MECHANISMS OF STREAM BANK EROSION

The Results of Five Years Of Bank Profile Monitoring - River Murray

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ABSTRACT: *Detailed monitoring of river banks is contributing to a greater understanding of stream processes on the River Murray near Albury-Wodonga. This paper will present a summary of the results of five years of stream bank profile monitoring at eight sites on the river. The paper also presents some preliminary interpretation of the results but much remains to be learnt from more detailed analysis.*

A consistent pattern of retreat of unvegetated banks is identified, dominated by parallel retreat of the mid-bank facet up to a bank height corresponding to summer release levels. Notching of the upper bank occurs at summer release levels which causes collapse of the overlying vertical upper bank facet. Vegetated banks are shown to retreat at slower rates than unvegetated banks.

1. INTRODUCTION

This paper presents the results of a detailed stream bank monitoring program at eight sites on the River Murray, Australia. The sites are focused on the river near Albury-Wodonga, 30-40 river kilometres below the Hume Dam (Figure 1). This dam, as the major storage on the River Murray, regulates irrigation flows for the Murray Valley irrigation areas in Victoria, New South Wales and South Australia, and ensures a water supply for Adelaide.

The Murray River is a special case in river management. It is a large river by Australian standards, and is highly regulated. The Hume Dam was constructed between 1919 and 1936, and enlarged to its present size (3040GL) in 1961 (Jacobs 1990). The catchment above the dam, while covering less than 1.5% of the Murray-Darling Basin, contributes 37% of the total inflow.

Construction of the Dam has altered the natural flow regime (Close 1990). In the reach between the Hume Weir and Yarrawonga, a distance of about 230 river kilometres, the seasonal flow regime has been almost reversed, with high flows in summer and autumn, and low flows in winter. Small annual floods have been virtually eliminated and moderate (5 year ARI) floods often modified. by pre-releases.

The total annual flow has also been modified by diversions from the Snowy River catchment through the Snowy Mountains Hydro-electric Scheme. For the period 1892 to 1974, the natural flow model run by the Murray-Darling Basin Commission indicates that the average annual flow has increased from 4670 GL/year to 5110 GL/year (Close 1990).

The reach of the river where the study was carried out carries more water than any other section of the Murray. The annual discharge has increased over the last forty years, since the diversions from the Snowy River commenced, and as regulation has increased, a greater proportion of the flows are confined within the channel, rather than occurring as overbank flows during small floods (T. Jacob *pers. comm.*).

The floodplain and river banks have been greatly changed by clearing and grazing, The river bank vegetation was probably once dominated by the Common Reed (*Phragmites australis*), wattles (*Acacia dealbata*), bottlebrushes (*Callistemon seiberi*) and River Red Gum (*Eucalyptus camaldulensis*). It is now grazed over much of its length, there are few shrubs, annual grasses and adventive weeds occur on the top of the bank and the face is bare. The bank sediments are therefore exposed to the effects of the long duration bank-full flows which occur as a result of regulation. A high proportion of the river banks appear to be eroding. By contrast, some banks, generally those which are covered with reeds, appear to be stable (Frankenberg 1992).

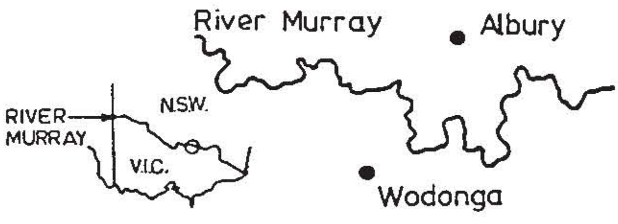

Figure 1. - Locality Plan

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2. RIVER EROSION PROCESSES

The Murray in the study area is a meandering stream with a wide alluvial floodplain. Bank erosion associated with meander processes is to be expected.

European settlement has introduced potential for additional episodes of erosion and bank instability. Likely causes are changed bank conditions, catchment clearing, changes in seasonal flow regimes, headward erosion and removal of bank vegetation.

Prior to selection of survey sites, four major categories of bank erosion were tentatively identified from preliminary observations in the field. (Frankenberg and Tilleard 1990).

