Hydraulic Aspects of Rehabilitation Planning for the Lower Snowy River Channel

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SUMMARY: Plans to rehabilitate the lower Snowy River channel are currently being developed. This paper presents the hydraulic component of this planning process. The available evidence indicates that reduced flows since the completion of the Snowy Mountain Scheme in 1967 has contributed to a reduced presence of pools. There is some concern that the current lack of pools is having a negative effect on native fish populations. This paper examines the natural processes of pool formation and the reasons for the loss of pools. An environmental flow and two structural approaches are proposed to promote pool formation and rehabilitate the channel to its pre-regulation condition.

MAIN POINTS OF THIS PAPER
- Different fluvial processes lead to pool formation and infilling during extreme floods, regular floods, high (within channel) flows, and low flows.
- Flow regulation is the most likely cause of an apparent decreased presence of pools
- Channel maintenance flows may reverse this morphological impact
- If these flows cannot be provided, installation of submerged vanes or deflectors may enhance pool formation

1 INTRODUCTION

Since European settlement along the Snowy River floodplain near Orbost, channel changes have occurred in response to a range of human activities including:

- modification of streamside vegetation,
- removal of large woody debris,
- the damming of low points in the natural channel levees, and
- flow regulation by the Snowy Mountain Scheme.

Historical surveys show that between 1865 and 1934, the width of channel more than doubled (Gippel, 1998). Historical aerial photographs and anecdotal reports show that for a period prior to approximately 1965, an alternate bar bedform created a regular sequence of pools and riffles along this reach (Erskine and Tilleard, 1997). Since 1970, full development of alternate bars has become a rare event. This bedform has been replaced by relatively featureless bed topography lacking pool-riffle variations (Erskine and Tilleard, 1997).

There is a concern that the current lack of pools is having a negative effect on fish populations (Raadik and O'Connor, 1997). There is considerable interest in recreating pool habitats along the lower Snowy River, as part of a river rehabilitation program. The rehabilitation of pools within the existing channel would return the channel to a condition resembling its pre-regulation state, when alternate bars and associated pools were more common. This condition, although different from the pre-European channel, is considered to have greater environmental value than the present channel. At this stage, there is little interest in attempting to return the channel to its pre-European settlement condition.

To provide a sound basis for developing a rehabilitation plan for the reach, this paper addresses the following questions:

1. What processes led to the development of pools prior to 1970?
2. What caused the loss of alternate bars and associated pools?
3. What rehabilitation measures could be used to encourage the development of pools?

The first two questions may seem academic to the problem of rehabilitating pools in the lower Snowy River. However, there have been repeated calls by international stream rehabilitation experts to examine the broader context of stream rehabilitation projects. In particular, it is recommended that the key fluvial process be understood and the cause of morphological change be identified (Sear, 1996; Kellerhals et al., 1996; Kondolf and Downs, 1996). These experts argue that consideration of this broader context is more likely to result in a longer-term and self-sustaining solution. Rehabilitation efforts that fail to account for the dominant fluvial processes controlling channel morphology are more likely to require costly maintenance.

This study contributes to rehabilitation planning for the channel between Jarrahmond gauge and the upstream extent of tidal influence below Orbost (Figure 1). This lowland reach is over 80 m wide and approximately 14 km long. Along this reach, the channel is elevated above the floodplain within natural levees. The

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floodplain has been largely developed for farming. The study is concerned mainly with morphological features of the channel. Other studies are underway to develop rehabilitation strategies for floodplain and estuarine wetlands and riparian vegetation.

