *oblique accretion* deposits can dominate the flood plain stratigraphy of many inland Australian rivers. For example, they constitute more than 65% of flood plain sediments along the Murrumbidgee River (Page *et al.*, in press) and almost the entirety of flood plains formed by bend migration on the suspended-load channels of the Darling and Cooper basins (Gibling *et al.*, 1998). Similarly, within-channel benches which are too large, well vegetated and stable to be seen simply as channel bars are interpreted as within-channel deposits (Erskine & Livingstone, 1999) and these can account for as much as 30% of the flood plain alluvium (Nanson & Page, 1983).

While the distinction between "narrow flood plains", "within-channel benches", and even "slack-water deposits" appears to be breaking down, and needs to be reasserted, there seems little doubt that within-channel, vertical and oblique accretion now represent dominant flood plain formation processes in some situations. However, the recognition of "counterpoint" or oblique deposition is not new (e.g. Taylor & Woodyer, 1978).

It is tempting to infer that the dramatic changes in sediment fluxes due to European settlement in Australia are reflected in the sediment deposits now forming a significant proportion of many lowland flood plains. While the specific response of flood plain systems to major land-use change will undoubtedly vary across environments (e.g. see Keesstra, 2002), the full implications of fine-grained, within-channel deposition on flood hydraulics, riverine ecology and carbon budgets have yet to be fully addressed.

FLOOD PLAINS AS EQUILIBRIUM AND NON-EQUILIBRIUM LANDFORMS

The role of flood plains in sediment and particulate-bound contaminant storage is now well established. Much work has been undertaken in quantifying sediment and contaminant storage on flood plain surfaces (Asselman & Middlekoop, 1995; Nicholas & Walling, 1997). The emergent picture is of highly variable flood plain accretion rates (e.g. Rumbsy, 2000) ranging from extremely slow on such systems as the Cooper in Queensland Australia (Gibling *et al*., 1998) to relatively rapid rates on the large flood plain systems of the Solimoes River, Brazil (Mertes, 1994). Fewer studies have addressed the significant spatial variation, yet we understand from studies on relatively small-scale flood plains that such variation can indeed be considerable, even within a single flood plain type (Leece, 1997; Nicholas & Walling, 1997).

The notion of flood plains as long-term sediment sinks, where mean deposition rates are steady for long periods of time and are spatially uniform, remains prominent. Following on from the recognition of "disequilibrium" flood plains (cf. Nanson, 1986), more recent research confirms the potential for flood plains to act as significant sediment sources due to catastrophic stripping and surface erosion (Ferguson & Brierley, 1999). In this volume, Erskine & Peacock (2002) and Webb *et al.* (2002) provide evidence for the reworking and catastrophic stripping of narrow sandy flood plains in the confined valley setting of Wollombi Brook near Sydney, Australia, as a result of exceptionally large floods since the mid Holocene. Likewise Webb *et al.* (2002) describe similar but much more frequent reworking of very narrow flood plains over the past 1200 years in Wheeny Creek, also near Sydney. These studies show parallels to observations by Brakenridge (1984), Pizzuto (1994), and Moody *et al.* (1999) on bench formation in less confined sandy streams in the USA. The influence of valley width and confinement, either directly or through morphological features such as levees, appears to be consistent amongst these studies.

It seems clear that if flood plain research is to effectively contribute to long-term catchment management strategies, our understanding of the conditions that cause changes in flood plain "state" should be pursued. For example, in a recent review of catchment sediment yields in Australia, Prosser *et al*. (2001) indicate from large-scale modelling predictions that approximately 80% of recently sediment eroded from large coastal catchments is now stored in flood plain and within-channel environments. The assumption that flood plains can continue to absorb the impacts of upland land degradation and erosion is likely to be a risky one in some environments, particularly those where deposition rates have accelerated dramatically over the past 200 years. At present our ability to predict or accurately model such changes in flood plain state is limited, although work in relatively small catchments in Japan (Nakamura & Kikuchi, 1995) appears to offer some promise at small spatial scales.

