TOWARDS INNOVATIVE SOLUTIONS FOR RIVER MANAGEMENT IN NEW ZEALAND

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Abstract

Freshwater management in New Zealand needs connected, innovative and interdisciplinary science to empower end-users of New Zealand's rivers, which therefore embraces the whole of society, to better understand and manage the nation's rivers and freshwater resources. Modern river science involves highly specialised, rapidly developing and diverse fields and there is a need to provide an integrated and more holistic perspective in catchment and river science to sustainably manage these systems. The future of our rivers will be determined by how we manage their catchments. Innovative solutions for river management are needed, which recognise natural river dynamism in space and time, understanding rivers as responsive and sensitive landscape features that function as integrated catchments. This is best achieved by taking a holistic, integrated river science approach, which identifies causes of problems and issues rather than their symptoms and treats reaches in a connected catchment context. In turn this requires development of catchment-scale integrated modelling tools to assess land and water management strategies, which, at least in part, can be derived from establishing field laboratories with shared and multiple use field experiments and monitoring sites across the range of environmental sciences and, importantly, connected with key end-users such as Regional Councils and Unitary Authorities. This paper thus sets out a vision for future river management that is both innovative and integrated, based on examples and case studies of issues to be addressed if future river management is to be successful.

Key words: river management, catchment connectivity, integrated science

Introduction: The Need

New Zealand's rivers are among the most dynamic in the world, subject to rapid change in response to storms and land clearance, as well as other drivers such as volcanic activity, earthquakes and mass movements (e.g. Grant, 1985; Manville *et al*., 2005; Fuller, 2008; Procter *et al*., 2010; Richardson *et al*., in review). Short, steep catchments generate high rates of erosion as well as flashy and potentially devastating flows. Sediment yielded to the ocean from some of New Zealand's rivers rate among the highest quantity per square kilometre anywhere on Earth: the average suspended sediment yield of the Waiapu River in the East Coast Region is 35 Mt yr^{-1} or 20,250 t km^{-2} (Hicks *et al*., 2000), which equates to c.0.2% of the global sediment yield to the ocean (Page *et al*., 2008). New Zealand's terrain and climate also renders its rivers subject to a high degree of variability, which in turn has produced an extraordinary diversity of river forms and habitats (Figure 1).

Figure 1. A small selection of New Zealand rivers highlighting the diversity of channel form (clockwise from top left): Waimakariri (Canterbury), Tiraumea (Manawatu), Fox (Westland), Mokihinui (Karamea), Makaroro (Hawkes Bay), Tapuaeroa (East Coast), Stony (Taranaki), Motueka (Nelson), Manawatu, Waimamaku (Northland).

River management in New Zealand is inevitably highly complex and extremely challenging in this context. An approach to manage a river such as the Waimakariri will differ considerably from one tailored to respond to the challenges posed by the Manawatu, but the essence is the same because the issues of flooding, erosion and aggradation are the same. New and innovative approaches are required to take into account the challenges imposed by the natural environment and yet maintain a degree of natural character and integrity in our rivers. Failure to innovate has lead to a loss of function in river geomorphology and ecology. Many rivers that would naturally have wide active channels have been modified by engineering to become much narrower (Figure 2), e.g. the Rangitikei at Bulls has been reduced in width by 75% by engineering approaches between the 1950s and 1980s (Fuller et al., 2012).

