Historical River Metamorphosis of the Cann River, East Gippsland, Victoria

*Wayne D Erskine** *and L.J. White***

ABSTRACT: *At least a 48 km long section of the Cann River has had its channel morphology completely transformed by large scale erosion since 1919. Massive channel erosion was initiated in a large capacity reach near Weeragua by a large flood following clearing of the riparian vegetation. Subsequent river management works in a small capacity reach immediately downstream of the initiation point caused a substantial increase in bankfull stream power which exceeded the stability threshold of* $35\ W/m^2$. *The original sinuous, small capacity, well vegetated stream was converted into a straight, large capacity, eroding river. River management works have now successfully stabilised this channel and are attempting to improve its habitat value.*

1. INTRODUCTION

Many rivers throughout Australia have changed dramatically since European settlement. Schumm (1969) coined the term, *river metamorphosis*, for the complete transformation of river morphology over time. This entomological analogy was made to emphasise that some channel changes are truly catastrophic (Erskine, 1986).

Human impacts on catchments and rivers have been recognised as significant causes of channel changes for a long period of time. Thompson (1938:p28) emphasised that clearing of vegetation from rivers and catchments combined with burning off increased runoff and soil loss rates. As a result, the severity of floods and stream sediment loads also increased. Topsoils were completely eroded in some places exposing subsoils. Timber was often felled directly into rivers causing debris dams and reduced channel capacity. Bare river banks started to erode creating a serious problem. Nevertheless, it does not necessarily follow that all channel changes are human-induced (Erskine, 1986; Brizga and Finlayson, 1990).

River management works should be undertaken following a detailed understanding of historical channel changes. Rivers can substantially alter their cross-sectional size and shape, longitudinal profile, pattern, bedforms and drainage network over short periods of time (Erskine, 1994). To understand the evolutionary stages through which channels develop, it is essential to reconstruct as long a record of channel changes as the available evidence permits. As noted by Wasson and Clark (1985), the past is the key to the present *and* the future. The past can be used to provide analogues of both present and future conditions. A detailed understanding of river channel changes can be used for the practical purposes of explaining present day conditions as well as predicting future trends. This must result in the selection and design of more cost-effective and environmentally sensitive river management works.

The purpose of this paper is to reconstruct historical channel changes on the Cann River, deduce the main causes of these changes and propose suitable strategies for the long term management of the river by the East Gippsland River Management Board. Before addressing these issues, the geomorphology of the study area and the previous approaches to river management on the Cann River will be briefly outlined.

2. CANN RIVER

The Cann River drains a largely forested area of over 700 km^2 in East Gippsland, Victoria (Figure 1). The section of the Cann River investigated here covers the 58 km from the junction of the East and West Branches at Weeragua to Bass Strait (Figure 1). The study area has been divided into 7 reaches which are now described in downstream sequence. The *Weeragua straight reach* is 14km long and extends from Weeragua to Neilson Creek near Noorinbee. A north - south oriented fault strongly controls both valley and channel alignment. Bedrock vertically and laterally confines the channel which has a large capacity with a pool-riffle sequence. The *Cann floodplain reach* is 17km long and extends to about 5km below Cann River township. This reach is characterised by a smaller capacity, active sand bed and a wide floodplain, both of which have substantially changed since European settlement. The *falls reach* is 4km long and is characterised by a series of steep, high granite falls. The *Tonghi straight reach* is 4km long and is a largely alluvial reach sandwiched between 2 bedrock sections. The *Reedy*

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* School of Geography, University of New South Wales, Sydney, NSW 2052.
Telephone: (02) 385 4603 **Fax:** (02) 313 7878 **Email:** W.Erskine@unsw.edu.au

** I.D. & A. Pty Ltd., PO Box 1372, Sale, Vic 3850.

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> "To recognise the balance of community values in achieving a compromise between the following aims:
> * alleviate or prevent stream related damage to public and private lands, lakes and assets; and
> * retain and enhance the amenity of stream systems for the benefit of the general community " (Ian Drummond and Associates, 1988).

The Board is actively trying to create a healthy river by such works as the eradication of willows and wattles growing within the channel, construction of stock exclusion fencing along the top of the banks and revegetation with native species.

