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Developing a Focused Vision for River Rehabilitation: the Lower Snowy River, Victoria

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SUMMARY: The initial step in establishing a vision for rehabilitation is to establish an ideal goal for ecological rehabilitation. This requires reconstruction of the ecological, hydrological and geomorphic conditions that existed before the river was disturbed on a large scale by human intervention. This forms a template from which a politically, economically, biologically, hydrologically and geomorphologically realistic plan for rehabilitation can be derived through negotiation between stakeholders. Application of this concept to the lower Snowy River reveals that the current emphasis on determining environmental flow allocations could be misguided.

MAIN POINTS

- A vision for rehabilitation is a template usually based on the pre-disturbance condition
- The vision provides a durable reference point from which realistic rehabilitation objectives can be determined
- Environmental flow recommendations only address some of the environmental problems on the Snowy River
- Science can assist, but not resolve, the problem of setting objectives for river rehabilitation

1 INTRODUCTION

The headwaters of the Snowy River are located in the Australian Alps in New South Wales. Of the total catchment of 15,800 km^2, 6,500 km^2 is situated in Victoria. The majority of the Victorian catchment is uninhabited and relatively inaccessible National Park land. Below Jarrahmond gauging station, where the river debouches from the foothills onto a vast alluvial fan, the land (the Snowy Flats) is cleared and utilised for agriculture.

The Snowy Mountains Scheme (SMS) is a complex system of diversions, impoundments and hydropower stations that effectively transfer water from the Snowy River to the Murrumbidgee and Murray Rivers. The SMS began to affect flows in the Snowy River in January 1955; by April 1967 regulation was complete, with the closure of Jindabyne Dam (Brizga and Finlayson, 1994). It is now widely recognised that this regulation of flow has led to environmental degradation of the Snowy River (and other rivers). A Federal Government inquiry has recently concluded an investigation of the environmental issues arising from the current pattern of water flows caused by the SMS (Snowy Water Inquiry, 1998). Options were considered that maintained or improved environmental values, but which did not threaten the continued viability of the SMS. The final recommendation to Government was to increase flows from Lake Jindabyne from the current release of about 1% of mean annual flow to 15% of mean annual flow. This is considerably less than the value of 28% of mean annual flow being demanded by interest groups in Victoria (e.g. Snowy River Alliance, 1998). This value of 28% originated in the recommendations of a so-called "expert panel" (SGCMC, 1996). The East Gippsland Catchment Management Authority has recently undertaken a study, complementary to the Snowy Water Inquiry, to identify works, supplementary to increased flows, that will lead to improved environmental conditions in the Victorian part of the Snowy River (ID&A, 1998).

Rehabilitation of the Victorian Snowy River has clearly been perceived by local interest groups as essentially an environmental (instream) flow issue. The Snowy Water Inquiry was also essentially an investigation of how best to distribute flows to improve environmental values, while attempting to maintain the *status quo* as far as irrigation and electricity generation was concerned. The assumption that flow regulation was responsible for the perceived degraded state of the river has given rise to the commonly held belief that implementation of a suitable environmental flow release strategy will rehabilitate the river.

The process of developing a vision for rehabilitation of the Victorian Snowy River has never been undertaken. It is not surprising then that a coherent vision has never been articulated, let alone agreed, by stakeholders. This paper reviews the concept of establishing a vision for ecological rehabilitation. The pre-disturbance condition of the Victorian Snowy River was reconstructed by critical examination of the available literature and data. Available data were examined with a view to establishing the most likely agents of environmental change. The environmental condition of the river at the time of regulation by the SMS was hardly pristine. The implication is that restoration to this condition (the implicit goal of flow restoration in isolation) may not necessarily be ideal from an ecological perspective.

