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Stream channels of the Illawarra

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Abstract
Streams that flow from the Illawarra escarpment are mostly small and may not flow all year, but because of regional topography, climate, and their rather unusual geomorphology, they are capable of flooding in a manner unrepresentative of their small size (Neller, 1980). This problem of flooding is made all the more important because of the extent of agricultural and residential development on the region's floodplains (Fig. 1).

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STREAM CHANNELS OF THE ILLAWARRA

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INTRODUCTION

Streams that flow from the Illawarra escarpment are mostly small and may not flow all year, but because of regional topography, climate, and their rather unusual geomorphology, they are capable of flooding in a manner unrepresentative of their small size. (Neller, 1980). This problem of flooding is made all the more important because of the extent of agricultural and residential development on the region's floodplains (Fig. 1).

Research done elsewhere only goes part way in helping to understand the fluvial processes and landforms of the Illawarra. In this region the particular combination of physical conditions result in streams which are unconventional when compared to those described in textbooks of geomorphology. This discussion outlines the distinctiveness of the region's streams, attempts to explain these unique characteristics, and examines man's role in dramatically altering this fluvial environment. Five streams were studied in detail. Three of these drain partially urbanised basins (Cabbage Tree Creek, Byarong Creek and American Creek) and two are in rural and forested basins (Minnamurra River and Marshall Mount Creak) (Fig. 2).

CHANNEL GEOMETRY

The size of a river channel normally relates to the volume of water the channel must carry. Many independent studies have verified this, although these studies have demonstrated that the exact relationship varies as a function of local climate and other environmental factors such as sediment load, catchment geology and vegetation, bank material, and changes in water discharge. For example, streams in glacial or arid areas subject to flash flooding and enormous variations in sediment load are usually wide and shallow, whereas those in marshlands carrying only fine suspended load are narrow and deep. Nevertheless the overwhelming concensus is that stream channels **increase** in size in the downstream direction as a function of the increase in runoff that derives cumulatively from the downstream increase in catchment area. In other words, the channel becomes larger downstream to accommodate the larger flow. This condition is typical of the headwaters of streams in this area and can be readily seen on the Minnamurra River between the escarpment and Jamberoo.

However, many streams in the Illawarra show a downstream **decline** in size at the lower end of their main channels. As these streams emerge from the foothills of the escarpment and are flanked by extensive floodplains, the channel gets progressively smaller and the frequency of flooding increases. The cross-sectional area of the Minnamurra channel near the mouth is only one third that of the channel near the middle of this basin, whereas on Marshall Mount Creek it reduces to one half (Figs. 3 and 4). Even more dramatic is the reduction in estimated bankfull water discharge which near the mouth of the Minnamurra River is only 10% of that carried in the channel near the centre of the basin, and for Marshall Mount Creek is 18% of that further upstream (Fig. 5). In other words, a flood wave passing downstream would reach a point near the middle of these basins below which proportionately less and less water can be carried in the channel, and consequently a proportionately greater amount of water must be rerouted over the floodplain. Clearly this situation has severe implications for downstream flooding in this region.