FLOOD PLAIN FORM AND VEGETATION

Over the past decade there have been major advances in our understanding of the role of vegetation in both channel and flood plain development (e.g. Gurnell, 1995). Early work primarily used vegetation, and specifically succession and stand age, as a means to estimate rates of lateral migration and scroll bar development (Nanson, 1980, 1981; Colonnello, 1990). Over the last decade there has been considerable attention given to the role of vegetation in promoting, and controlling, specific flood plain and channel formation processes. This is well-demonstrated in the study of the low-gradient anabranching systems in Botswana (McCarthy *et al*., 1991) where it is the density and trapping efficiency of the reed-swamps that have dominated the evolution of these flood plains and flood basins. The influence of vegetation on channel and flood plain form has now been described across the full energy spectrum, from large woody debris in high-energy mountain streams (e.g. Montgomery *et al*., 1996) to swampy and organic rich vegetation in the low-medium energy channels (Fryiers & Brierley, 1998).

The role of riparian vegetation adjacent to the channel has also been a focus of attention (e.g. Nanson *et al*., 1995). Research now indicates the profound impact that both the existence and subsequent removal of such vegetation has on channel and flood plain stability. In a lowland environments in southern Victoria, Brooks & Brierley (2002) have shown the effect of riparian vegetation in maintaining continuously stable flood plains for the last 20 000 years or more. Conversely, riparian clearance has caused the destruction of these ancient, stable, flood plain systems, and Brooks *et al.* (in press) suggest that "the massive volume of sediment eroded from the Cann River in recent decades represents sediment accumulated over millennia within a low-energy vegetated and wood-dominated channel environment."

It is clear from recent research that flood plain vegetation represents much more than a convenient dating tool. In many environments, relatively unusual flood plain systems now appear to exist solely due to the interactions between flow and the nature, density and vigor of the surrounding vegetation. Detailed quantification of such interactions over a range of spatial scales requires attention particularly for the purposes of modelling the hydraulics of overbank flow on flood plains.

ISSUES OF SCALE AND FLOOD PLAIN RESEARCH

With the exception of classic work on the Mississippi, most previous research into the geomorphology of flood plains has excluded research on some of the world's largest flood plains, such as the Amazon, Ganges or Congo. Preliminary research in these large flood plain systems over the past few years suggests these areas may be strongly heterogenous and therefore difficult to categorize into the relatively simple classifications developed so far. Flood plain scale appears to be important, especially in terms of whether water and sediment are derived from the main river channel, and in terms of the variety of flood plain styles that may coexist along a single reach of a large river. Mertes (1997) has made the important observation that on large flood plains in the Amazonia, overbank flows and hence the material fluxes are not derived solely from the river. This can result in large variations in flood plain sedimentation, nutrient transfer and chemical deposition, and consequently on flood plain ecology and the ecotones that arise.

Similar to the issue of flood plain scale and the representation of specific flood plain types, there is also a notable bias towards the study of flood plains in temperate and tropical environments. As a consequence, we appear to have limited understanding of the dynamics of dryland river flood plains. Although broadly assessed by Nanson *et al*. (2002), with specific recent investigations by Tooth (1999) and Makaske (2001), further studies are required in these environments before we can confidently begin to attempt their characterization. This is particularly relevant in Australia where so many large river systems are located in semiarid to arid environments. Existing studies on the ecology of these systems could clearly benefit from more detailed geomorphological and hydrological studies (e.g. Walker *et al*., 1995).

FLOOD PLAINS IN INTERDISCIPLINARY RESEARCH

The most notable and significant advance in flood plain research over the past decade has been the broadening of studies to incorporate a wide variety of scientific disciplines. Flood plains are now well recognized as geomorphic, hydrological, sedimentary, chemical and ecological systems, each integral to understanding the behaviour of the catchment as a whole. Our understanding of the river flood-plain ecosystem, in aquatic and terrestrial ecology has advanced considerably in the last decade. Particular attention has been given to the interaction between flood plain ecology and river flow. The majority of flood plain ecological models are related to some aspect of the variability, timing, frequency and duration of floods (e.g. Vannote *et al*., 1980; Junk *et al.*, 1989). Of particular relevance for Australian flood plains is the extreme variability in flows (Kingsford *et al*., 1998). Recent pioneering studies which describe the ecology of these inland systems are likely to prove invaluable in providing base-line data for these unusual ecosystems (Bunn & Davies, 1999; Kingsford *et al*., 1998; Puckeridge *et al*., 1998).