4. HISTORICAL RIVER METAMORPHOSIS

The information used in this section includes vertical air photographs (1941, 1961, 1973, 1974, 1979, 1986, 1990), river planform surveys (1876, 1886, 1935, 1970, 1979), channel cross section surveys (1935, 1963, 1971, 1973, 1974, 1983, 1984, 1986, 1993, 1995), hydrological information at 3 river gauging stations, ground photographs (Rural Water Corporation, East Gippsland River Management Board, local landowners and Anderson (1985)), personal interviews with long-term residents, field and aerial inspections, and stratigraphy and palynology of sediment cores from the Cann River estuary and Tamboon Inlet. Channel changes were not initiated until 1919 and have been closely associated with the occurrence of large floods, the clearing of riparian vegetation and the removal of large woody debris from the channel. The following subsections will outline the flood history of the Cann River, the pre-1919 channel and floodplain conditions and the post-1919 channel changes.

4.1 Flood History

Table 1 lists the major floods which have been recorded on the Cann River since 1893. It was compiled from historical sources, rainfall records and river gauging records. While the floods of February 1919 and February 1971 are the largest events this century, the rainfall records suggest otherwise. The reason for this discrepancy is that there are only a few rainfall stations with relatively short records in the catchment and, as a result, they were rarely located at the centre of individual storm cells.

Rivers exhibiting a large range of flood peak discharge are sensitive to flood - induced channel changes (Baker, 1977; Erskine, 1993; 1994). Flood variability is usually measured by the standard deviation of the logs$_{10}$ of the annual maximum flood series. The values for the 3 stations on the Cann River range between 0.542 and 0.671, and average 0.580. These values are similar to those for NSW rivers but are higher than those for most Victorian rivers and indicate that the Cann River has a high potential for large floods. The 1971 flood had a peak discharge at Weeragua which was 12.96 times greater than the mean annual flood. This is close to that for the 1971 flood on the Genoa River (Erskine, 1993) and indicates that flood stream power would have greatly exceeded the usual range experienced by the channel. Therefore, catastrophic erosion should have been expected during this event (Erskine, 1993).

4.2 Channel and Floodplain Conditions Before 1919

The focus of early agriculture was in the valley upstream of Noorinbee. The channel in the Weeragua straight reach before 1919 was certainly a sand-bed stream with a clear bed but well vegetated banks. Channel width was much narrower than it is today. No bedrock was present at the Cann Valley Highway bridge (the Double Bridges) where extensive outcrops are now exposed. The channel in the Cann floodplain reach was sinuous (P=1.60) and exceptionally well vegetated with much coarse woody debris in the bed. We believe that *Tristaniopsis laurina* and *Callistemon palludosus* were very common bankside shrubs.

The floodplain in both reaches was well vegetated in the nineteenth century. Eucalypt forest dominated on the better drained sections with Leptospermum and Melaleucas common in the poorly drained areas. Ringbarking was used extensively to kill the trees (Anderson, 1985).

4.3 Post-1919 Channel Changes

Accelerated bank erosion and channel widening started during the February 1919 flood in the Weeragua straight reach. Further erosion occurred during the August 1919 flood. It has not been possible to identify a specific location as the initiation point, rather erosion seems to have started simultaneously at a number of spatially disjunct sites. Photographs of the Weeragua straight reach taken in the 1920s, 1930s, 1940s and 1950s (Ian Drummond and Associates, 1985; Anderson, 1985, Rural Water Corporation collection), which will be shown at the conference, depict a very wide, active, sand- bed stream with high, bare, eroding banks. The initial isolated erosion sites rapidly expanded and coalesced. The sand generated by the massive widening of the channel on the Weeragua straight reach, produced a sand slug or bed load wave (Erskine, 1994) which propagated progressively downstream through the Cann floodplain reach. The slug produced rapid *granite reach* extends for 4km upstream of the Reedy Creek junction where the channel is laterally and vertically confined by bedrock. Deep pools are present where the channel is laterally confined and divided channel sections are common where the river is vertically confined. The *O'Meara's estuarine reach* extends for 12km from Tamboon Inlet to Reedy Creek and is characterised by deep pools on bends and sandy shallows on cross-overs between bends. Today, the limit of tidal influence only extends to O'Mearas whereas it reached Reedy Creek before 1971. Lake Furnell is a shallow mud basin connected to the Cann River estuary. A well-developed fluvial delta has formed where the Cann River debouches into Tamboon Inlet. The *Tamboon lagoonal reach* is about 3km long and is a coastal lagoon cut along the contact between granite to the east and sand dunes to the west. Harford (1973) has discussed the geomorphology of Tamboon Inlet which is an important recreational resource.