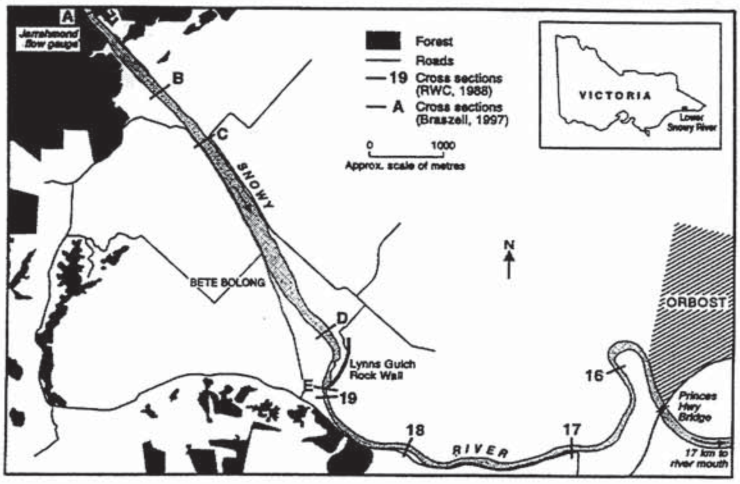

Figure 1: The lower Snowy River

This paper builds on a number of earlier studies including Brizga and Finlayson (1994) Erskine and Tilleard (1997), Stewardson et al. (1997). For the sake of completeness, results of this earlier work have been reproduced here and the source acknowledged. In some cases, the earlier results have been revised using additional historical data.

2 HOW WERE POOLS FORMED PRIOR TO 1970?

The processes of pool formation in the lower Snowy River involve the re-distribution of sand sediments in the bed of the channel. The presence and size of pools is determined by the recent history of flows. Alternate bars and associated pool-riffle sequences are thought to have formed during extended periods of high flows (Erskine and Tilleard, 1997). Prior to regulation there was normally an extended high flow period during spring, when snow in the river's headwaters melted. The evidence discussed in this section suggests that alternate bars are destroyed during flood flows and can be replaced by much larger pools during extreme floods. During periods of low flows, pools are infilled and the bed becomes relatively flat and featureless. The following discussion examines the effect of different flow magnitudes on the distribution of bed sediments within the lower Snowy River channel.

2.1 Extreme Floods

Flow across the floodplain is constricted upstream of Bete Belong by hills, and at Orbost by a combination of high ground, a railway bridge, and a road embankment. These two floodplain constrictions direct overbank flows into the channel and act as hydraulic controls on the upstream water surface profile. High velocities within these constrictions result in the scour of large pools. Mobilised sediment is probably deposited a short distance downstream, at Gulches, through which floodwaters can move back onto the floodplain.

There is some historical evidence of bed scour at the floodplain constrictions during the two biggest floods on record in 1934 and 1971. Peak discharges during both floods exceeded 600,000 ML/d. A cross-section survey at Orbost following the 1971 flood indicates a 3 m deep scour hole. Anecdotal reports suggest that it was possible to water ski on a large pool upstream of Bete Belong at this time. An aerial photograph taken in 1973 also indicates the presence of a large pool upstream of Bete Belong.

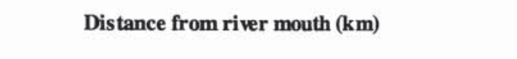

Figure 2: Peak flood stage along the lower Snowy River, January 1934 (from State Rivers and Water Supply Commission Plan, Corr. No. 34/10569)

The hydraulic significance of these floodplain constrictions is supported by observations of peak water level along the floodplain during the 1934 flood event recorded on a plan drawn soon after the flood (Figure 2). These surveys indicate that the floodplain constrictions are hydraulic controls at the height of the flood. There appears to be an additional control at

Lynns Gulch. This may be the result of a reduction in the width of the main channel downstream of Lynns Gulch.

2.2 Regular Floods

According to the State flood warning service, minor, moderate and major floods along the lower Snowy River correspond to discharges of 20,000 ML/d, 71,000 ML/d, and 103,000 ML/d respectively. The minor flood level is lower than the one year flood level and the major flood level is exceeded every 2-3 years (Stewardson et al., 1997). Flows in this range are likely to fill reaches of the channel to bankfull levels. At these high stages, it is to be expected that scour will occur at channel bends. Several cross-sections along the lower Snowy River have been resurveyed a number of times between 1920 and 1988 (RWC, 1988). Where cross-sections are at meander bends repeated surveys indicate a scour pool on the outside of the bend indicating that point bar formation associated with meander bands is an important process leading to pool development in the sinuous reaches (eg. Figure 3).