- Upper bank fretting apparently associated with wave action during prolonged periods of regulated flows. Fretting can occur on both inside and outside bends, wherever the bank material is susceptible. Within the study reach, fretting is particularly noticeable on unconsolidated deposits of alluvium kept bare by grazing. It was also observed on any bare bank unprotected by vegetation.
- Undermining and collapse associated with meander development and movement. Secondary currents circulating in river bends remove material from the toe of the bank, generally on the outside of the bend, causing undermining and collapse.
- Slumping associated with saturation of the river bank profile, leading to a loss of soil structure. Within the study area, slumping failures are typically associated with saturation of the bank profile by subsurface drainage from the adjacent floodplain, or rapid drawdown of the river level, which leaves the saturated bank unsupported by water in the channel.
- Gradual attrition on bare banks where material is lost from the face of the bank. This causes a continual retreat of the bank, which does not batter back to a stable alignment.

Often individual banks display a combination of processes

3. METHODS

3.1 Selection of sites

Following a general survey of the river banks in the vicinity of Albury-Wodonga, eight sites were chosen for monitoring activities.

The sites represent the range of different bank types within the study area. Considerations included erosion modes, types of bank material, channel alignment (ie. inside/outside of bend), grazing regime, existing vegetation; suitability for vegetative treatment and accessibility for monitoring program.

At the selected monitoring sites two survey datum bases were established where regular detailed measurements could be repeated.

- The 'top-of-bank' survey identifies the location of the top edge of the river bank in three dimensions, relative to a base line.
- Vertical bank profiles were established at several locations along the bank. The bank shape was measured from the top of the bank to below water level.

All survey work was undertaken to Australian Height Datum. Permanent marks have been established to ensure that base lines can be re-established in the future.

3.2 Survey Techniques

Following a review of alternatives for monitoring river bank movement, techniques using electronic distance measurement were adopted. Measurements were taken from the same or the opposite bank of the river, depending on the height and shape of the bank. Surveys were repeated annually, during winter when river levels are low, in the years when funding was available.

Surveys employed to monitor the rate and mechanism of erosion included:

- top of bank surveys at seven of the eight sites; and
- a series of detailed bank profiles at six sites. Sites were pegged so that exactly the same profile was measured each year. A total of 40 profiles have been measured five times, in 1988, 1989, 1992, 1993 and 1994. An additional survey of five profiles at one site was carried out in 1987.

Survey data were processed and stored on computer using the reduction and plotting software "Geocomp".

3.3 Water Level Records

Gauging boards were installed at four of the survey sites, and surveyed to the same datum as the bank profile surveys. The gauges were read regularly, and the results for each site were correlated with

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the daily gauge readings at Albury or Doctors Point to allow an estimate of daily river levels at each site during the study.

The record of daily river levels at each site has been analysed to give a frequency analysis of river heights. These results have been plotted to the same scale as the river bank profiles to facilitate comparison of the erosion pattern with dominant flow levels.

3.4 Erosion Control Structures.

At one site (Site H) erosion control structures were installed in 1992. These needle groynes were used to enable the establishment of vegetation at the site. Their position was recorded with respect to the profile survey datum.

4. RESULTS

Forty profiles and seven 'top of bank' surveys have been measured at eight sites. A representative selection of these are discussed in this paper. Analysis of the data is not yet complete.

4.1 Top of Bank surveys.

All Top of Bank surveys showed some retreat of the bank during the survey period. The results from representative Sites B, F and H are shown in Table 1 and Figures 2 and 3. Sites F and H were situated on an outside bend and experienced a regular rate of retreat throughout the survey period. Site B, located on an inside bend, also showed a consistent although slightly lesser retreat during the period.

YEAR	*SITE H OUTSIDE BEND AREA*	*RETREAT PER METRE OF BANK m^2*	*SITE B INSIDE BEND AREA*	*RETREAT PER METRE OF BANK m^2*	*SITE F OUTSIDE BEND AREA*	*RETREAT PER METRE OF BANK m^2*
1988						
	15.81	0.25	34.27	0.33	16.03	0.11
1989						
	41.14	0.66	36.44	0.35	85.09	0.60
1992*						
	17.29	0.28	19.21	0.18	65.38	0.46
1993						
	2.7	0.04	2.25	0.02	4.6	0.03
1994						

Table 1. - Top of Bank Surveys - Area of Retreat (Total area and rate per linear metre of bank).
* Three year period (1989 - 1992).