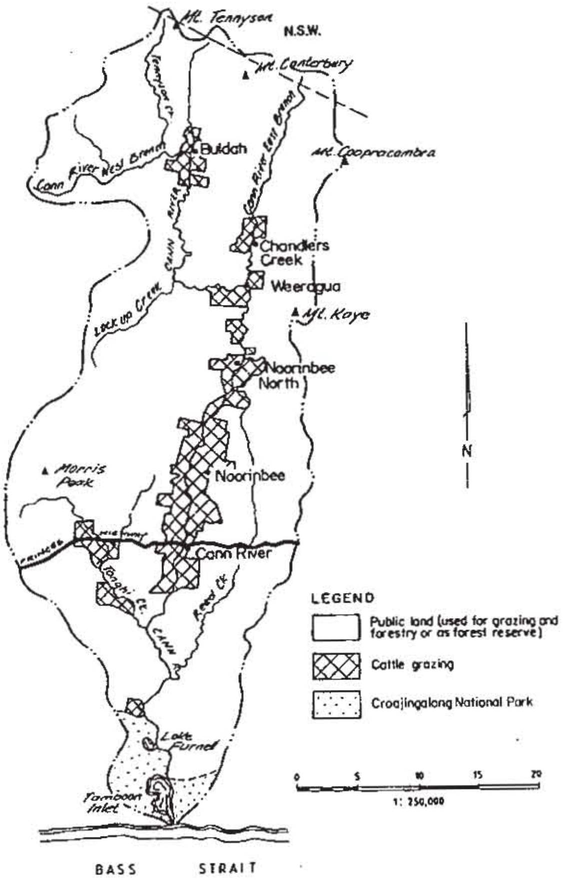

Figure 1 Cann River catchment.

3. RIVER MANAGEMENT

River management of the Cann River has progressed through 3 stages characterised by minimal structural works (before 1963), large scale structural works (1963 to 1989) and riparian zone management (1989 to present).

3.1 Before 1963

Early settlers were preoccupied with clearing vegetation on the floodplain and the river banks, and channel erosion did not become a problem until the flood of February 1919. Between 1919 and 1963 significant erosion problems developed in the Weeragua straight reach and at the upstream end of the Cann floodplain reach near Noorinbee. A total of 13 Rivers and Streams Grants were made by the State Rivers and Water Supply Commission for desnagging, obstruction removal, groyne construction, willow planting and cutting , and channel excavation between 1940 and 1962. These works were largely undertaken by private land holders and generally consisted of desnagging. However many artificial cutoffs were also effected (Ian Drummond and Associates, 1985). The move for the formation of a River Improvement Trust commenced in 1950.

3.2 1963 - 1989

The Cann River Improvement Trust was formed in September 1963 to:

1) clear the channel and Blue Nose Creek (a floodplain drainage line near Cann River) downstream of Noorinbee;
2) protect the natural levees from erosion and prevent an avulsion into Blue Nose Creek ; and
3) protect eroding banks (Ian Drummond and Associates, 1985).

The trust district was a riparian corridor from just upstream of Weeragua to the Tonghi Creek junction (Figure 1). To 1985, $2.162 million were spent on river works. The Trust carried out a lot of desnagging in its first 3 years and then started river training works (including artificial cutoffs), similar to those described by Erskine (1990; 1992) in the Hunter Valley. An artificial levee was built for 5 km upstream of the Princes Highway to prevent the avulsion of the Cann River into Blue Nose Creek. Restoration works of $1 million were completed after the 1978 flood and the Country Roads Board funded $140000 of alignment works near the Princes Highway. Retard fields and rock breaching were built after 1978.

3.3 1989 - present

The Cann River Improvement Trust was replaced by the East Gippsland River Management Board in 1989. The new Board was whole - of - catchment based and had much broader objectives, namely:

aggradation and directly caused channel straightening by natural cutoffs. However, at least 16 artificial cutoffs were also constructed .

The downstream progression of the sand slug is shown on the aerial photographs by the conversion of a well vegetated, sinuous channel into a straighter, wider stream with well developed sandy point bars and side bars. Downstream propagation rates were relatively slow before the 1971 floods. In 50 years, the sand slug moved 10 km (200 m/a) but during the 1971 floods the whole channel between the Cann Valley Highway bridge and the start of the falls reach was substantially widened and infilled with sand . Further erosion was continued by the June 1978 flood. The 1979 air photographs depict a very wide sand-bed stream with a bar braided pattern. Sand oversupply produced bed aggrdation which, in turn, caused the development of small but numerous longitudinal bars. By 1986, the extent of the longitudinal bars had been reduced and transverse and side bars had started to replace them as rapid bed degradation occurred. This is still continuing today.