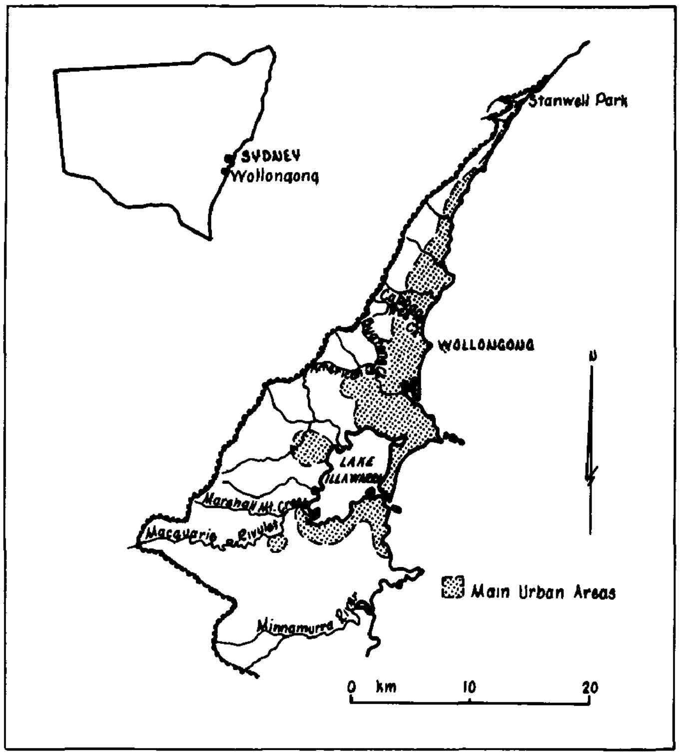

Figure 1: Study Area

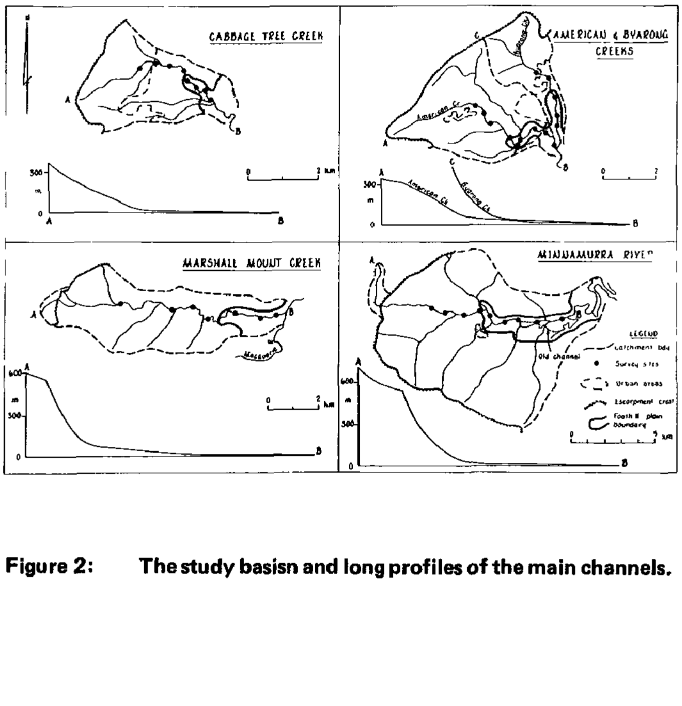

Figure 2: The study basisn and long profiles of the main channels.