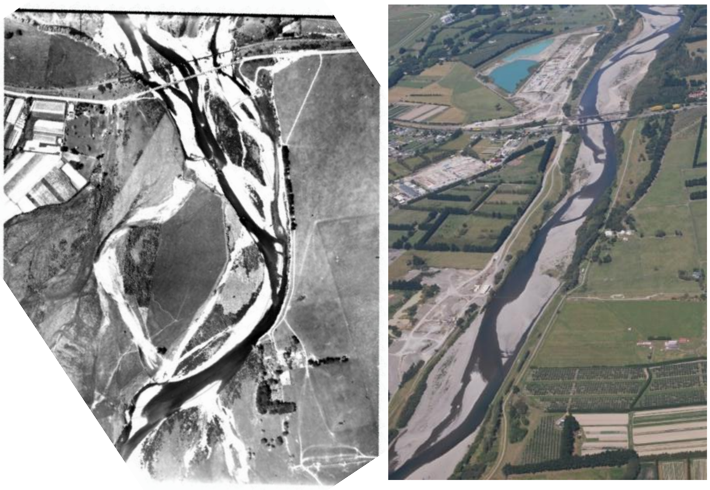

Figure 2. The lower Otaki River has been straightened and narrowed by river engineering approaches since the 1950s implemented for flood protection. It provides a typical example of the reduction in geomorphic and habitat complexity in many previously laterally active gravelly rivers in NZ: (a) 1939, (b) 2013 (SH1 bridge for reference in the top of each photo).

The Challenge

River catchments are complex entities, comprising a series of interconnected elements transferring water and sediment along a jerky conveyor from slope to sea. Each discrete reach of river reflects unique and distinctive boundary conditions imposed by the catchment upstream, as well as the interactions with adjacent reaches and valley floor (Figure 3).