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2 A VISION FOR REHABILITATION

Most river management has been undertaken under the paradigm that emphasizes control over geomorphological and hydrological processes, and often involves introduction of artificial (or alien) elements. The corresponding vision is of a river that is predictable in its behaviour, and efficient in economic terms. There is plenty of evidence in the literature that this approach impacts ecological communities - impacts that are often termed degradation. Degradation is to reduce worth - a concept that is concerned with human values. Perhaps partly in response to widespread physical, biological and chemical degradation of streams worldwide, the stream rehabilitation movement is challenging this dominant paradigm of control. Vision, in the context of ecological stream rehabilitation, is the perceived ecological potential of the stream. A currently fashionable vision is the condition of the stream as it existed prior to significant disturbance by humans.

The origin of the concept of vision for rehabilitation appears to be *Leitbild*, a geomorphologically-based classification scheme developed in western Germany to define the desired end state for restoration (Kern, 1992). The literal translation of *Leitbild* is "model", but in the context of its use by Kern (1992) it means "guiding image". The *Leitbild* is an ideal solution involving restoration of all natural stream and floodplain properties, ignoring economic and political factors that may act to limit to adoption of this option. Kern (1992) recognised that only in very few cases would this option be feasible. However, the model can be used to identify realistic and achievable goals, by incrementally removing elements of the vision from consideration based on current political, economic, or practical constraints. This could be termed a top-down approach. The vision is a fixed reference point that can be revisited in the future as economic, cultural, and political factors change.

Pristine condition refers to the so-called "primitive" or "original" state that existed prior to intensive and wide-spread disturbance by humans. In many places the period of major disturbance would have corresponded with rapid population expansion. However, significant cultural changes that affected the patterns of land use would also have been relevant, as would have occurred during the agricultural and industrial revolutions for example. However, the pre-human disturbance date is just an arbitrary reference point. In much of Europe, river landscapes have been directly and indirectly modified for so long that it may not be possible to determine the pristine condition due to lack of data. In such cases, the earliest date for which data are available usually determines the reference point. However, data from reference (relatively undisturbed) sites and better documented comparable sites in other areas can be used to help reconstruct the pre-disturbance conditions. A complicating factor here is that if significant climatic change has occurred, it may be impossible to return a river to its original or pristine (pre-human disturbance) condition, even if it was fully restored and the whole catchment designated a wilderness area.

Sometimes the pre-disturbance condition may refer to conditions that prevailed prior to a *specific* disturbance, such as widespread catchment deforestation, channel de-snagging, or flow regulation. However, the terms "original" and "pristine" should probably be reserved for conditions that applied prior to widespread and intensive human disturbance. The term "natural" can mean "not affected by man or civilization" (Collins English Dictionary). Although the term "close to nature" is synonymous with rehabilitation in some European countries and in Japan, the term "natural" is too ambiguous to be of any real value in describing the condition of a river or stream. In any rehabilitation project it is important to explicitly state the historical time period to which "pre-disturbance" refers, and to describe the conditions that prevailed at this time.

To establish a vision for rehabilitation based on pre-disturbance conditions is simply to produce a template that may help shape the desired outcome. The vision describes a condition that was probably, at a previous time, (putting definitional problems aside) ecologically sustainable. This is a logical reference point, if the goal of river management is to maintain an ecologically diverse and sustainable system (as proposed by Brookes and Shields, 1996, p. 385 for example). However, rivers have many other (non-ecological) values, some of which may be mutually exclusive and/or incompatible with this ecological goal. The template of a pre-existing system that was sustainable could provide the common ground to an otherwise disjointed or uncooperative group of stakeholders. Conflicts could be resolved through a combination of scientific and economic investigation, negotiation, compromise, or even voting by majority. In the process, some elements of the template would be modified, scaled down, sacrificed, or traded for alternative elements. It seems unreasonable to expect any single group (e.g. "expert panel") to be able to establish a set of integrated, achievable and acceptable rehabilitation objectives prior to and independently of this process. An appropriate metaphor is the (native American) aphorism that "it is easier to ride a horse in the direction that it is already going".