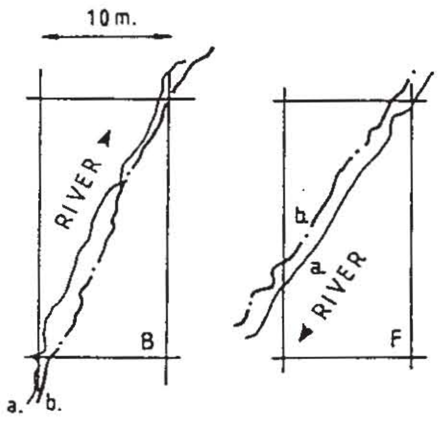

Figure 2. - Top of Bank Surveys, Sites B and F.

Figure 3. shows the results of all surveys at Site C, which was a top of bank site only. This bank is the upstream end of a slight outside bend. It was fenced from grazing in 1984 when trees were planted but by the end of the project was grazed again as the fence was not maintained once the trees gained some height. Two small patches of the Common Reed (Phragmites australis) spread during the fenced period but the extent of the stand was reduced once grazing recommenced. The survey shows a constant rate of retreat, greater at the downstream end, closer to the outside bend.

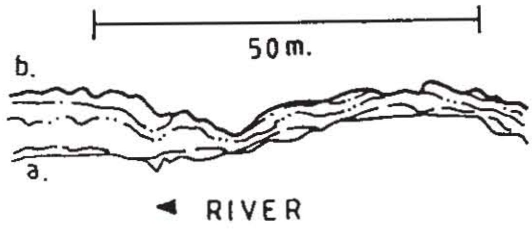

Figure 3. - Top of Bank Survey, Site C. a - Survey details 1988, b - Survey details 1994

4.2 Bank Profiles

The profiles show a consistent pattern of erosion. This can be related to the duration of flow levels, and demonstrates that the steady irrigation supply levels have a significant influence on the erosion pattern and rate.

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The un-vegetated banks have a characteristic shape, with a sloping lower bank, a notch at the summer irrigation flow level (noted as HWM on the Figures 4.) and a vertical upper bank. The degree to which the notch will develop before collapse of the upper bank depends on the type of bank material involved. Clay banks will maintain a notch up to 40cm deep before bank collapse, while more sandy sediments suffer more frequent collapse.

To assist in understanding erosion processes the record of daily river levels at each site was analysed to give a frequency analysis of river heights. This allowed plots to be prepared showing the number of days that the river was at each height during the period (Figure 4).