The width of the lower Snowy River varies from between 80 m to 200 m. During flood events, bed sediments are likely to be transported from narrower reaches of the channel and deposited downstream where the channel widens (Jensen et al. 1979). This argument, is supported by a series of historical surveys conducted since 1920 (Gippel, 1998; RWC, 1988). For example, a survey in 1988 (Figure 4) indicates high points in the channel where the channel widens at 17 km, 14 km, and 11 km from the river mouth.

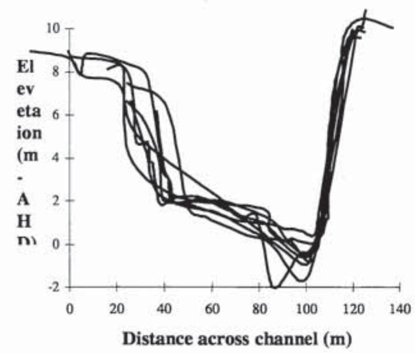

Figure 3: Cross-section profiles at section 18 on the lower Snowy River (23.6 km from river mouth) surveyed eight times between 1956 and 1988 [re-drawn from RWC (1988)].

2.3 High (Within Channel) Flow Periods

Anecdotal reports and aerial photographic records suggest that for a period prior to 1965, alternate bars were a common feature along the lower Snowy River (Erskine and Tilleard, 1997; Stewardson et al., 1997). The alternate bar bedform is a rhythmic sequence of bars, attached to alternate banks, creating a meandering thalweg. A sequence of pools and riffles develop with a pool located off the point of each bar. An aerial photograph taken in 1965 shows the alternate bar bedform in the lower Snowy River (Figure 5).

Erkine and Tilleard (1997) identified the loss of flows in the range 2,000 ML/d to 12,000 ML/d as the main hydrological impact of regulation. The circumstantial loss of alternate bars after regulation led them to speculate that it was this range of flows that maintained alternate bars. A different approach is used to identify discharges during which alternate bar formation occurs in section 2.3.

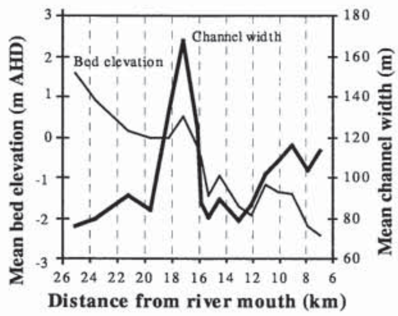

Figure 4: Mean channel width and bed elevation for the lower Snowy River in 1988 [redrawn from Gippel (1998)]

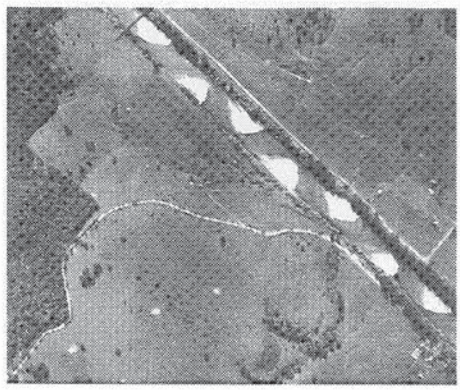

Figure 5: 1965 aerial photograph of the Snowy River, 31 km to 29.5 km from river mouth (Qasco/VicImage, Snowy River 912, B/W)

2.4 Low Flows

Because bed material is fine enough to be mobile at all flows, at low flows alternate bars are eroded and sediment is deposited in pools. This creates a uniform bed gradient along the lowland reach. Local scour holes are preserved around woody debris and some slightly deeper channels will be maintained along which there is some preferential flow. Braszell (1997) surveyed longitudinal bed profiles between Jarrahmond streamflow gauge and Lynns Gulch after an extended period of low flows. These surveys indicated irregular fluctuations in bed level of approximately 0.5 m amplitude, but no larger scale pools.