A weakness of many restoration projects to date has been their narrow focus, either in terms of the expected outcomes, or their limited spatial scale (Brookes and Shields, 1996, p. 11). Establishing an appropriate vision allows stakeholders to take an holistic view of the system. The current stream condition can then be understood within the historical context of catchment and channel change. Realistic rehabilitation objectives are more likely to be a set of specific objectives for certain river reaches, plant or animal species or community, chemical or physical features, or aesthetic or recreational values, rather than a well-intentioned but nebulous proposal to rehabilitate a stream to what is perceived to be a more "natural" condition.

3 CONDITION OF THE VIC SNOWY RIVER

3.1 Hydrology

The lower Snowy River (Snowy Flats area) has long been subjected to high magnitude flooding. If the flood mark at F. Mundy's ("Avalon") is to be believed (see RWC, 1988), by far the largest flood in historical times occurred in May 1870, not long after settlement. In terms of peak magnitude, this flood could have been more than double that of the largest recorded floods (in 1934 and 1971). Floods having a peak discharge between 40,000-170,000 ML/d have occurred regularly from 1922 to the present time, with their frequency (for a given discharge) being unaltered after regulation.

The most dramatic change to the hydrology of the lower Snowy River brought about by regulation has been storage of low magnitude spring snow melt floods in Jindabyne dam. This has resulted in a much reduced frequency of occurrence of flows between 2,000-30,000 ML/d. Regulation reduced the mean annual flow at Jarrahmond by 45%. Low flow events now occur more frequently (James, 1989). Analysis of rainfall records, examination of land use changes, and generation of a synthetically generated post-regulation natural flow record (i.e. simulated unregulated conditions) suggested that these recorded changes in the flow regime post-regulation were primarily due to regulation by Jindabyne dam (James, 1989).

3.2 Geomorphology

E.L. Bruce drafted a detailed map of the Snowy Flats area based on a survey done in 1865. This map pre-dates any significant development or clearing of the floodplain. The map shows riparian vegetation patterns, plots the boundaries of the wetlands, and depicts the course of the lower Snowy River.

It is a commonly held local belief that the Snowy River more than doubled in width in the first 15 years of European settlement (Seddon, 1994, p. 232). Finlayson and Bird (1989) dismissed this widely held view on the basis of insufficient evidence. However, they ignored E.L. Bruce's map, which depicts the river as being 50-100 m wide in 1865, whereas 1934 surveys show it to be 375 m wide at Lynn's Gulch and is up to 150 m wide at Gilbert's Gulch. Available data suggest that the river widened catastrophically in the very early period of European settlement. The catastrophic flood of 1870 was a possible cause of, or trigger for, this widening. Other cases of rapid channel width change due to large discharge events have been reported in the literature (e.g. Brookes and Shields, 1996, p. 133). Other factors that could have contributed to rapid widening are clearance of riparian vegetation by the first settlers, and the removal of large woody debris by the early snagging parties.

In an attempt to explain the persistent claims from locals that the river was aggrading, RWC (1988) suggested that the low regulated flows could have created an illusion of aggradation, because a greater percentage of the bed was now exposed. Wasson and Pulsford (1993) examined the evidence and concluded that "*there is no systematic aggradation occurring*". In contrast, The Snowy River Improvement Trust (1993, pp. 10-17) held the view that "*Sand deposition has increased in the lower Snowy River since European settlement...*"

While the "illusion" theory of bed aggradation appears to have some merit (Brizga and Finlayson, 1994), this does not preclude the possibility that the nature of the dominant bed form changed after regulation. Bedforms partially determine habitat availability. The fish communities that reside in the lower Snowy River require the availability of pool habitat and adequate depth of flow to allow passage for migration. The current bedform of the river, variously termed flat and featureless, shifting sand, plane bed or sand-choked is thought to provide poor habitat conditions because of the lack of deep pools (Raadik and O'Connor, 1997). It is commonly asserted that, prior to regulation by Jindabyne dam, the lower Snowy River had more pool habitat available because of the dominant presence of alternating bar morphology.