Flood Month	Year	Peak Instantaneous Discharge (ML/d)	Maximum Monthly Rainfall (mm)
Dec	1893	N/A	451 [1]
Feb	1919	N/A	311 [2]
Aug	1919	N/A	337 [2]
Mar	1938	N/A	530 [1]
June	1952	N/A	263 [3]
May	1956	N/A	310 [3]
Jan	1971	24 600 [5]	324 [4]
Feb	1971	53 800 [5]	261 [4]
June	1978	23 600 [5]	470 [4]

1- Noorinbee (084026) gauge
2- Tonghi Creek 1 (084066) gauge
3- Cann River Forestry (084027) gauge
4- Tonghi Creek PO (084072) gauge
5- Cann River (West Branch) at Weeragua gauge (2212018)

Table 1. Major floods on the Cann River

Between 1886 and 1935, the sinuosity of the channel in the Cann floodplain reach varied slightly between 1.57 and 1.60. By 1970, sinuosity had declined to 1.23, a trend which has continued to the present day (P=1.10). In 1935, the mean bankfull cross-sectional area in the Cann floodplain reach was 42.3 m^2, width was 19.5 m and mean depth was 2.13 m. By 1970, the mean bankfull channel geometry had increased to an area of 102.0 m^2 (141% increase), a width of 49.3 m (153% increase) and a mean depth of 2.02 m (5% decrease). By 1995, there had been further channel enlargement with the mean bankfull channel geometry having a cross-sectional area of 249.2 m^2 (144% increase since 1970), a width of 82.9 m (68% increase since 1970) and a mean depth of 2.97 m (47% increase since 1970). The change in mean bankfull channel geometry between 1935 and 1995 was a 489% increase in cross-sectional area, a 325% increase in width and a 39% increase in mean depth. While the increase in width has been progressive, depth first decreased, due to the passage of the sand slug, and then increased by degradation following the passage of the sand slug. Ian Drummond established 5 cross sections in the Cann floodplain reach in 1983 to determine bed level dynamics. These sections were resurveyed in 1984, 1986, 1987, 1993 and 1995 and demonstrate that there has been up to 1m of bed degradation since 1983, although the trend is not continuous and progressive.

Reach	Channel Erosion (t/km^2 /yr) 1935-1970	1970-1995	1935-1995
Weergold straight reach	N/A	N/A	27.7
Cann floodplain reach	69.8	203.5	128.0

1- data only exists for the section between the Cann Valley highway bridge and Neilson Creek (6.5 km).

Table 2 Sediment yields produced by channel erosion on the Cann River

The volume of sediment eroded by recent channel enlargement can be estimated by comparing the channel network volume at various time periods (Table 2). The volume of sediment eroded between each survey was equated to the increase in channel network volume. This volume was converted to mass by assuming a bulk density of 1.6 t/m^3. Specific sediment yields were calculated for a catchment area of 670 km^2 which corresponds to that at the downstream end of the Cann floodplain reach. Given that the bulk of the 1970 to 1995 erosion occurred during the 1971 floods, the 1970-1995 and 1935-1995 yields should be viewed as minimum rates only.

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Nevertheless, those yields greater than 100 t/km^2/yr are comparable to the highest yields recorded in temperate south-eastern Australia from agriculturally disturbed catchments (Olive and Rieger, 1986) and further demonstrate that channel erosion alone can produce all of the sediment yield from a catchment for short time periods (Erskine 1994). In keeping with the results of Erskine (1993;1994), a catastrophic flood has again produced massive channel enlargement.

The 1971 flood and the large volumes of sand generated by upstream channel erosion completely destroyed the pre-1971 channel in the falls, Tonghi straight, Reedy granite and O'Meara's estuarine reaches. Essentially all of the pools evident on the 1941 and 1961 air photographs were completely infilled with sand. Furthermore, the limit of tidal influence was displaced at least 4 km downstream by bed aggradation. Below the tidal limit, there has also been substantial aggradation at cross-overs between bends. Estuarine sedimentation represents deposition of the coarse bed load sediments. In an effort to assess the affects of historical river metamorphosis on mud deposition, sediment cores were collected from Tamboon Inlet, the fluvial delta and Lake Furnell. The first presence of such introduced pollen taxa as *Pinus* and *Plantago lanceolata* was taken as the time of European settlement. Up to 0.45m of post-European sediment has been found and this depth far exceeds that recorded in neighbouring lakes and lagoons. It is assumed that most of this sediment was deposited during the 1971 floods.