3 WHAT CAUSED THE LOSS OF ALTERNATE BARS?

The loss of pools is associated with a reduced presence of alternate bars. Although historical records of the duration of this bedform are not available, anecdotal accounts and aerial photography suggest that they have been rare or absent since between 1965 and 1971 but were common for a period prior to 1965 (Erskine and Tilleard, 1997; Stewardson et al., 1997). The cause of this change may be associated with a number of changes occurring at this time. Possible contributors to the loss of bars are:

- reduced flows in the post-regulation period,
- an increase in the size of bed sediments, and
- the construction of a rock wall across Lynns Gulch.

3.1 Reduced Flows

The Snowy Mountain Scheme (SMS) diverts water from the headwaters of the Snowy River into the Murray and Murrumbidgee rivers for hydro-electric power generation and agricultural use. The Scheme was completed in 1967. Comparison of streamflow records (from the Jarrahmond streamflow gauge) for periods pre- and post-regulation indicates a 45% reduction in mean annual flow. The loss of alternate bars occurred around the time flow regulation began.

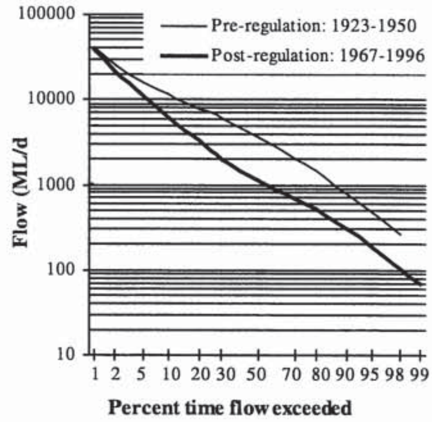

Figure 6: Mean daily flow duration curves for pre- and post-regulation in the lower Snowy River at Jarrahmond gauge

Lane (1955) provides a threshold shear stress below which scour of the stream bed and hence alternate bar formation is unlikely to occur. Using surveys conducted after (i) a large flood in 1978 and (ii) a long spell of low flows in 1997, Lane's threshold for bed scour was achieved at 3,800 ML/d and 1850 ML/day (Stewardson, 1998) respectively. The threshold discharge was higher following the flood because a build up of sediment at Lynns Gulch reduced the upstream bed gradient and hence shear stresses. Flows below 3,800 ML/d occurred for 55% of the time prior to regulation and 80% of the time since regulation by the SMS (Figure 6). The reduced duration of bar-forming flows and increased duration of flows responsible for infilling pools could explain the loss of alternate bars, and increased prominence of the relatively featureless bed.

Because knowledge regarding the processes of alternate bar formation is limited, it is not possible to be certain that flow regulation is the sole cause of a reduced presence of alternate bars. For this reason, other possible causes of this change are considered in the following sections.

3.2 Increased Sediment Size

The lower threshold for scour defined by Lane's (1955) critical shear stress (Section 3.1) varies with the size of bed material. Sediment samples taken from the lower Snowy River at Bete Belong indicate an increase in median particle size from 0.3 mm to 0.6 mm over the period 1958 to 1965 (RWC, 1988; Stewardson et al, 1997). As a result, the discharge corresponding to Lane's (1955) critical shear stress increased from 3,100 ML/d to 3,800 ML/d (using the 1978 survey). In the pre-regulation flow regime, flows are below these threshold levels for 47% and 55% of the time respectively. The increase in the duration of flows below this scour threshold as a result of increased sediment size is considerably less than the increase due to flow regulation. This would suggest that flow regulation is more likely to be the major cause of the loss of pools, although an increase in sediment size may have contributed to this change.