Given the dependence of flood plain ecosystems on flow, understandably, much attention has also been given to the response of flood plain ecosystems to changes in water uses and the impact of grazing practices on aquatic and terrestrial (Ogden, 2000; Jansen & Robertson, 2001; Thoms *et al*., 1999). In this volume, Dyer (2002) reports the impact of river regulation on flood regimes and the drying of wetlands and subsequent deterioration in wetland diversity.

Given the central role of flood plains within catchment ecosystems, they are ideally suited to interdisciplinary research programmes where the hydrology, geomorphology and ecology of these landforms, when combined with their response to anthropogenic changes, can be studied holistically. Such integrated and well-coordinated studies remain few, however, and it would appear that whilst we recognize both the need and utility of such an approach, there remain some barriers to its practical implementation, most notably funding.

ADVANCES IN TECHNIQUES IN FLOOD PLAIN RESEARCH

There have been considerable advances in the application of sediment tracers and heavy metals as chrono-markers for determining both contemporary and historic flood plain sedimentation rates through overbank deposition (He & Walling, 1996; Walling & He, 1997; Leece & Pavlowsky, 2001). The geochemistry of flood plains is now a strong field of research which has successfully contributed to the environmental management of flood plains (e.g. Macklin, 1996).

New instrumentation and renewed determination are likely to improve our understanding of the conveyance capacity, hydraulic resistance, sediment transport and depositional characteristics of overbank flow. Advances in this area are now achieved mainly through a combination of numerical and physical modelling with some calibration and validation from field estimates of flood plain sedimentation. Carling *et al*. (2002) in this volume examine a vertically double-layered structure between the main channel and the flood plain on the River Severn in the UK. At the scale of large flood plains, considerable promise is offered by the approach outlined by Pickup & Marks (2000) which uses radiometric data and a simple backwater calculation to investigate patterns of flood inundation and deposition in some large arid flood plain systems in central Australia. It seems likely that such approaches, and the continuing advancement of remote sensing and airborne imagery data, will become highly relevant in studies of large flood plains (Mertes, 1994).

Advances in our understanding of flood plain flows and return flows in multi-channel systems (e.g. Fagan, 2001) suggest that modelling flood plain hydraulics in systems with highly variable topographic features such as islands and narrow inset flood plains will require continuing refinement of existing numerical models. Probably the major limitation is not the capability of the models or the modellers, but that appropriate empirical data is as yet unavailable at the level of resolution needed.

CONCLUSION

Flood plain research continues to be an active and relevant discipline which, perhaps now more than ever, is central to the management of whole-catchment ecosystems. Since the pioneering work of Wolman & Leopold (1957), our understanding of flood plain form and process over the past 50 years has expanded considerably. We now accept process variability as the norm and descriptions of large flood plains from the more remote and less-well studied parts of the world reaffirm the heterogeneity of these landforms. Recent research appears to indicate that within-channel deposition of fine-grained deposits is emerging as a dominant process in some low-energy flood plains. If this is a response to the dramatic changes in sediment fluxes since European settlement, we may expect to see increased observations of channel narrowing and flood plain formation through bench and oblique accretion. This also raises interesting issues with respect to the long-term stability of these landforms. Reports of flood plain catastrophic stripping have increased and flood plain destabilization is now described in a range of environmental settings. The assumption that flood plains can continue to act as buffers and sinks for upland soil degradation, contaminant and pesticide releases thus seems unnecessarily risky. Improved understanding of the response of flood plains to major changes in deposition rates seems important if our contribution to long-term catchment management strategies is to be effective. Flood plains as landforms are now integral to hydrological, geomorphological, ecological and geochemical research. Continuing efforts to integrate research will undoubtedly provide a solid basis upon which to expand scientific understanding and ensure the application of this work to meaningful catchment management.

REFERENCES

Alexander, J & Mariott, S. B. (1999) Introduction. In: *Floodplains: Interdisciplinary Approaches* (ed. by S. B. Marriott & Alexander, J.), 1–13. The Geological Society, London.

Anderson, M. G., Walling, D. E. & Bates, P. D. (eds) (1996) *Floodplain Processes*. John Wiley, Chichester, UK.