Brizga and Finlayson (1994), Erskine and Tilleard (1997) and Stewardson et al. (1997) reviewed the evidence for the assertion that alternating bars existed prior to, but not after, regulation. The evidence is in the form of aerial photographs and anecdotal evidence. The other approach taken to this problem has been to determine the flow conditions that are conducive to alternating bar formation, and then compare the frequency and duration of such "bar forming flows" before and after regulation (Stewardson et al., 1997).

The quality of physical habitat provided by alternating bar morphology compared with that provided by the current relatively flat bed is undisputed in the literature. This is not because of the desirability of the bars *per se*, but the deep pools that seem to be associated with this bedform. There is photographic evidence that very well-formed alternating bars existed in certain parts of the river prior to regulation. The bars only ever formed in the straight reach down to Lynn's Gulch, and a short reach near Gilbert's Gulch (i.e. where the river has over-widened) (a total of 10.2 km of channel). As it appears that the river at least doubled in width in these sections some time between 1870 and 1920, then it is possible that alternating bars did not exist prior to

European settlement because the channel would probably have been too narrow. Alternating bars formed post-regulation, but the evidence suggests that they were not as strongly defined, as frequently occurring, or as widely distributed as they appear to have been prior to regulation.

3.3 Water Quality, Including Salt Wedge Penetration

It is unlikely that regulation of flows by the SMS has significantly altered water quality of the Victorian Snowy River. In terms of suspended solids, turbidity, pH, dissolved oxygen and water temperature, water quality since regulation has been well within the range desirable for protection of aquatic ecosystems, and similar to that of the Thurra River, a neighbouring unregulated stream draining a relatively undisturbed catchment. However, nutrients have been elevated on occasions (Data from Water EcoScience).

There is little doubt that regulation of the Snowy River has allowed tidal saline water to penetrate further upstream for longer periods. Modeling predictions suggest that the median position of the salt wedge shifted about 2.7 km upstream after regulation (ID&A, 1998). The area below chainage 7 km to chainage 2.5 km suffered the greatest increase in the duration of saline water being present in the channel. At 4.5 km, the river was more often fresh before regulation, but now it is more often saline. While these changes are quite distinct, they should be seen as relatively minor alterations to the margin of the estuary, rather than representing a fundamental alteration of the character of the estuary. There is no strong evidence linking changes in the position of the salt wedge since regulation to die back of riparian vegetation and/or erosion of river banks (as claimed by Owen, 1977).

3.4 Riparian Vegetation

Prior to European settlement, the riparian vegetation along the Snowy River Flats consisted of areas of Warm Temperate Rainforest some 200-500 m wide. In other areas the dominant vegetation was Mahogany Forest and Schlerophyll Forest, while in some areas the lower banks were covered in ferns. The majority of this riparian vegetation was cleared by early settlers. The banks are now mostly covered by either narrow remnant stands that are infested by weeds, or by kikuyu and willow. Owen (1997) estimated that 70% of the area is dominated by these exotic species.

It appears that the original vegetation of the Snowy Flats was important in that it contained an impressive diversity of plants, and unique stands of Mahogany Forest and Warm Temperate Rainforest. There are only a few patches of remnant vegetation remaining. The original 1865 map of vegetation distribution by E.L. Bruce and the floristic descriptions by von Mueller (1854) provide an ideal template of the pre-disturbance vegetation distribution.

