

The contribution of channel banks and gully walls to total phosphorus loads in the Murrumbidgee River

P.J. Wallbrink*, J.M. Olley*, A.S. Murray* and L.J. Olive**

ABSTRACT: *It is important that land managers have a quantitative understanding of the relative contributions to the suspended sediment and nutrient loads in our inland waterways of topsoil and subsoil. This is especially so in view of the increased frequency of algal blooms and the fact that P has been identified as a key nutrient for algal growth. This paper argues that the sediment load in the lower Murrumbidgee River is dominated (90%) by subsoil material from channel banks and gully walls primarily from tributary catchments between Burrinjuck Dam and Wagga Wagga. Particulate phosphorus concentrations measured in Murrumbidgee channel and tributary sediments, are consistent with those observed in the fine fractions of catchment soils, suggesting that the source of P is predominantly natural. This is supported by the uniform concentration of P along the length of the Murrumbidgee channel, which show no evidence of significant point source impact. In combination the data suggest that the concentrations of P in the Murrumbidgee suspended sediments are derived from subsoil sources within the tributary catchments between Burrinjuck Dam and Wagga Wagga.*

1. INTRODUCTION

1.1 The Murrumbidgee catchment

The Murrumbidgee River is one of Australia's largest inland rivers and drains approximately 84,000 km² of the Murray Darling Basin (see Figure 1). The river rises in the Snowy Mountains and flows through undulating terrain to Wagga Wagga. Between Gundagai and Wagga Wagga the river has formed a well defined floodplain approximately 1 to 2 km wide (Page, 1994). Downstream of Wagga Wagga the gradient decreases and the floodplain width increases to between 5 and 20 km. At Narrandera the Murrumbidgee enters the Riverine Plain and from there follows a highly sinuous course to its junction with the Murray River below Balranald. The area studied extends from Burrinjuck and Blowering Dams downstream to the Murray junction. In this reach most of the major tributaries join the river between the storages and

Wagga Wagga. Downstream of Wagga Wagga there are a number of distributaries.

Grazing is the main land use in the upper basin. The more undulating area around Wagga Wagga is a major grain producing area. There is extensive grazing in the Riverine and Hay plains, with intensive cropping in the irrigation areas. A strong rainfall gradient exists across the basin and most of the downstream flow is derived from the storage reservoirs (Burrinjuck and Blowering) and the tributaries upstream of Wagga Wagga. Maximum discharge is at Wagga Wagga; downstream the river enters a semi-arid area and there is a progressive decrease in flow with distance.

The river is a major supplier of irrigation water and flow is heavily regulated, both by the two major dams and a series of weirs below Wagga Wagga. The flow regime before regulation was highly variable with a winter maximum. However the combination of regulation and extraction for irrigation has resulted in a major change with flow now being spring and summer dominated when water demand by irrigators is highest.

1.2 The Problem

In recent years there has been wide-spread community concern about turbidity and the occurrence of algal blooms in the lower Murrumbidgee River. It is widely believed that the recent blooms in rivers such as the Murrumbidgee are due to elevated nutrient levels. Diffuse anthropogenic sources (eg. agricultural fertiliser) and point sources (sewage treatment plants, feedlots etc.) are often considered the most likely cause of this enhancement (Bek and Robinson, 1991).

In the generally turbid waters of rivers such as the Murrumbidgee, phosphorus is predominantly bound to particles (Oliver, 1993). Therefore if P levels in the Murrumbidgee have increased as a result of human activity, it would be expected that P concentrations on the suspended sediments would be higher than those present on unfertilised catchment