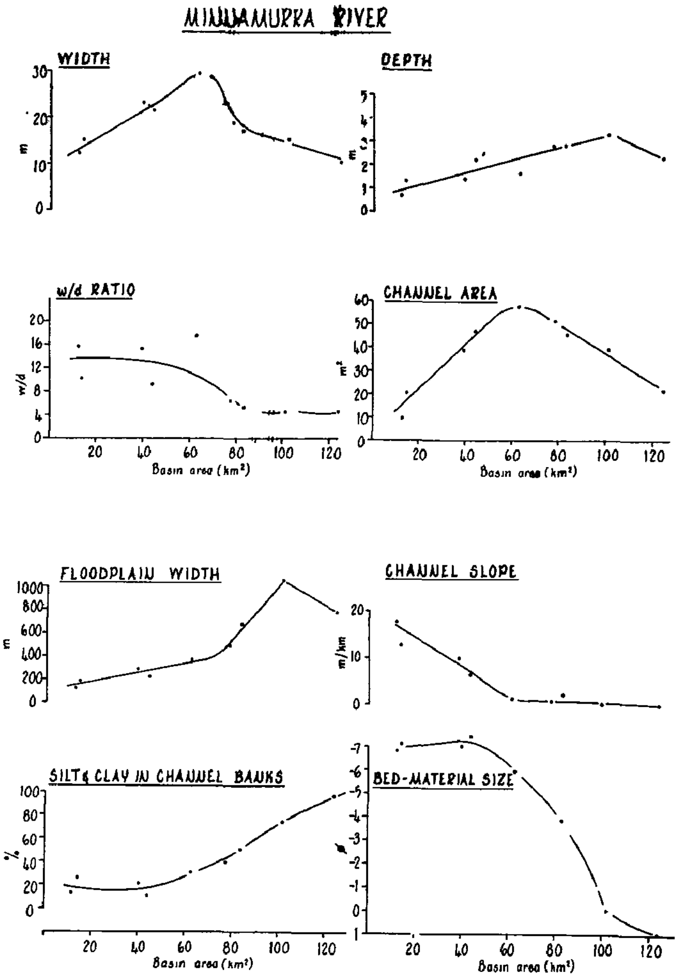

Figure 3: **Downstream changes on the Minnamurra River of channel size and slope, floodplain width, silt and clay in the channel banks, and bed material size.**

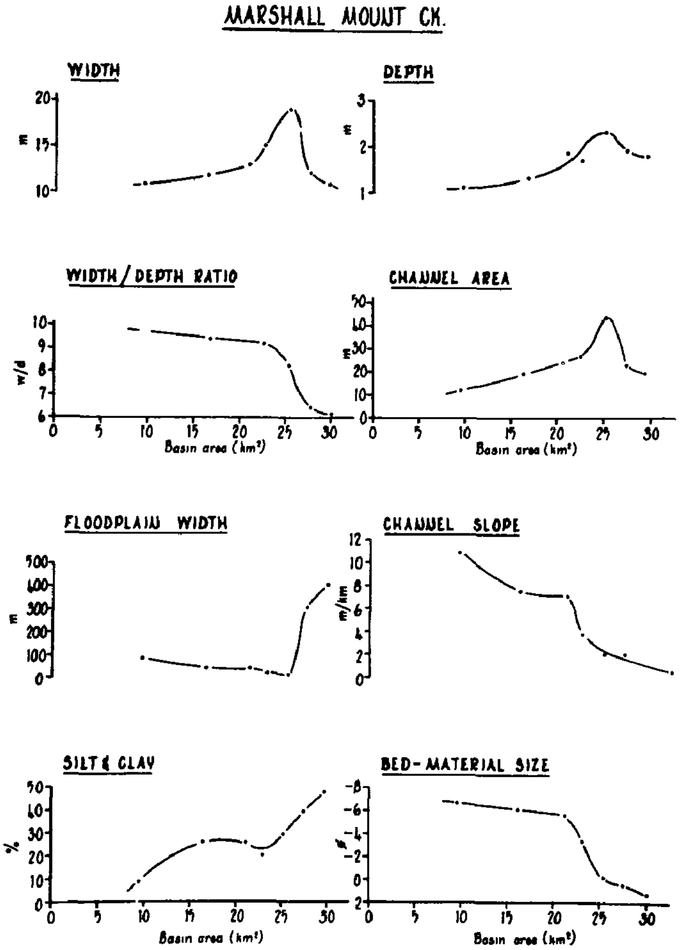

Figure 4: **Downstream changes on Marshall Mount Creek of channel size and slope, floodplain width, silt and clay in the channel banks, and bed material size.**

Accompanying this reduction of channel capacity on both these streams is a sudden decrease in channel and valley slope, an increase in percentage of silt and clay (cohesiveness) in the channel banks, and a pronounced increase in floodplain width (Figs. 3 and 4).

The apparent explanation for this unusual loss of channel capacity in the downstream reaches of these streams is as follows. In the upstream channels slopes are steep and bed and bank sediments are comparatively coarse, uncohesive sands and gravels. Under these conditions of high energy and low bank resistance, the power of the stream is sufficient to erode the channel to a size capable of accommodating all but the largest flows. However, in the lower reaches of each stream, the channel boundary is composed of fine cohesive silt and clay deposited on the very gently sloping lower floodplains. With this sharp reduction of gradient beyond the escarpment foothills, there is a correspondingly sharp reduction of stream power. The streams here are not capable of eroding their cohesive channel boundaries and instead they become constricted with the growth of vegetation and further sediment depostion. This results in flood waters spilling out of the channel and over the wide open floodplains of the lower valleys. Here the floodplain becomes a vitally important component of the total flow system, for the channel itself can carry only a very small proportion of the flood discharge. Residents along both the Minnamurra River and Marshall Mount Creek support this argument by observing that overbank flow occurs only once every 3 - 8 years along the upstream channels, but approximately 1 - 2 times a year from the constricted channels in the lower valleys. This is in stark contrast to research done overseas and widely reported in textbooks of geomorphology, which states that bankfull flow occurs every 1 or 2 years along a river's length and for a wide range different of rivers.