Asselman, N. E. & Middlekoop, H. (1995) Floodplain sedimentation: quantities, patterns and processes. *Earth Surf. Processes and Landforms* **20**, 481–499.

Brakenridge, G. R. (1984) Alluvial stratigraphy and radiocarbon dating along the Duck River, Tennessee: implications regarding floodplain origin. *Bull. Geol. Soc. Am.* **95**, 9–25.

Brooks, A. P. & Brierley, G. J. (2002) Mediated equilibrium: the influence of riparian vegetation and wood on the long-term evolution and behaviour of a near-pristine river. *Earth Surf. Processes and Landforms* **27**, 343–367.

Brooks, A. P., Brierley, G. J. & Milllar, R. G. (in press) The long term control of vegetation and woody debris on channel and flood-plain evolution: insights from a paired catchment study in southeastern Australia. *Geomorphology*.

Bunn, S. E. & Davies, P. M. (1999) Aquatic food webs in turbid arid zone rivers: preliminary data from Cooper Creek, Queensland. In: *Freeflowing River: the Ecology of the Paroo River* (ed by R. T. Kingsford), 67–76. New South Wales National Parks and Wildlife Service, Sydney.

Carling, P. A. & Petts, G. E. (eds) (1992) *Lowland Floodplain Rivers: Geomorphological Perspectives*. John Wiley, Chichester, UK.

Carling, P. A., Cao, Z. & Ervine, D. A. (2002) Flood plain contribution to open channel flow structure. In: *The Structure, Function and Management Implications of Fluvial Sedimentary Systems* (ed. by F. J. Dyer, M. C. Thoms & J. M. Olley) (Proc. Alice Springs Symp., September 2002). IAHS Publ. no. 276 (this volume).

Colonnello, G. (1990) A Venezuelan floodplain study on the Orinoco River. *Forest Ecol. Manage.* **33/34**, 103–124.

Dyer, F. J. (2002) Assessing the hydrological changes to flood plain wetland inundation caused by river regulation. In: *The Structure, Function and Management Implications of Fluvial Sedimentary Systems* (ed. by F. J. Dyer, M. C. Thoms & J. M. Olley) (Proc. Alice Springs Symp., September 2002). IAHS Publ. no. 276 (this volume).

Erskine, W. D. & Livingstone, E. A. (1999) In-channel benches: the role of floods in their formation and destruction on bedrock-confined rivers. In: *Varieties of Fluvial Form* (ed. by A. J. Miller & A. Gupta), 445–475. John Wiley, Chichester, UK.

Erskine, W. D. & Peacock, C. T. (2002) Late Holocene flood plain development following a cataclysmic flood. In: *The Structure, Function and Management Implications of Fluvial Sedimentary Systems* (ed. by F. J. Dyer, M. C. Thoms & J. M. Olley) (Proc. Alice Springs Symp., September 2002). IAHS Publ. no. 276 (this volume).

Fagan, S. D. (2001) Channel and floodplain characteristics of Cooper Creek, central Australia. PhD Thesis, University of Wollongong, New South Wales, Australia.

Ferguson, R. J. & Brierley, G. J. (1999) Downstream changes in valley confinement as a control on floodplain morphology, lower Tuross River, New South Wales, Australia—a constructivist approach to floodplain analysis. In: *Varieties of Fluvial Form* (ed. by A. J. Miller & A. Gupta), 377–408. John Wiley, Chichester, UK.

Fryiers, K. & Brierley, G. J. (1998) The character and age structure of valley fills in Upper Wolumla Creek, South Coast, New South Wales, Australia. *Earth Surf. Processes and Landforms* **23**, 271–287.

Gibling, M. R., Nanson, G. R. & Maroulis, J. C. (1998) Anastomosing river sedimentation in the Channel Country of central Australia. *Sedimentology* **45**, 595–619.

Gurnell, A. M. (1995) Vegetation along river corridors: hydrogeomorphological interactions. In: *Changing River Channels* (ed. by A. Gurnell, A. & G. Petts), 237–258. John Wiley, Chichester, UK.