*CSIRO, Division of Water Resources, PO Box, 1666, ACT, 2601, Australia

Tel (06) 246 5823 Fax (06) 246 5800 Email wallbrin@cbr.dwr.csiro.au

** Australian Defence Force Academy, (ADFA), Northcott Drv. Campbell, 2600, ACT, Australia

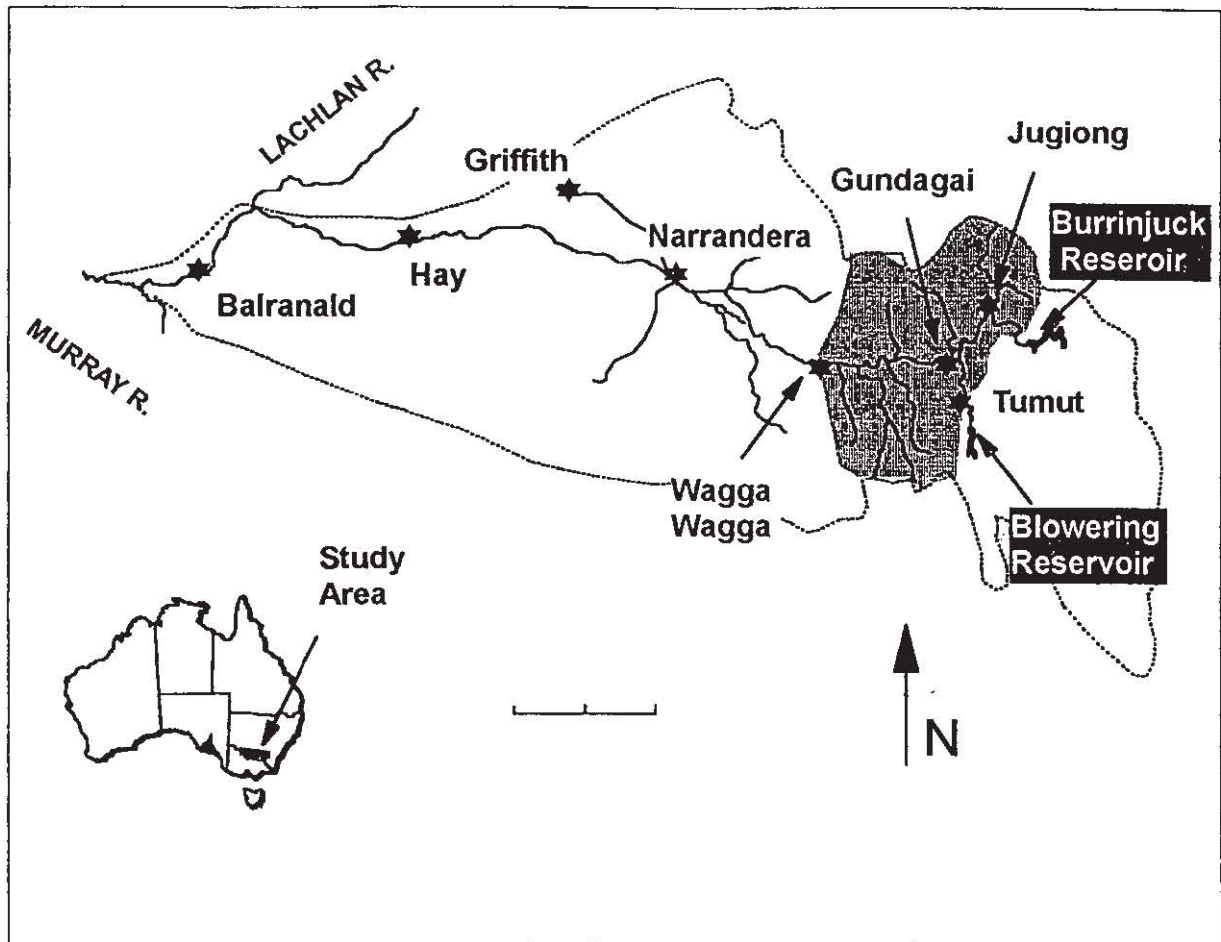


Figure 1: Location diagram of Murrumbidgee catchment, NSW, Australia.

soils. More importantly, if the phosphorus is being derived from fertilised farmland then a significant topsoil component in the suspended sediments of the Murrumbidgee River would be expected. Consequently in order to investigate the source of P to the Murrumbidgee river we have i) determined the relative contribution of topsoil to the suspended sediment load using fallout ^{137}Cs and ii) compared P concentrations on suspended sediments with those in unfertilised catchment soils.

2. MATERIALS AND METHODS

2.1 Catchment sampling strategy

Measurements of ^{137}Cs and P have been undertaken on soils and suspended sediments. The soils in the catchment were sampled both by depth and lithology (two types of granite and an Ordovician metasediment) and taken from locations at which it was believed that no addition of phosphorus had occurred. About 25 % of the samples were from the soil surface and 75 % were from subsoils, to about two metres soil depth.

The suspended sediment samples were obtained by a CFC (continuous flow centrifuge, Alfa Laval model M102b) which can accumulate masses up to 300 grams. Suspended sediment samples were taken from the larger tributaries; Adelong, Jugiong, Tarcutta, Billabung, Kyeamba, Tumut and the Lachlan River, just upstream of their junction with the main Murrumbidgee channel. They were also taken from thirteen sites along the main channel between the towns of Jugiong and Balranald (approx. 1,000 km dist.). Sampling was undertaken over a period of four years in a range of conditions from baseflow to a one in 12 year flood event.

2.2 ^{137}Cs radioactivity

The anthropogenic radionuclide ^{137}Cs has been used extensively in erosion studies to distinguish surface soil from subsoil (eg Ritchie et al., 1974; Burch et al., 1988; Walling and Woodward 1992; Wallbrink and Murray, 1993). Fallout of this nuclide was derived from atmospheric testing of atomic weapons during and after the 1950's. While deposition of ^{137}Cs in Australia began in 1954 it did not reach levels detectable today until about 1958 (Olley et al.,

1991). Fallout essentially ceased in the mid 1970's. In south-east Australia detectable ^{137}Cs tends to occur in only the top 100 to 200 mm of soil profiles (Wallbrink and Murray, 1993). Therefore, it is an ideal tracer to examine the relative contributions of surface to subsoils in suspended sediments. ^{137}Cs concentrations were determined by high resolution gamma spectrometry, as described by Murray et al. (1987).

