The 'Physical Form Five': Weaving strategic geomorphology into waterway management

Geoff Vietz[1], Christine Lauchlan-Arrowsmith[1], Greg Peters[1]

1 Streamology, Melbourne, Victoria, 3000. Email: geoff@streamology.com.au

Key Points

- Proactive management and long-term thinking are critical to the future of our waterways
- Physical form and functioning, also referred to as geomorphology, provides the basis for this
- The 'Physical Form Five' is a set of geomorphically-based principles for waterway management
- The development and adoption of high-level principles is critical at all levels of the waterway industry to ensure we can support ecological, economic and community/cultural waterway values

Abstract

When it comes to waterway management it is increasingly understood that "*long-term thinking is required to continue the emerging trend away from reactive management to proactive and strategic planning – particularly in how to respond to future natural disasters, and climatic and environmental change*" (Russell et al., 2023). The field of waterway geomorphology, also called physical form management, is central to this. Yet, guidance is commonly focused on engineering works, and there is a lack of guidance on the fundamental geomorphic understanding required for more strategic, long-term and sustainable waterway management. This requires efforts from the industry as-a-whole to weave knowledge into management at all levels from statewide decision making to on-ground implementation. To address this, a two-year project developed a framework to integrate physical form and function into guidance for waterway management, supported by the Victorian government. This led to the team developing, amongst other elements, a set of overarching geomorphically-based principles, referred to as the 'Physical Form Five'. Whilst developed for Victoria, these principles are broadly applicable in an Australian context and could be used globally. The Physical Form Five principles assist decision-making for waterway management, apply over a range of time and spatial scales, and should provide a precursor to all intervention programs. The principles are not stand-alone guidance and must be woven into guidance at all levels. The challenge is in obtaining an agreed pathway that ensures support and adoption with multiple stakeholders including managers, practitioners, and community.

Keywords

Waterway, stream, management, geomorphology, fluvial, works, catchment

Introduction

Protecting and maintaining the physical form and processes of waterways is critical to supporting landscape character and diversity, and the future of ecological, social, cultural and economic values integral to our aquatic systems. It is internationally recognised that dynamic and complex waterways are also more resilient and are of critical importance to the provision of ecosystem and ecological values (Wohl et al. 2015) and that we must work toward understanding fluvial geomorphology to work *with* waterways (Fryirs and Brierley, 2021). In the Australian waterway management industry, we have guidance on geomorphic categorisation and catchment understanding, and 'works in waterways' manuals, but we don't have accessible guidance for the 'when' and 'how' of waterway management. As a result, this understanding of the role of physical form and function, the overarching approach to dealing with river response, and its incorporation into management, is not evident in a significant proportion of waterway works. Clear direction is required on managing the physical form and function at all levels of management.

This paper focuses on overarching principles for waterway management. It is one component of a project developed by a team of consultants for the Department of Energy, Environment and Climate Action (DEECA) that aims to clarify waterway management challenges, linkages to values, stressors to physical form and functioning, and waterway typologies. We consider waterways to cover streams, rivers, creeks and their associated floodplains, and also recognise connections to wetlands, and estuaries. The high-level nature of the principles presented here means they are broadly applicable across the Australian landscape, in both urban and regional settings.

Physical form importance and management paradigms

While channel reconfiguration projects, including rock protection, often include objectives to improve instream ecological condition, whereas there is evidence highlights that they rarely do (Laub et al., 2012; Sudduth et al., 2011; Violin et al., 2011). We know that waterway physical form (e.g. pools, riverbanks and sediments) and processes (e.g. the way in which flow, sediment and vegetation interact) play an important role supporting not only ecological, but ecosystem, social, cultural, and economic values. The most recent review of the Victorian Waterway Management Strategy (RMCG 2021) highlighted that physical form and function (geomorphology) has lacked consideration, suggesting we '*Continue to build an understanding in some areas, such as physical form and functioning (geomorphology)*'. This focus on 'hydromorphological' qualities, such as river bank structure, river continuity or substrate of the river bed, has international precedence (UNEP 2020).

Current waterway management challenges will not be solved by further detailed works guidance (e.g. rock protection approaches), leading the practitioner to an interventionist approach predicated on 'control' (our historical waterway legacy). Rather, to achieve sustainable, long-term benefits, and increased waterway resilience, requires a paradigm shift from 'channel stability' as a goal, to opportunities for working with rivers by understanding them. This will ultimately achieve greater gains with less effort. The Physical Form Five provides a step toward addressing these challenges by providing an improved approach to understanding and managing the physical form and processes of waterways.