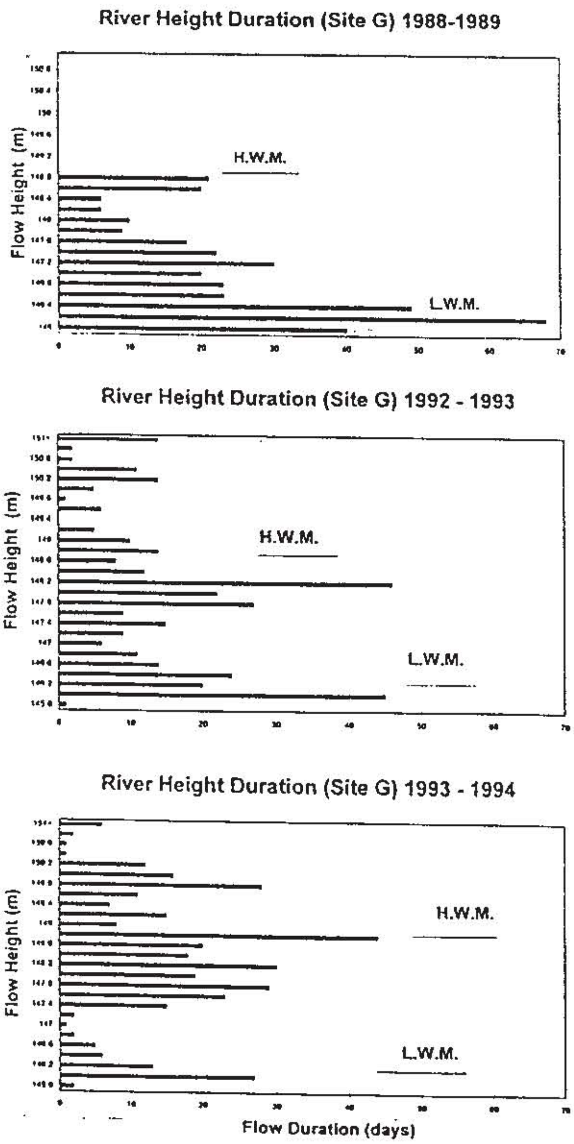

Figure 4. - Examples of River Height Duration Plots (1988/89, 1992/93, and 1993/94)

The profile data document the process of undercutting of the upper bank at the notch, the subsequent collapse of the upper bank, the removal of this material from the lower bank, and the re-instatement of the notch over the next couple of years. This can be seen clearly on the profiles A - C at Site G (Figure 5).

This site is on a slight outside bend just downstream from a 1940's cut-off, with a hard clay bank. The profiles at the upstream end of this Site, (H - J) (not shown) are protected by willows and Phragmites and are closer to an inside bend. Erosion rates on these profiles are less.

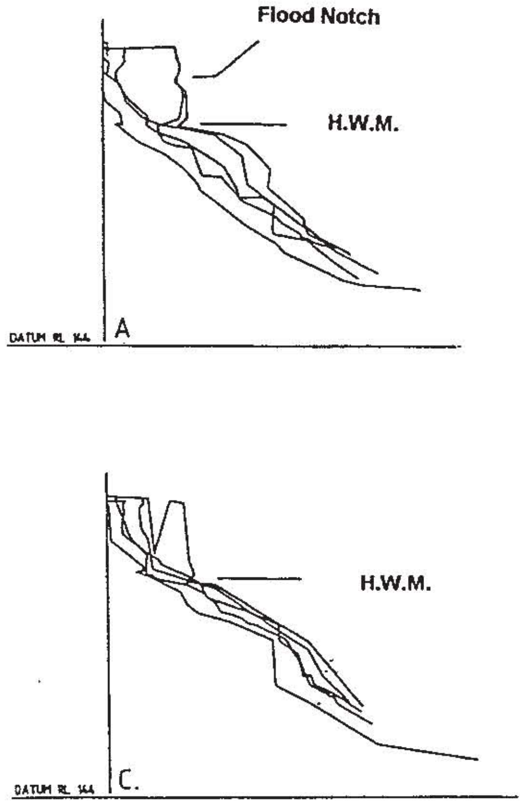

Figure 5. - Site G, Profiles A and C.

Floods cause a change in the pattern described above. The level of the flood can be recognised by a notch higher on the bank, which persists until the original bank shape is reset by the next bank collapse over the irrigation notch. At Site G, the evidence of flood flows prior to the survey in 1988, a notch on the upper bank, persisted for two years until that section collapsed.

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An important observation is that on most banks the lower sloping bank consistently moves back, maintaining a constant batter angle. This consistent "parallel bank retreat" on both sides of the river means that the river appears to be widening.

No significant accretion of the bank has been measured at any site to date. On inside bends, the lower bank is very mobile and sand and gravel beds are constantly moving, but there is consistent attrition of the upper bank at the summer flow level.

	Above Maximum Regulated Flow Level		Between Maximum and Estimated Minimum Flow Level		BANK	RETREAT
	CUT AREA m^2	FILL AREA m^2	CUT AREA m^2	FILL AREA m^2	Top of Bank m	Maximum Regulated Flow Level
AVERAGE (per annum)						
Unvegetated Profiles	1.61	0.18	3.71	0.59	1.64	1.16
Vegetated Profiles	0.18	0.32	0.87	0.27	0.19	0.12

Table 2. Erosion Rates of Vegetated and Unvegetated Profiles at Site E.