URBAN CHANNELS

When a rural or forested area is subdivided for urban development, there follows a dramatic change in surface water hydrology. Runoff from rainfall is no longer slowed by the resistance offered from grass and tree cover, nor does it infiltrate into the soil to gradually find its way through the subsoil to the stream channels. Instead it is shed as a sudden wave of water off roadways, footpaths, rooftops and parking lots, through gutters and storm-water drains directly into adjacent streams. The outcome is a pronounced increase in the size and number of flood flows in the channel in any given period, usually resulting in channel enlargement.

Three partially urbanised stream basins were selected for study within the city of Wollongong and channel geometries of these streams are compared with the rural streams described above. They are Cabbage Tree Creek, Byarong Creek and American Creek. Cabbage Tree Creek draws from a catchment of 13 km2 of which the lower 50% is urbanised (Fig. 2). Byarong Creek drains a catchment of 12 km 2 of which the lower 45% is urbanised. American Creek is the largest of these three streams, draining an area of 27 km2 (above Allen's Creek), but only the lower 10% is urbanised.

Immediately apparent from a comparison of urban and rural channels in the Illawarra is that urban channels exhibit cross-sectional areas that are 2 - 3 times larger than rural channels of the same drainage area (Fig. 6). Of the urban channels studied very few have reaches that were artificially enlarged. For the most part channel maintenance has taken the form of partial straightening and regular clearance of vegetation growing within the channel. Follow-

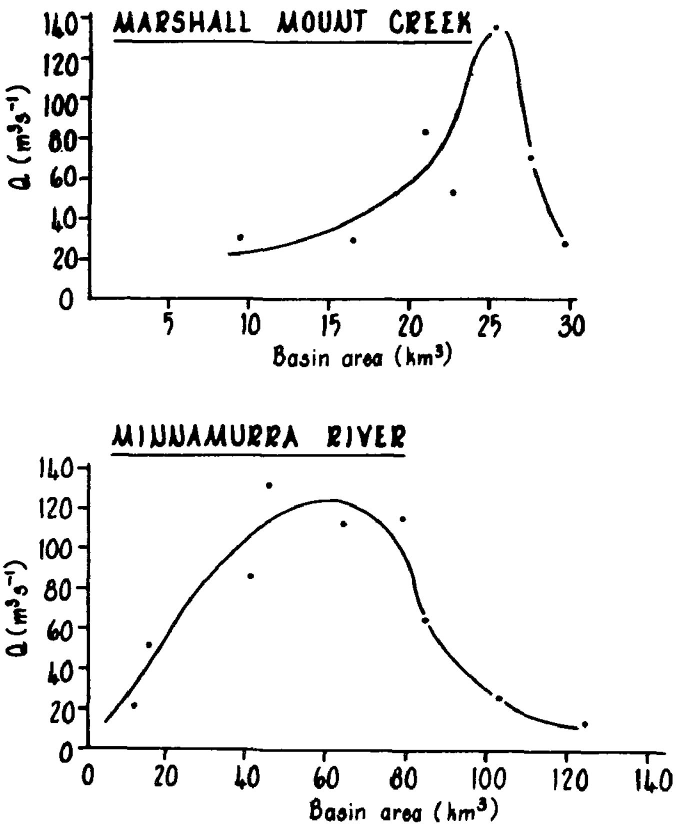

Figure 5: **Downstream changes in bankfull channel capacity on Marshall Mount Creek and the Minnamurra River.**

ing this disturbance, flood discharges have done the rest by scouring away the fine sediments forming the banks and readily entraining the pebble to sand-sized bed material common on these lower reaches.