He, Q. & Walling, D. E. (1996) Use of fallout 210 Pb measurements to investigate longer-term rates and patterns of overbank sediment deposition on the floodplains of lowland rivers. *Earth Surf. Processes and Landforms* **21**, 141–154.

Jansen, A. & Robertson, A. I. (2001) Relationships between livestock management and the ecological condition of riparian habitats along an Australian floodplain river. *J. Appl. Ecol.* **38**, 63–75.

Junk, W. J., Bayley, P. B. & Sparks, R. E. (1989) The flood-pulse concept in river–floodplain systems. *Can. Spec. Publ. Fish. Aquat. Sci. 106*, 110–127. NRC Research Press, Ottawa.

Keesstra, S. D. (2002) Channel and flood plain response to reforestation in the Dragonja basin, southwestern Slovenia: linking past and present. In: *The Structure, Function and Management Implications of Fluvial Sedimentary Systems* (ed. by F. J. Dyer, M. C. Thoms & J. M. Olley) (Proc. Alice Springs Symp., September 2002). IAHS Publ. no. 276 (this volume).

Kingsford, R. T., Boulton, A. J. & Puckridge, J. T. (1998) Challenges in managing dryland rivers crossing political boundaries: lessons from Cooper Creek and the Paroo River, central Australia. *Aquat. Conserv.: Mar. Freshwat. Ecosys.* **8**, 361–378.

Leece, S. A. (1997) Spatial patterns of historical overbank sedimentation and floodplain evolution, Blue River, Wisconsin. *Geomorphology* **18**, 265–277.

Leece, S. A. & Pavlowsky, R. T. (2001) Use of mining-contaminated sediment tracers to investigate the timing and rates of historical floodplain sedimentation. *Geomorphology* **38**, 85–108.

Macklin, M. G. (1996) Fluxes and storage of sediment-associated heavy metals in floodplain systems: assessment and river basin management issues at a time of rapid environmental change. In: *Floodplain Processes* (ed by M. G. Anderson, D. E. Walling & P. D. Bates), 441–460. John Wiley, Chichester, UK.

Makaske, B. (2001) Anastomosing rivers: a review of their classification, origin and sedimentary products. *Earth Sci. Rev.* **53**, 149–196.

McCarthy, T. S., Stanistreet, I. G. & Cairncross, B. (1991) The sedimentary dynamics of active fluvial channels on the Okavango fan, Botswana. *Sedimentology* **38**, 471–487.

Mertes, L. A. K. (1994) Rates of floodplain sedimentation on the central Amazon River. *Geology* **22**, 171–174.

Mertes, L. A. K. (1997) Documenation and significance of the perirheic zone on inundated floodplains. *Wat. Resour. Res.* **33**, 1749–1762.

Montgomery, D. R., Abbe, T. B., Buffington, J. M., Peterson, N. P., Schmidt, K. M. & Stock, J. D. (1996) Distribution of bedrock and alluvial channels in forested mountain drainage areas. *Nature* **381**, 587–589.

Moody, J. A., Pizzuto, J. E. & Meade, R. H. (1999) Ontology of a floodplain. *Bull. Geol. Soc. Am.* **111**, 291–303.

Nakamura, F. & Kikuchi, S. (1995) Some methodological developments in the analysis of sediment transport processes using age distribution of floodplain deposits. *Geomorphology* **16**, 139–145.

Nanson, G. C. (1980) Point bar and floodplain development of the meandering Beatton River, northeastern British Columbia, Canada. *Sedimentology* **27**, 3–9.

Nanson, G. C. (1981) New evidence of scroll bar formation on the Beatton River. *Sedimentology* **28**, 889–891.

Nanson, G. C. (1986) Episodes of vertical accretion and catastrophic stripping: a model of disequilibrium floodplain development. *Bull. Geol. Soc. Am.* **97**,1467–1475.

Nanson, G. C. & Page, K. J. (1983) Lateral accretion of fine grained concave-benches on meandering rivers. In: *Modern* *and Ancient Fluvial Systems* (ed. by J. Collinson & J. Lewin), 133–143. Special Publ. of the International Association of Sedimentologists no. 6, Blackwell, Oxford.

Nanson, G. C., Barbetti, M & Taylor, G. (1995) River stabilisation due to changing climate and vegetation during the late Quaternary in western Tasmania, Australia. *Geomorphology* **13**, 145–158.