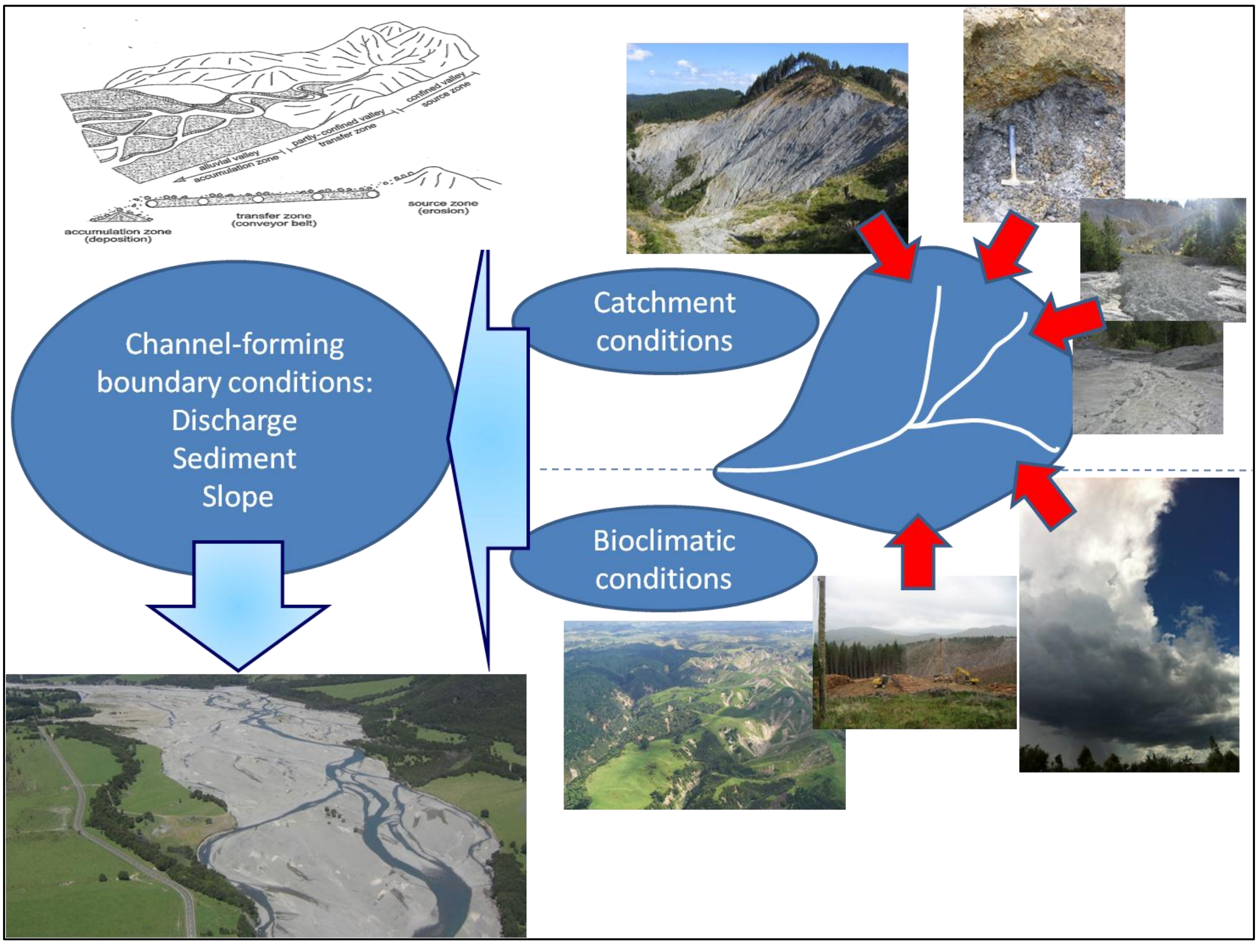

Figure 3. River catchments as complex, connected entities conveying sediment and runoff from slopes to sea. The combination of environments, processes, landscapes, inputs and connections between these variables will impact channel-forming boundary conditions in each coherent reach / segment of river channel, which conditions the type of channel manifest. The transfer of material is not continuous, but reflects flood regime and variable sediment inputs along a jerky conveyor belt (conceptual diagram from Brierley and Fryirs, 2005).

Each unique reach of river will respond to changes in its catchment, both natural and anthropogenic. Rivers are highly sensitive and responsive landscape elements. The array of variables conditioning channel morphology (e.g. catchment characteristics, discharge, sediment supply, channel boundary, human interference), which vary continuously in time and space, mean there is always potential for instability and change within any river channel. The norm for river channels is instability (Raven *et al*. 2010) and change should therefore be anticipated and incorporated into river management (Newson and Large, 2006). A major challenge for effective river management is not to 'fight the site', but rather to 'work with nature' (Brierley and Fryirs, 2009) and the natural propensity for change. The impacts of significant natural events can be long-lasting in a catchment, for example streams in the SE Ruahines continue to display a legacy of Cyclone Alison's impact in 1975 (Schwendel and

Fuller, 2011). This means that river channel behaviour has a history that must be recognised and understood if management is to be effective.

At the same time that New Zealand's river morphology is changing under natural and anthropogenic pressures, the ecology of our rivers is also under increasing pressure from declining water quality, water abstraction, invasive species and anthropogenically altered habitat structure of those rivers. Management of rivers is a constant tension between protecting instream biological and geomorphological characteristics, consumptive use for agriculture and industry, discharge of waste, and the protection of property from erosion and inundation (Wohl *et al*., 2005; Vorosmarty *et al*., 2010; Feld *et al*., 2011). The biological communities that inhabit our rivers and streams are declining nationally (Joy, 2009) and internationally (Dudgeon & Chan, 1992; Allan, 1995; Dudgeon, 2000; Poff *et al.*, 2003; Olden *et al.*, 2010; Vorosmarty *et al.*, 2010) with freshwater biodiversity having the greatest extinction rates of any habitat worldwide.