3.5 Floodplain Wetlands

Prior to European settlement, the Snowy Flats area was a vast wetland system. The first explorers and settlers on the lower Snowy River Flats apparently encountered "*jungle, swamp and fertile soil*" (Seddon, 1994, page 259). Apart from the lower estuarine lakes, which remain intact, there is only about 2-3 km^2 of wetland on the floodplain (representing <4% of the 1870 area). Ephemeral wetlands have been removed almost entirely. Most of the wetland destruction occurred in the first few decades of settlement through clearing and drainage. Expansion of channel capacity through widening, and construction of levees probably reduced the frequency of flooding in some areas, and continued grazing and cropping have prevented regeneration of wetland plants.

The loss of ephemeral wetlands from the floodplain (along with the loss of riparian vegetation) is arguably the most dramatic historical alteration in the character of the lower Snowy River environment.

3.6 Instream Habitat and Ecology

The lower Snowy contains a highly valued fish fauna consisting of 17 native fish species (Raadik and O'Connor, 1997). Most concern seems to be directed at the perceived deficiency of habitat for Australian Bass, which requires deep water.

Despite the perceived differences in habitat quality at their fish sampling sites, Raadik and O'Connor (1997) found that "*Species diversity was relatively high and similar at all sites...No dramatic differences were noted in the species composition between the degraded sites (Jarrahmond and Sandy Point) and the reference site (Jackson's Crossing), though there were some variations in abundances.*" In fact, the Jarrahmond site had a much greater abundance than the other two sites, with the reference site scoring the lowest abundance. Raadik and O'Connor (1997) explained this unexpected result in terms of ease of sampling at Jarrahmond due to the shallowness of the water, and the lack of habitat causing the fish to congregate in a small area. It could also be that their notion of what constitutes suitable habitat was flawed.

Macroinvertebrate survey data (Butcher et al., 1994; Chessman, 1979) indicate that most of the recorded taxa were typical of families that are able to live in a wide range of habitats, with a smaller number of taxa typical of upland cool waters, and some being typical of warmer lowland waters. No taxa were found that favour excessive nutrient or organic enrichment and/or a high concentration of suspended solids. In contrast, Lake (in SGCMC, 1996) described the macroinvertebrate fauna of the Snowy River just above Orbost as typical of a river subject to considerable disturbance and temperature fluctuations. Most of the fauna were confined to the littoral edges. Raadik and O'Connor (1997, p. 46) noted that the spatial distribution of fish was similarly restricted, but admitted that "*historically [i.e. pre-regulation], the majority of the instream habitat would also have been located along the edges of the stream, and around the instream vegetated sandbars.*"

Large woody debris (LWD) is recognised as an important structural and ecological component of many stream environments (Gippel, 1995). The current small loadings of LWD in the Lower Snowy River probably restricts the distribution and abundance of most instream organisms (ID&A, 1998). There is little doubt that the Snowy River below Jarrahmond gauge once contained a high loading of LWD. Snags were initially removed to improve navigability of the river. A second phase of snag removal occurred during the period 1932-1941. In an effort to control the perceived build up of sediment, the Snowy River Improvement Trust spent a large proportion of its funds in the 1950s on de-snagging the river.

The issue of availability of pool habitat is inextricably linked to the issues of bedforms, sand transport and flow levels. Strong claims have been made that pools were common in the river for at least 30 years prior to regulation. However, it appears that this type of morphology only ever existed in a limited area of the river. The hydrological and geomorphological conditions under which alternating bars form are not fully understood. However, it appears that conditions were less than ideal after regulation (Erskine and Tilleard, 1997; Stewardson et al., 1997).

It has been hypothesised that post-regulation, excessive transport of sand has in-filled pools, thereby reducing habitat availability. The availability of sediment for transport does not appear to have altered remarkably in historical times. However, the post-regulation decrease in frequency and duration of flows with the capacity to scour bed sediments, combined with an increase in duration of flows that are high enough to transport sediment but not scour it (<2,000 ML/d) (Erskine and Tilleard, 1987; Stewardson et al., 1997) can explain pool in-filling becoming more dominant. Apart from the nature of the bedforms, water depth is also determined by the flow level, and the average flow level has been lowered by regulation.