Nanson, G. C., Tooth, S. & Knighton, A. D. (2002) A global perspective on dryland rivers: perceptions, misconceptions and distinctions. In: *Dryland Rivers: Hydrology and Geomorphology of Semi-arid Channels* (ed. by L. J. Bull & M. J. Kirkby), 17–54. John Wiley, Chichester, UK.

Nicholas, A. P. & Walling, D. E. (1997) Modelling flood hydraulics and overbank deposition on river floodplains. *Earth Surf. Processes and Landforms* **22**, 59–77.

Ogden, R.W. (2000) Modern and historical variation in aquatic macrophyte cover of billabongs associated with catchment development. *Regul. Rivers: Res. and Manage.* **16**, 497–512.

Page, K. J., Nanson, G. C. & Frazier, P. S. (in press) Floodplain formation and sediment stratigraphy resulting from oblique accretion on the Murrumbidgee River, Australia. *J. Sed. Res.*

Pickup, G. & Marks, A. (2000) Identifying large-scale erosion and deposition processes from airborne gamma radiometrics and digital elevation models in a weathered landscape. *Earth Surf. Processes and Landforms.* **25**, 535–557.

Pizzuto. J. E. (1994) Channel adjustments to changing discharges, Powder River, Montana. *Bull. Geol. Soc. Am.* **106**, 1494–1501.

Prosser, I. P., Hughes, A., Rustonji, P., Young, B. & Moran, C. (2001) Predictions of the sediment regime of Australian rivers. In: *Third Australian Stream Management Conference Proceedings* (Brisbane), vol. 2, 529–536.

Puckridge, J. T., Sheldon, F., Walker, K. F. & Boulton, A. J. (1998) Flow variability and the ecology of large rivers. *Mar. Freshwat. Res.* **49**, 55–72.

Robertson, A. I., Bunn, S. E., Boon, P. I. & Walker, K. (1999) Sources, sinks and transformations of organic carbon in Australian floodplain rivers. *Mar. Freshwat. Res.* **50**, 813–829.

Rumbsy, B. (2000) Vertical accretion rates in fluvial systems: A comparison of volumetric and depth-based estimates. *Earth Surf. Processes and Landforms* **25**, 617–631.

Taylor, G. & Woodyer, K. D. (1978) Bank deposition in suspended-load streams. In: *Fluvial Sedimentology* (ed. by A. D. Miall), 257–275. Canadian Society of Petroleum Geologists, Calgary.

Thoms, M. C., Ogden, R. W. & Reid, M. A. (1999) Establishing the condition of lowland floodplain rivers: a palaeo-ecological approach. *Freshwat. Biol.* **41**, 407–423.

Tockner, K., Ward, J. V., Kollmann, J. & Edwards, P. J. (2002) (eds) Riverine Landscapes. Special issue of *Freshwater Biol.* **47**, no. 4.

Tooth, S. (1999) Floodouts in central Australia. In: *Varieties of Fluvial Form* (ed. by A. J. Miller & A. Gupta), 219–248. John Wiley, Chichester, UK.

Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R. & Cushing, C. E. (1980) The river continuum concept. *Can. J. Fish. Aquat. Sci.* **37**, 130–137.

Walker, K. F., Sheldon, F. & Puckridge, J. T. (1995) A perspective on dryland river ecosystems. *Regul. Rivers* **11**, 5–204.

Walling, D. E. & He, Q. (1997) Use of fallout Cs^{137} in investigations of overbank sediment deposition on river floodplains. *Catena* **29**, 263–282.

Webb, A. A., Erskine, W. D. & Dragovich, D. (2002) Flood-driven formation and destruction of a forested flood plain and in-channel benches on a bedrock-confined stream: Wheeny Creek, southeast Australia. In: *The Structure, Function and Management Implications of Fluvial Sedimentary Systems* (ed. by F. J. Dyer, M. C. Thoms & J. M. Olley) (Proc. Alice Springs Symp., September 2002). IAHS Publ. no. 276 (this volume).

Wolman, M. G. & Leopold, L. B. (1957) River flood plains: some observations on their formation. *US Geol. Survey Prof. Pap. 282-C*, 87–109.