Physical Form Five principles for waterway management

The Physical Form Five is a set of geomorphically-informed principles for waterway management, Figure 1. The intent is to provide a high-level, reasonably simple set of principles for Victoria that informs the management of physical form and function as it relates to its intrinsic values, and to the values it supports (e.g., social, ecological, cultural). These principles should be understood by a range of stakeholders, from the public to the on-ground waterway works team to the state level policy makers.

Drawing upon geomorphic 'think tanks', and many geomorphic brains in Australia, these principles reflect, build upon, and formalise many of the ideas previously developed. This includes documents such as: 'Improving our Waterways: Victorian Waterway Management Strategy (DEPI, 2013)', the 'Stream Rehabilitation Guidelines for Queensland' (McPhail et al., 2018), River Styles™ (Fryirs and Brierley, 2021), and the 'Channel Form and Function Position Paper for Melbourne Water's Healthy Waterways Strategy' (Smith and Vietz, 2010, unpublished), amongst others.

Figure 1. Overview of the Physical Form Five principles as they relate to waterway and catchment management that considers geomorphic theory and working *with* waterways (Diagram developed by Streamology and Ooid Scientific).

Principle 1 - Value form and process

1a Recognise physical form and processes in waterways

Physical processes in waterways play an important role supporting social, ecological, cultural, and economic values. The physical character, and dynamics, of waterways also have a value in their own right, that is increasingly being recognised, such as the way it shapes a landscape, or creates a unique feature.

Of all the legacy impacts on waterways (such as water quality, regulation, vegetation removal), modification of physical form is among the most difficult to restore. The hysteresis[1] of physical form means that it is very difficult to return to a prior state. Hence, protection of physical form as an inherently dynamic process is a waterway management priority, and should be a key goal for preserving waterway values into the future.

Broadly, the protection of physical form and process includes:

1) the features within the river channel which may include bars, benches, pools and substrates, and the many other elements, many of which provide for habitat that support ecosystem, ecological and social values
2) the floodplain and its interactions with the river channel
3) the processes that maintain the dynamic, and self-regenerating nature of the river channel and floodplain.

It is recognised that waterway type can modify the focus. For example, in confined reaches there is a focus on channel processes and the flux of fine-grained sediments (e.g. too much or too little?), in unconfined channels the floodplain and groundwater connections are integral (e.g. have these connections been impacted?), and in artificial channels the 'least harm' principle to upstream and downstream waterways should be the focus (e.g. what do these works mean for channel incision upstream?). The starting point is to map the otherwise poorly represented physical form values across a range of setting.

1b Rivers move and change: natural rates of erosion and deposition are to be encouraged where possible and beneficial to associated values.

A healthy waterway is unlikely to be a stable, 'fixed in place' channel. We now know that physical interventions that attempt to stabilise all/most stream movements can result in waterways with low ecological diversity and reduced ability to support instream values such as fish and aquatic mammals. We also know that direct disturbance to the dynamic balance of a waterway can lead to localised bank instabilities and subsequent excessive erosion and deposition that may require intervention. We must accept and support natural rates of channel erosion and deposition where possible and only consider physical form interventions in waterways where significant values (environmental, social, cultural or economic) are threatened and no acceptable alternative (e.g. relocation of infrastructure) can be identified.

Recognising and supporting waterway processes enables resilience, as distinct from resistance. Resilience allows a waterway to not only withstand perturbations, but also self-regenerate and recover following them. Any actions undertaken at a site should at least result in the site, reach or catchment being better able to cope with, and mitigate, future climatic and hydrological events. Protecting both physical form AND process should be a core goal within any waterway management strategy.

We can build resilience into the system by:

1) considering likely climatic conditions that will influence future waterway conditions
2) considering the waterway corridor and opportunities for river channel movement
3) focussing on working with processes instead of physical form

[1] Hysteresis – the idea that sometimes the way to reverse a change is different than just reversing what caused the change in the first place.

4) considering opportunities for, and the benefits of, riparian vegetation in supporting physical form and function
5) reducing reliance on 'resistance' approaches, and inflexible options, such as rock protection.

Principle 2 - Create corridors

Rivers need room and space

Waterways are more than their channel as they include the floodplain. By considering the channel more broadly as a 'waterway corridor', the opportunities for management can be more holistic and better able to work with natural processes. This enables all activities and structures within the waterway corridor to be considered in terms of their current or future interactions and impacts.