3.3 Construction of a Rock Wall at Lynns Gulch

The lower Snowy River channel is perched within natural levees that are higher than the surrounding floodplain. Low points in these levees allow floodwaters to escape the channel and spill onto the floodplain. Two such low points, collectively referred to as Lynns Gulch, are located at the downstream end of a straight reach of the channel at a distance of 6.4 km from the Jarrahmond streamflow gauge (Figure 1). During floods, the river at this point divides into three channels: the main channel, a flood channel that continues on the straight alignment to the south-east, and a second flood channel that flows to the north-east. Following an extreme flood in 1971, a rock wall was constructed at Lynns Gulch to prevent channel avulsion and to protect farmland from flooding (Figure 1).

The construction of a rock wall across Lynns Gulch may have contributed to the loss of alternate bars by enhancing a backwater effect. This wall redirects flow into the narrower main channel downstream of Lynns Gulch. The resulting flow constriction is an hydraulic control on the upstream reach. The degree to which the wall affects upstream hydraulic conditions is in part determined by the discharge at which flow would occur through Lynns Gulch in the absence of a wall. Below this discharge, Lynns Gulch has no direct hydraulic effect. Using calculations based on the 1978 flood surveys, the level at which water begins flowing through Lynn's Gulch corresponds to a discharge of 30,000 ML/d at Lynns Gulch. A discharge of 30,000

ML/d is exceeded less than 2% of the time. Lynns Gulch will not directly affect hydraulic conditions at flows below this level.

The backwater effect introduced by the rock wall will be at its greatest when the rock wall is about to be overtopped. An unpublished flood study estimates that the wall is overtopped at 52,000 ML/d (DCE, 1992). At this discharge, sediment transport rates upstream of Lynns Gulch are reduced by an order of magnitude by the backwater effect (Stewardson, 1998). This suggests that, by contributing to the constriction of flow, the rock wall at Lynns Gulch enhances sediment deposition upstream of the gulch during flood events. This additional accumulated sediment would need to be redistributed following the flood before alternate bars could develop. For this reason, the rock wall probably delays the reformation of alternate bars following flood events. The duration of this delay cannot be determined using available knowledge.

4 HOW COULD POOLS BE RE-CREATED?

As flow regulation appears to be the single major cause of the loss of this bedform, the provision of an environmental flow is the preferred option for rehabilitating the lower Snowy River channel. However as there is the possibility that changes other than flow regulation may have contributed to the loss of alternate bars, even the complete elimination of flow regulation cannot be guaranteed to result in alternate bars. For this reason, two structural approaches to pool formation are proposed to enhance the benefit of an environmental flow release.

4.1 Environmental Flows

An environmental flow provided in the lower Snowy River to rehabilitate pools should equal or exceed the lower threshold for scour that is defined by Lane's (1955) criteria. To encourage the pre-regulation frequency and duration of pool formation, this environmental flow release should be maintained for a sufficient period to ensure that the duration of flows exceeding Lane's threshold is the same as prior to regulation. Less water may be required for this release if releases are timed to complement higher flows entering the Snowy River from unregulated tributary streams. The magnitude of this environmental flow release required to form bars or pools cannot be determined from available knowledge. It is recommended that this magnitude be determined through trial releases. To ensure that water is not released unnecessarily, these trials should initially use Lanes' scour threshold as the flow magnitude to be maintained in the lower Snowy River. If this discharge is inadequate, higher discharges should be trialed depending on the availability of water. If insufficient water is available, structural rehabilitation measures should be considered.

4.2 Deflectors

Stewardson et al. (1997) propose the use of deflectors, constructed using a row of timber-piles extending from one bank, to promote scour through channel constriction (Figure 7b). Models are available to estimate the depth of scour induced by such channel constrictions at a design flow (Jensen et al., 1979). The design flow used for deflectors in the lower Snowy River is the flow exceeded 53% of the time. This is the pre-1955 duration of flows exceeding Lane's threshold for scour. This flow is chosen so that pools formed by the deflectors are as common as pools associated with alternate bars were prior to regulation. Prior to regulation, 3,100 ML/d is exceeded for 53% of the time. In the current regulated flow regime, the corresponding design flow is approximately 1,200 ML/d. For a simulated flow regime, subject to environmental flow releases specified by an expert panel (SGCMC, 1996), the design flow is 2,000 ML/d. To induce a scour pool of 1 m depth at 1,200 ML/d and 2,000 ML/d, the channel must be constricted to between 20% and 25% of its current width respectively. The crest of the deflector will be approximately 0.8 m above the current bed level.