Although considerable focus has been given to the need for an integrated catchment approach to addressing issues of maintaining and enhancing ecological health and biodiversity (e.g., National Policy Statement on Freshwater, Land and Water Forum and McFarlane *et al*. (2011) have recently made recommendations for incorporation of geomorphic principles into holistic river condition assessments) there has been considerably less attention on how to integrate the science to positively impact waterbody condition at a catchment scale. An illustrative example is the large periphyton (algae growing on stone surfaces) blooms that can occur downstream of river dams (Figure 4) . These blooms are partly attributable to increased nutrients in the water column that may arise from rotting vegetation in the impoundment, but predominantly from the change in substrate and flow characteristics. Periphyton growth is controlled by a variety of physical, chemical and biological characteristics including temperature, nutrients, light, invertebrate grazing, type of substrate and the mobility of that substrate. Changes to the hydrological pattern of a river as a result of an upstream impoundment means that flows able to move the substrate and scour the attached periphyton can be reduced in magnitude and frequency. Furthermore, changes in the particle size distribution result in generally larger particles that are in turn more difficult to move even if flow patterns remain unaltered (Figure 5). The challenge is to bring together an understanding of the ecology, hydrology and geomorphology so that flushing flows can be established that are frequent enough and large enough to prevent the periphyton biomass accruing to the point where it starts to decompose, sucking oxygen from the water and sending the river ecology into a downward spiral.

Figure 4. Periphyton blooms during stable warm periods when the substrate is not being disturbed by high flows.

Figure 5. Substrate downstream of the Rangipo dam on the Tongariro River.

The Solution

Freshwater management in New Zealand needs connected, innovative and interdisciplinary science to empower end-users of New Zealand's rivers to better understand and manage the nation's rivers and avoid a loss of integrity and function that has been imposed by 'classic' hard engineering approaches. The traditional hard engineering approach to river management has often failed to recognise the importance of integrated connections between the various components within a river catchment as a whole. Problems have been addressed 'at site', with little reference to what may be going on upstream / downstream and adjacent to the channel. For example, hardening river banks with rock protection ensures lateral stability, but results in a disconnection between channel and floodplain, potentially reducing sediment replenishment in a system and promoting bed-scour (e.g. Fuller and Basher, 2013), which may result in further channel narrowing and deepening, in turn threatening the integrity of the original bank protection structures, while downstream reaches may be subject to aggradation as scoured bedload is deposited. This see-saw of degrading/aggrading adjacent reaches is a current issue in the Manawatu River in the vicinity of Palmerston North (Bell, 2012). The issue is not confined to fluvial geomorphology either, because these changes have a commensurate impact on stream biota and ecology. Flows which were conveyed in multiple, shallow channels have become confined in single thread, uniform 'runs', which lack the diversity of the pre-engineered channel form. Not only is there a reduction in habitat diversity, but there may be complete change in habitat type (riffles and pools replaced by continuous runs).

Accordingly, a focus on one of: ecology, hydrology, geomorphology is inadequate to properly manage these complex and dynamic systems. Channel geomorphology is strongly conditioned by linkages with slope processes and sediment transfer pathways in a catchment and is in turn linked with ecological habitats. Hydrology is required to understand modified flows into and through the system. Hydrological models are also useful in informing the pathways of flow to a channel, which can also be used to assess the impacts of water abstraction or contamination of influent water to a channel. A holistic, integrated river science approach that recognises the complexity of river systems and begins to respond to the challenges identified here provides a way forward towards innovative river management that works outside of any single subject silo. Innovative, integrated solutions must identify causes of problems and issues rather than simply list their symptoms. Discrete reaches must be treated in a connected catchment context with management approaches informed by proper engagement with the range of subjects aligned with river science (Figure 6).