4 TOWARDS A REHABILITATION STRATEGY FOR THE VICTORIAN SNOWY RIVER

The process of developing a rehabilitation strategy for the Victorian Snowy River gained momentum when the NSW, Victorian and Commonwealth Governments announced a decision to move towards corporatising the Snowy Mountains Hydro-electric Scheme. This decision involved establishment of an Inquiry that was required to cost options to address environmental problems associated with regulation of flows. Much of the Victorian Snowy River flows through a relatively undisturbed and uninhabited catchment. However, the Snowy Flats area has been utilised for agriculture for nearly 130 years (i.e. beginning almost 100 years prior to regulation).

While regulation has altered some aspects of the flow regime, major changes to the lower river's geomorphology, riparian vegetation, floodplain wetlands and instream habitat occurred in the first few decades of European settlement. Prior to European settlement the river was much narrower, the banks were covered in dense Warm Temperate Rainforest, and the floodplain was a vast wetland system. Regulation has possibly caused a reduction in the frequency of occurrence and distinctiveness of alternating bar and pool morphology, but there is some doubt whether this morphology existed prior to European settlement. Regardless, this morphology only ever occurred in a relatively short reach of the river. Water quality has probably changed very little since first settlement. Fish and macroinvertebrate diversity are as expected for a lowland river in this area. Instream habitat conditions have changed in response to desnagging and flow regulation, but the impact of this change on the abundance of aquatic organisms can only be inferred.

Progress towards a realistic rehabilitation strategy is not being helped by continued uncritical publication of certain myths regarding the lower Snowy River. Despite the availability of convincing evidence to the contrary, the Snowy Water Inquiry Final Report (1998) stated, for example, "*The lower flow regime...has allowed saline water from the estuary to progress some 7-10 km upstream of its pre-Scheme location.*" (Appendix 2, p. 26). The maximum upstream extent of saline water is determined by drought conditions, not regulation, and the median position of the saline wedge has shifted by less than 3 km; "*Both the total fish abundance and native fish abundance are low compared to pre-Scheme.*" (Appendix 2, p. 26). This cannot be stated because no fish surveys were undertaken prior to regulation; "*The shallower pools also result in summer temperatures that are high for trout and native colder water species*." (Appendix 2, p. 27). Available water temperature data show no difference between sites on the Snowy River and the undisturbed Thurra River; "*In addition, the sand slug in the river acts as a partial barrier to the migration of smaller fish.*" (Appendix 2, p. 27) and "*Sand extraction from the river channel is another measure that could form part of an intervention strategy...*" (p. 112). These statements imply that the lower river has an oversupply of sand, but surveys indicate no change in bed elevations since 1920. It is possible that the river aggraded prior to 1920, but there is no evidence to support this hypothesis.

The emphasis on correcting environmental disturbance of the Snowy River through provision of environmental flows seems inappropriate, when much of the disturbance has been unrelated to flow regulation. Regardless, the proposed environmental flow regimes should be viewed with caution. A recent postcard produced by Environment Victoria (1998) states that "*Independent scientific panels have said that a minimum of 28% of the Snowy's original flow needs to be returned to the river to allow it to live again.*" For the record, there was only one panel (SGCMC, 1996), it was not scientific (not all members were scientists, and an arbitrary method, rather than an established and predictive scientific method, was used to derive the recommended flow), and it was not what is commonly regarded as independent (two members had local community interests, and two members were from government authorities responsible for resource management in the catchment).

There is enough information available to establish a vision for rehabilitation of the Snowy River. One way forward is to actively involve the local and wider community in a process of establishing consensus on what a desirable and achievable end-point might be. In the field of river rehabilitation, science cannot provide the "right" answer. Science can make valuable contributions by refuting false notions and providing predictive models of how various components of the environment work. However, it has no power to establish the relative merit of values that the community assigns to the environment.

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