In the memory of elderly residents along Byarong Creek, near Lindsay Park School, is the recollection of a small rural stream, with vegetation growing down to the water's edge, transformed into a 2 - 3 metre deep and 20 m wide chasm. To accomplish this Byarong Creek, in the 20 or so years since urbanisation of the basin commenced, has eroded 23,000 to 25,000 m3 (43,900 to 47,500 tonnes) of sediment per kilometre in the downstream 2.6km of trunk channel (these estimates are based on a 2.5 fold increase of channel cross-sectional area (Fig. 6) and an unconsolidated sediment density of 1,900 kg/m3).

Similar channel enlargement has occurred on parts of American and Cabbage Tree Creeks, although here erosion has not been so evenly distributed along each stream. On the downstream reach of American Creek, between the Princes' Highway and the freeway, there has been a 48,000 m3 (91,200 tonne) loss of sediment per km of trunk channel (as estimated from the 2.7 fold difference between the urban channel area and the rural channel area immediately upstream). On Cabbage Tree Creek the urbanised channel (between Chalmers Road and Foothills Road) shows obvious signs of recent enlargement, for in some places sewer mains buried beneath the creek bed in 1960 are now exposed by nearly 2 m. However, very unusual for urban streams in Wollongong is the return of Cabbage Tree Creek to a greatly constricted channel just above the foot bridge at Guest Park. The channel here is five times smaller than the expected size of a rural stream draining the same area. and some eleven times smaller than most equivalent urban channels (Fig. 7). The floodplain here is very wide, relatively free of trees, and floods frequently. This pronounced channel reduction appears to be due to two factors. Firstly, public pressure by local residents has resulted in a complete lack of disturbance of this reach by City Council maintenance workers. Consequently there has developed a dense mat of pasture grasses which cover the channel banks and floodplain, trap