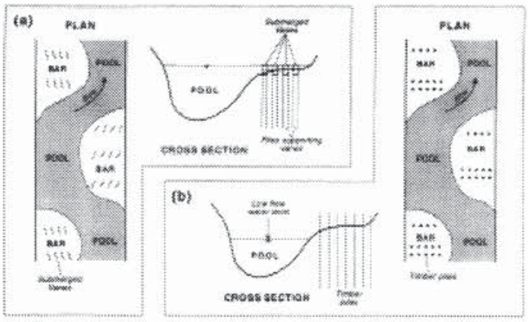

Figure 7: The use of (a) submerged vanes, and (b) deflectors, to create pools

These design calculations are based on the assumption that secondary currents will not contribute substantially to scour. If a series of deflectors are located along the lower Snowy River to encourage the development of scour pools on alternate banks (Figure 7b), the resultant meandering thalweg may induce secondary currents. Such an arrangement is likely to increase the depth of scour achieved using these structures.

4.3 Submerged Vanes

Submerged vanes are instream structures designed to promote bed scouring by developing secondary circulations in the flow. They can be used in rivers to protect streambanks, create scour pools, reinstate meanders, improve navigability, and limit pump station intake shoaling (Stewardson et al., 1997). Submerged vanes are considered to be suited to lowland sand and gravel-bed rivers of a range of sizes. Odgaard and Wang (1991) provide a design procedure for submerged vane fields to produce a desired depth of scour. Submerged vanes are generally designed for bankfull flow conditions. For this application, the discharge corresponding to the minor flood level is used (20,000 ML/d). Preliminary design calculations suggest that to achieve a scour depth of 1 m, vanes would need to be spaced at 3 m intervals across more than 50% of the channel width (Figure 7a). Individual vanes would have a height of 1 m and length of 3 m and be oriented at 20° to the flow direction. Vanes will be partially buried by the side bars that they are intended to develop.

4.4 Do Nothing

A possible management option that should be considered is to continue to do nothing regarding pool formation. It is to be expected that scour pools will develop in response to flood events regardless of rehabilitation. It is also possible that partial development of alternate bars under the current regime may occur from time to time and result in the development of pools in the absence of any management intervention. However, given no management intervention, long periods during which pools are absent should be expected in the future.

5 CONCLUSIONS

Two large scour pools are formed at floodplain constrictions in the lower Snowy during extreme floods. During regular floods, pools develop at channel bends and along narrower reaches. Prior to 1967 alternate bars and associated pool-riffle sequences developed during periods of moderate (within channel) flow. At low flows, larger scour pools are filled with sediment and the channel becomes relatively featureless.

Flow regulation, beginning in 1967, is likely to be the major cause of loss of pools in the lower Snowy River. As a result of regulation by the SMS the duration of low flows has increased, and the occurrence of fully developed alternate bars has become rare. An increase in sediment size and the construction of a rock wall at Lynns Gulch may have also contributed to this change.

It may be possible to recreate pools by providing an environmental flow to ensure discharges exceed 3,800 ML/d for a period of approximately 6 months each year. The actual magnitude required cannot be determined from available theory and must be assessed through trial releases. If insufficient water is available to provide the required environmental flow, two alternative instream structures (deflectors and submerged vanes) offer some potential for maximising the benefits of available water. However, an environmental flow release is the favoured rehabilitation option.

ACKNOWLEDGEMENTS

This work was funded by East Gippsland Catchment Management Authority and Department of Natural Resources and Environment (Victoria) and was conducted in collaboration with ID&A Pty. Ltd.

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