By managing the waterway corridor our approaches can be less reactive and more efficient and effective in the long-term e.g. creating system resilience. One of the most important strategic management actions is to avoid future problems by providing floodplain space for waterways to move and change. It is imperative to protect existing floodplain space from encroachment, such as infrastructure, inappropriate land uses, or flood levee banks. The key directive is to: Broaden the scope of waterway physical form and process management by considering, and referring to, the waterway or waterway corridor, rather than the river channel.

Principle 3 – Think about the system

3a Recognise and manage the whole fluvial system

The fluvial system is not just the main-stream channel, it is also the small headwater catchments, the tributary streams, floodplains, and floodplain channels and wetlands, and the groundwater/hyporheic zone. Catchment and reach scales are where actions will achieve the greatest outcomes.

3b Address the cause, not the symptom: by thinking big

Often, local physical form issues can be the consequence of larger scale changes in a waterway system. In these circumstances, catchment and reach scale interventions are where actions may achieve the greatest outcomes. To avoid simply treating symptoms without thinking about the context, and particularly the root cause of the problem, the waterway manager needs to understand how physical form stressors (e.g. sediment regime changes, streamflow alteration) and threats (e.g. excess sediment, excess streamflow) impact physical form indicators (e.g. bed substrate, large wood) and key ecological values (e.g. fish, macroinvertebrates, vegetation, and platypus). A key example is the role of excess runoff to streamflow from urban or urbanising areas, yet we increase channel size, line it with rock and pass on the problem (Vietz and Hawley, 2019). In waterway management we often see a band aid on a broken leg. Think 'outside the channel' to ensure you are tackling the cause and not the symptom (Vietz et al., 2016).

3c Protect and restore connections: look upstream, downstream, out to the side and at your feet

Waterways are part of a connected catchment system. Streams are conduits of water and materials, downstream, but also onto the floodplain and into the hyporheic zone. This movement should be protected and enhanced where possible. Note that by intervening in a stream you can be harming others upstream and downstream, but also restricting the opportunities of future generations.

Address physical form issues using the following intervention hierarchy:

1. Halt or modify the threatening activity (stressor) causing the altered physical form/process.
2. Address the direct threat/s (resulting from the threatening activity) to physical form/process.
3. Intervene to control the altered physical form/process.
4. Manage the impacts resulting from the altered physical form/process.

Assess site-based interventions within a whole-of-landscape context, considering the physical form processes occurring within the broader reach or catchment scale. To enable this, the waterway managers need to be aware that stream interventions, whilst planned to improve conditions and values at a site, may negatively impact waterway conditions or values up and downstream. Consider both the positive and negative impacts of interventions and prioritise interventions based on the best net benefit to the waterway and its connected catchment system.

Principle 4 - Understand your waterway

4a Determine what will happen if you do-nothing, or do-something

Understanding what happens if you do nothing is the cornerstone of management, and it is not only the base case against which all other intervention options should be compared, but also the first option available to the waterway manager, e.g. the do-nothing scenario. It may be that after building a geomorphic trajectory under a do-nothing scenario, no further action is taken.

Alternatively, the do-nothing scenario may reveal that some form of intervention is required or beneficial. We can't manage physical form and process if we can't predict what will happen without intervention. Our capacity to predict future change has improved substantially. Develop and utilise geomorphic trajectories of channel change to:

- identify future impacts to waterway values under a no intervention option
- determine if intervention is required or beneficial
- estimate the scale of intervention required to manage impacts and protect values.

A waterway trajectory is a prediction of the future changes in waterway form, condition, and processes. Wherever possible, the best available data and conceptual models should be used to quantify the rate of channel change, and the timescales involved in predicted future channel changes. Waterway managers can use the understanding of the waterway system gained by identifying waterway values, threats, physical form processes and impacts, and by considering climate change, to develop a trajectory for the study site, reach or catchment, providing not only a management tool, but also a communication tool.

4b Don't repeat the mistakes of the past

Waterway management is subject to fashion and habit. We often continue to manage in ways that could be improved upon review and reflection. Mistakes are valuable learning experiences if used to do better next time. Ensure that the maintenance, repair or reinstatement of past waterway works considers: both the waterway benefits and the impacts of the works i.e. do they remain fit for purpose?; the objective for management i.e. are the works protecting public or private assets?; and alternative ways to protect assets into the future e.g. via infrastructure relocation. Provide direction and advice to ensure that the design and location of new infrastructure will not impact, or be impacted by, the natural physical form and processes of waterways.