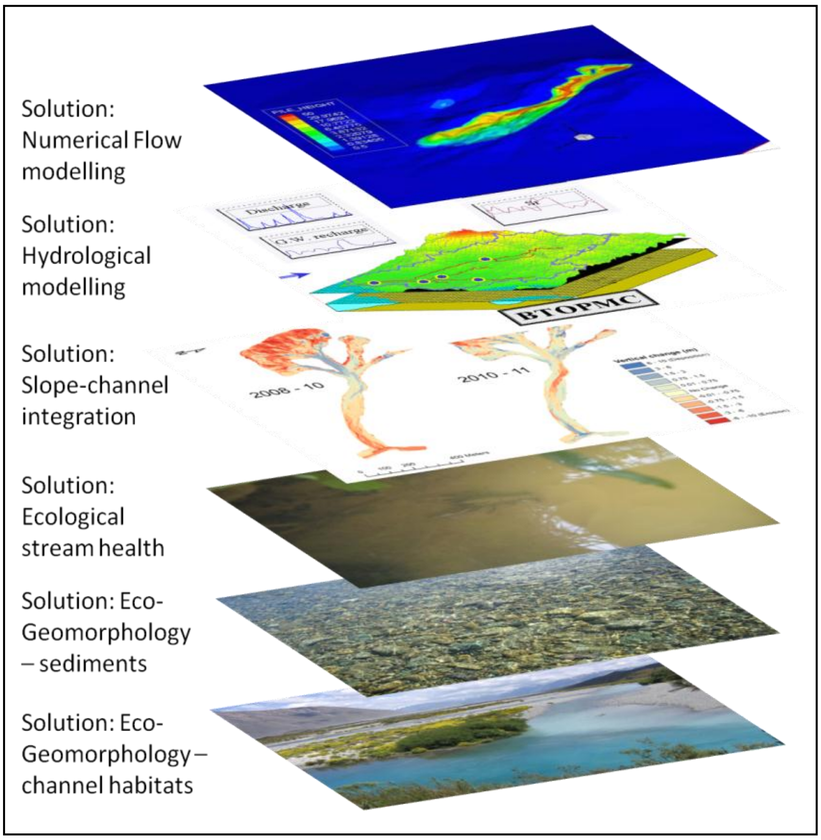

Figure 6. An example of a multi-layered, integrated approach providing holistic river science for river management, which is informed by geomorphology, ecology and hydrology and the various tools offered by these disciplines.

The Prospect

To work towards providing innovative solutions for river management in New Zealand, requires:

1. Development of catchment-scale integrated modelling tools to assess land and water management strategies. Since the issues of river management must be understood at a catchment scale, an approach recognising the connections between catchment components (catchment connectivity) is essential, both in a hydrological (water) and geomorphological (sediment and landforms) context. These parameters in turn impact stream ecology. For example, riparian planting is recognised as part of an effective strategy to manage effluent runoff from agriculture, but to maximise the benefit to stream health requires understanding of flow pathways in a catchment. Similarly catchment afforestation is being proposed as a means to reduce river sediment loads and delivery of fine sediment, the sedimentation of which has a potentially negative impact of stream biota in gravelly streams. The impacts of afforestation are not immediate, due to potentially long residence time of alluvium in successive stores within a catchment (slopes, channels, floodplains), thus catchment connectivity is important to define.

2. Establishing field laboratories with shared and multiple use field experiments and monitoring sites bringing together geomorphology, ecology and hydrology expertise. In-field monitoring provides important data to underpin the integrated science and understanding of catchment function.

3. Connection with key end-users tasked with the complex challenges of managing our rivers. This is vital if the science of points 1 and 2 is to be effective and have an impact on river management. This means that integrated river science must engage with the community of end-users, which includes Unitary Authorities, agriculturalists, land-owners, environmental groups, planners and the general public. If river management in New Zealand is to be truly innovative, public opinion will need to be convinced of the need and the benefits.

Conclusions

This paper has outlined the need for a new, innovative approach to river management in New Zealand, which has traditionally been the realm of river engineers. To deal with the challenging complexity of the nation’s diverse river systems needs a more expansive approach to management than any one subject area can provide. To meet the needs and challenges requires a holistic approach to river management that draws from a range of disciplines allied to river science. To be successful, river management must be both grounded in integrated science and connected with key strategic end-users. Such integrated and connected science provides a way forward towards a more innovative approach to solve the issues involved in river management in New Zealand.

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