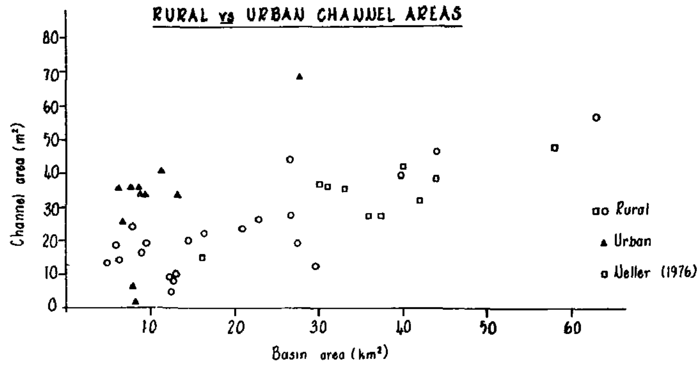

Figure 6: **Rural compared with urban channel size for Illawarra streams.**

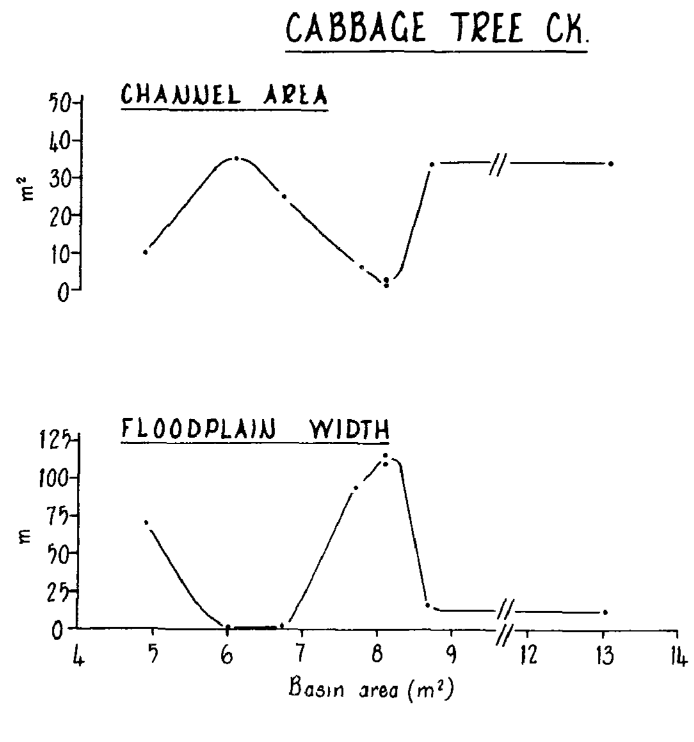

Figure 7: **Downstream changes in channel size and floodplain width for Cabbage Tree Creek. The very small channel sizes (three points) near the centre of the basin are just upstream of the walking bridge at Guest Park. The return to a large channel area downstream of these three points is at the nickpoint upstream of Anama Street. *It continues as a very large channel to the next* (last) point just below Princes' Highway.**

sediment and prevent erosion. Secondly, the erosion of substantial fine sediment during maintenance and straightening of the upstream channel, with the downstream deposition of at least some of this sediment, is probably the explanation for the abundant supply of sediment to this reach. Interestingly, however, the progressive upstream migration of a large nickpoint created by clearance of the downstream channel (between the Guest Park footbridge and Anama Street) means that this greatly constricted channel is only a temporary feature and that the whole lower part of Cabbage Tree Creek will eventually change to a fully developed urban stream (Fig. 7).

These observations of Wollongong's urban streams indicate that the constricted lower reaches of rural streams on the coastal plain will greatly enlarge their channels if urbanisation is accompanied by channel disturbance such as straightening and vegetation removal. It is also possible for rural channels to dramatically reduce in size should urban expansion be accompanied by no artificial channel disturbance. However, this condition may be fragile and subject to sudden change as is presently occurring with the upstream migration of a nick point on Cabbage Tree Creek. On most urban streams in Wollongong, channel incision and enlargement has been of such magnitude that even the increased peak discharges resulting from urban development no longer reach the floodplain surface, and channels appear as deep trenches in the urban landscape.

DISCUSSION AND CONCLUSION

The purpose in describing decrease in channel capacity on Illawarra streams has not been to discredit the textbook assumption that most streams show a progressive downstream increase in size, but rather to emphasise certain limitations of this assumption. A number of studies have suggested using channel geometry to predict mean flow and flood values, yet downstream decreases in channel size may be quite common where flow confined by steep narrow valleys debouches onto lowlands with extensive floodplains formed of fine cohesive sediment. Clearly channel size cannot be used to estimate flood discharges under such conditions.

Until a wider variety of streams showing a downstream decline in channel size are described, it will be difficult, if not impossible, to isolate precisely which variable is most influential in controlling this condition. From this study it appears that the availability of extensive floodplains and fine cohesive sediment in the lower reaches are definitely important. The deposition of fine cohesive sediment on the gentle gradients of the coastal plain acts to constrict the channel, but with the absence of a floodplain for routing excess flow, even very cohesive sediment would probably be eroded and channels would probably respond by increasing in size downstream. This identifies fine-sediment deposition and an available floodplain as both necessary for downstream channelsize reduction, and also emphasizes the importance of the floodplain as part of the total flow system, a point that should be recognised by landuse planners.

The reduction of channel size downstream makes the lower floodplains in this region particularly susceptable to frequent and severe flooding. These floodplains are vitally important both for carrying and temporarily storing floodwaters during severe storms which characterise the region's late summer weather patterns. Recently developers have been reclaiming portions of floodplain for urban subdivision by filling certain areas to a level above that of expected flooding. The result will be reduced floodwater storage, higher flood levels, greater flow velocities, channel scour, and the relocation of large volumes of sediment downstream to the still-water areas behind the coastal sand barriers. The most notable of these areas are, of course, Port Kembla harbour and Lake Illawarra.

Clearly, great care must be exercised in altering the existing streams of this region in order to avoid severe practical and aesthetic repercussions. Attractive streams can quickly be changed into unsightly deep trenches dangerous to young children living nearby. Furthermore, the displacement of large amounts of sediment into bodies of water, such as Lake Illawarra, will have obvious detrimental affects on swimming, boating, fishing and the general appearance of the lake. The region's streams and associated floodplains are fragile and need careful consideration.

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