Principle 5 - Vegetate

Vegetation is physical form's best friend

Vegetation is as critical to the physical form and processes of waterways as water and sediment.

Vegetation in the channel, on the banks and on the floodplain is the key natural control and, in most cases, the most effective long-term solution to slow meander migration rates. Compared to rock beaching, vegetation delivers multiple, complementary benefits such as: carbon inputs; a source of in-stream wood; habitat for terrestrial fauna; shading; filtration of catchment runoff; suitable banks for platypus burrows; and lower overall cost. It also allows greater channel complexity and natural processes, has significantly less

detrimental geomorphic effects downstream and is increasingly been considered as a form of "nature based" solution for flood mitigation (Fryirs et al, 2023).

Where the cause of a threatening activity cannot be managed, promote and utilise native vegetation as the key intervention option (both strategic and responsive) for reducing accelerated bank erosion. Managers should ensure that selected plantings include species with root systems that will cross potential failure planes i.e. by matching the rooting depth of the vegetation with the size of slumps (Price and Lovett, 1999). Some examples of useful plant species include: *Eucalyptus camaldulensis*, *Callistemon sieberi*, *Lomandra longifolia* and *Phragmites australis*.

Aim for the minimum level of engineering required in cases where native vegetation alone is considered insufficient to effectively reduce accelerated bank erosion.

Incorporating Traditional Ecological Knowledge

The process for the development of the Physical Form Five can be enhanced and complemented by the incorporation of Traditional Ecological Knowledge (TEK), which can be weaved into a more considered and comprehensive set of guidance. By virtue of ongoing two-way learning we can build upon shared approaches that closely align with the principles outlined here, such as the notion of the 'living river', e.g. 'Waring will find its way' (Taungurung, undated). We acknowledge and respect the Traditional Owner's deep spiritual connections, and their unique ability to care for Country, recognising that these principles can be enhanced through TEK and guidance, and that ongoing learning and engagement is required for all aspects of waterway management to protect our water and waterways.

Conclusions

The Physical Form Five principles are: 1) Value form and process; 2) Create Corridors; 3) Think about the system; 4) Understand your waterway; and 5) Vegetate. We propose that these principles can be woven into myriad levels of guidance for waterway management across Australia, and more broadly. There are, of course, challenges in achieving the Physical Form Five principles, in particular:

1. Reducing our reliance on reactive works, by encouraging proactive management through informing and applying our understanding of geomorphic processes and trajectories e.g. minimising highly-localised interventions such as the reliance on rock protection through consistently documenting likelihood and consequence (risk) and recognising alternative, more strategic options.
2. A lack of understanding of the links between physical form and ecological outcomes e.g. the role of physical form in supporting ecological values, such as how fish might use undercut banks or refuge pools as shelter or how macroinvertebrates rely on bed sediments and plants (to demonstrate the often negative implications of business as usual approaches to stabilisation).
3. Community expectations often consider that waterways remain static and stable, through extensive and ongoing communication and engagement throughout our broader industry and stakeholders, e.g. education/awareness regarding channel migration as a naturally important and commonly self-correcting process.
4. Recognising the floodplain as an important part of the waterway, providing room for the river and reconnecting waterways to floodplains, e.g. to accommodate river processes and support riparian vegetation.
5. The increased loss of intact river systems, i.e. once modified these waterways are difficult to return to a pre-modified state. We must ensure that waterway management is proactively seeking opportunities rather than reacting to development or planning requests.

We see a paradigm shift as we move from 'channel stability' as an ultimate goal, to considering opportunities for working with rivers by understanding them. Enabling greater gains with less effort. To do so requires

identifying an agreed pathway that ensures support and adoption with multiple stakeholders including managers, practitioners, and the community, all of which must incorporate Traditional Owners. This leads to a 'strawman' vision for waterway management, and hopefully some inspiration that our efforts in the industry can achieve more if we all look long-term:

> *Waterways that are living features with a unique character and behaviour that represents the landscape and its interactions, and connects along and across landscapes and people. Waterways that are accommodated with space in which they demonstrate physical diversity and processes (e.g. migration and avulsion), that are supported to be resilient through activities such as revegetation and flow stress management, and that are self-sustaining and require less active management. Waterways that can best support a range of physical, ecological, social, cultural, and economic values, becoming the envy of the country and abroad.*

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