On banks covered by Phragmites, the profiles have a different shape. The bank tends to be convex, without a notch at irrigation supply level. Accurate profile measurement is more difficult on these banks, but over a period of years, any changes can be detected. The profiles at Site E (Table 2 and Figure 6 and 7), demonstrate the contrast between the bare banks and those partly or wholly covered by Phragmites.

Figures in Table 2 represent the average erosion rates per annum for three vegetated and five unvegetated profiles at the site. A gradual increase in Phragmites cover on Profile C (Figure 8) was reflected by an increasing stability of the upper bank.

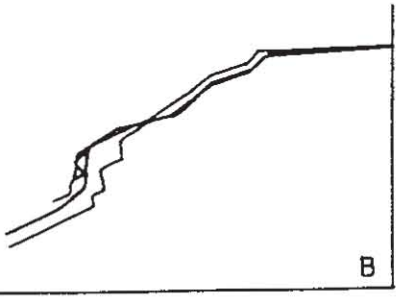

Figure 6. - Site E, Bank Profiles B, Vegetated Bank.

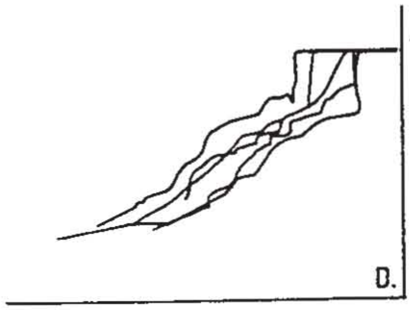

Figure 7. - Site E, Bank Profiles D Unvegetated Bank

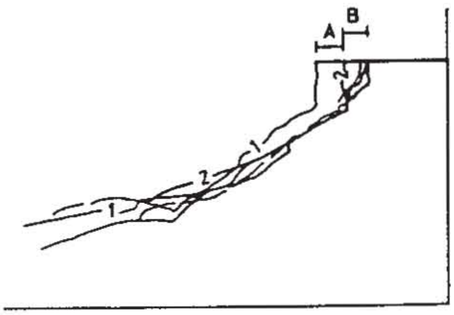

Figure 8 Site E Profile C, Establishment of Phragmites,
A - Bank retreat 1988 to 1989, B - Bank Retreat 1989 to 1994

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5. DISCUSSION

The bank profiles show that during the period of the survey there has been a consistent retreat on all unvegetated banks measured. The rate of retreat has varied from site to site and year to year, and is greater at sites on outside bends, as would be expected. However no sites have stable banks, except possibly those which are well covered by Phragmites. On these profiles the bank shape is more difficult to measure accurately, and results are less clear. Unfortunately some of the sites which were fenced from grazing at the beginning of the project did not remain so, and the Phragmites which had begun to thicken and spread at the top of the bank was grazed and weakened by the end of the survey period. Despite this, the erosion rate on the vegetated banks was markedly less than on comparable bare banks (Table 2).

Analysis of the surveys is not yet complete, and relationship between flow and erosion rate cannot be drawn across all sites. It appears that floods can increase the loss of bank material on bare banks, and can cause some slumping of Phragmites covered banks. However the most consistent pattern of erosion shown by the profiles is the loss of material at the regulated flow level, which continually undercuts the upper bank and causes bank collapse. This process can be recognised on every unvegetated bank surveyed. The rate depends on the type of bank material, but the pattern is the same.

It is also apparent from the profiles that this loss from the upper bank is accompanied by a general retreat of the lower bank, so that the angle of the bank remains constant. A battering process which would ultimately reach an angle of equilibrium does not seem to be occuring.

This "parallel bank retreat" appears to be the dominant erosion process. It is the retreat of the sloping section of bank that actually drives the overall bank movement. The notching and subsequent collapse of the upper bank, while visually impressive to casual observation, is not the primary cause of bank retreat. If it were, banks would exhibit extensive upper bank benches, instead of the progressive parallel retreat of the whole bank face.

The complete set of forty bank profiles, each measured five times over a period of six years, represents an invaluable data set. Much is yet to be learnt from further interpretation.

6. ACKNOWLEDGEMENTS

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Daily flow data for the study period was provided by the Murray-Darling Basin Commission.

The data manipulation on GEOCOMP was carried out by Geoff Claffey.

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