5. CAUSES OF CHANNEL CHANGES

River metamorphosis was caused by the interaction of the following 4 factors. Firstly, erosion was initiated by a large flood in February 1919 and was continued by subsequent large events in 1938, 1952, 1956, 1971 and 1978. Undoubtedly, the 1919, 1971 and 1978 floods were the most significant. The high flood variability of the Cann River means that large events occur relatively frequently and predispose the channel to erosion by the high stream powers generated by these large events (Erskine, 1994).

Secondly, riparian and particularly bankside vegetation in the Weeragua straight reach was cleared for access to water and river crossings, and by stock, exposing the underlying sandy sediments. The channel was stable until bank resistance was reduced by vegetation removal in the early part of this century.

Thirdly, there are marked spatial changes in bankfull stream power between the Weeragua straight reach and the Cann floodplain reach. In 1935, bankfull unit stream power in the Weeragua straight reach was 72 W/m^2 but in the stable section of the Cann floodplain reach, it was only 27 W/m^2. Brookes (1988) found that channels with low unit stream power do not have sufficient energy to modify their boundary. He proposed that a critical value of 35 W/m^2 discriminated between stable and unstable rivers. Once stream power exceeds 35 W/m^2, channel erosion and/or alignment instabilities usually develop. The Weeragua straight reach was more sensitive to disturbance than the Cann floodplain reach because of its higher channel capacity and hence stream power.

Fourthly, the extensive desnagging and channel straightening carried out by the Cann River Improvement Trust between 1963 and 1970 increased stream power in the Cann floodplain reach to such an extent that it exceeded the threshold of 35 W/m^2. The 1970 data yield a mean bankfull unit stream power of 70 W/m^2 and the 1995 data, a mean of 74 W/m^2. River management works directly contributed to the channel erosion effected by the 1971 floods.

6. RIVER MANAGEMENT STRATEGIES

The existing bankfull unit stream power in both the Weeragua straight and Cann floodplain reaches exceeds 35 W/m^2. Therefore, both reaches are potentially capable of reworking their channel boundaries. Bank erosion is currently not occurring because of the extensive bank protection works (rock beaching, groynes, training fences, etc.) and the dense riparian vegetation, particularly willows. However, bed degradation is still active in the Cann floodplain reach, except where 3 rock chutes have been constructed. Bed armouring and bedrock bars have successfully stabilised the bed in the Weeragua straight reach and armouring is developing by selective winnowing of the finer bed material at the upstream end of the Cann floodplain reach. Nevertheless, degradation will continue to progress downstream until a static armour layer forms, or until relatively non-erodible sediment is exposed or until slope is reduced to a value below that required for bed-material transport. We predict that the channel is now actively recovering from the metamorphosis of 1919 to 1978. This recovery phase is thought to progress through a series of intermediate steps from the large capacity, straight, bare channel to a small capacity, sinuous, well vegetated stream. This prognosis is supported by the presence of at least 5 abandoned channels on the floodplain in the Cann floodplain reach. These abandoned channels are very similar in morphology to the pre-1919 channel and were abandoned by avulsions. The new channels next to the abandoned ones had evolved to the stage where they mimicked the parent stream before the recent metamorphosis.

Riparian landowners do not want to recreate the pre-1919 channel because of poor floodplain drainage. Similarly, they do not want to maintain the 1978 channel because of the rapid erosion. To maintain the present channel in a stable state requires the maintenance of dense bankside vegetation but the removal of vegetation, particularly willows, from the bed and bars. Willow replacement by native riparian vegetation should be progressively implemented and habitat creation for fish should be attempted. Stream monitoring must be carried out to detect changes in morphologic state. Gravel seeding for the creation of rhythmically-spaced, artificial riffles is suggested to assist in the formation of a pool-riffle sequence.

7. CONCLUSIONS

Historical data show that the Cann River at the township of Cann River has metamorphosed from a small capacity, sinuous, well vegetated snag-filled channel to a large capacity, straight, bare, eroding stream since 1919. Erosion was initiated upstream in a sensitive reach of higher stream power due to the interaction of riparian vegetation clearing and the episodic occurrence of large floods. This erosion progressed downstream and was accompanied by the passage of a sand slug. Since 1978, the channel has been stabilised by river management works. Riparian landowners do not want the recreation of the original channel nor the maintenance of the 1978 stream. River management is expected to short circuit the natural channel evolution by maintaining a large capacity, straight, well vegetated stream. Willows will be selectively replaced by natives and instream habitat will be recreated.

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