2.3 Phosphorus

The concentrations of total phosphorus in soils and sediments were measured using standard X-ray fluorescence (XRF) and are given as weight percent P. Concentrations were determined using a Phillips PW1404 spectrometer; samples were prepared according to the method described by Norrish and Chappel (1977).

3. RESULTS

3.1 ^{137}Cs Concentrations in suspended sediments

The ^{137}Cs concentrations in suspended sediment samples from the Murrumbidgee and its tributaries are all generally low, less than 3 Bq/kg (see Table 1). The average value of all the samples collected along the main channel is 2.38 ± 0.13 (n=164) and from the tributaries, 2.29 ± 0.19 (n=49) (see Table 1). These are statistically indistinguishable and support the hypothesis of Olive et al; (1994a) that most of the suspended sediment in the main channel is derived from the tributaries which enter the river below Burrinjuck Dam and above Wagga Wagga. This zone has been defined by the hatched area given in Figure 1.

Location	^{137}Cs (Bq/kg)	sc	(n)
Main Channel	2.38	0.13	164
Tributaries	2.29	0.19	49
Topsoil sediment	26.4	4.9	190

Table 1: ^{137}Cs concentrations in suspended sediment from the Murrumbidgee catchment.

The average ^{137}Cs concentration of the surface derived fine particles is about 26 ± 5 Bq/kg (n=190), see Table 1. The considerable difference between this value and those observed on the suspended

sediments can be explained in terms of dilution by subsoil material, which is not labelled by ^{137}Cs . About 90 % of non-labelled subsoil is required to dilute these surface concentrations to those observed in the Murrumbidgee river.

The ^{137}Cs concentration values from the tributaries, channel and topsoils can also be used to estimate the proportion of fines derived from surface versus gully erosion processes. Unlabelled subsoils are usually derived from channel or gully wall collapse. When this collapse occurs a topsoil contribution is also added to the volume of sediment entering the drainage line. The fine grained fraction of topsoil will be labelled by ^{137}Cs (at approximately 26 ± 5 Bq/kg), however it will be diluted to approximately 0.7 ± 0.2 Bq/kg if the channel walls are about 4 m in height (a reasonable estimate of bank height within the Murrumbidgee channel below Wagga Wagga). The collapse of a 2 m section of wall (such as typically found within the tributary catchments) would produce fine grained sediments with an average net ^{137}Cs signature of approximately 1.3 ± 0.3 Bq/kg.

These data can be used to calculate an upper limit to the relative contribution to total sediment load in the Murrumbidgee by sediment derived from surface erosion processes alone. If the tributary ^{137}Cs concentration is C_T , the predicted concentration from channel/gully erosion is C_G , and the concentration from sheet/rill erosion is C_S , then the fractional contribution F_S of sheet/rill erosion in the sediment derived from the tributaries is:

$$F_S = \left(\frac{C_T - C_G}{C_S - C_G} \right) \times 100$$

Substituting the values given in Table 1 gives a limit to the sheet/rill contribution of < 4 %.

3.2 Phosphorous in soils

Estimates of the natural concentrations of P in Murrumbidgee soils were first obtained by Colwell (1977), who reported concentrations on 41 Murrumbidgee catchment soils. In this study an additional 48 samples were collected from the locations described in section 2.1. In combination these 89 soils are considered to be typical of the region and P concentrations are in the range 0.009 to 0.062 wt% P, mean 0.030 ± 0.001 (see Table 2).

3.3 Effects of fluvial sorting

It is known that fine soil particles contain the highest concentrations of P. In non-aggregated soils, such as those in the Murrumbidgee catchment,

Location	Phosphorus (wt %) measured range	Phosphorus (wt %) mean	Number of samples (n)
Soils			
Soils (bulk)	0.009 - 0.061	0.03 ± 0.001	89
Soils (<2 µm)	0.025 - 0.157	0.07 ± 0.01	12
Sediments			
Tributaries (susp. sed.)	0.026 - 0.137	0.065 ± 0.004	87
Main Channel (susp. sed.)	0.060 - 0.210	0.096 ± 0.004	134

Table 2: Summary of Phosphorus concentrations of sediments and soils within the Murrumbidgee

the fine soil fraction (<2 µm) can be enriched in P over the bulk soil by up to 10 times (Sharpley and Menzel, 1987). Krumbein and Sloss (1963) also suggest that fluvial transport will result in a gradual decrease in average particle size by selective transportation. This effect has been examined in 12 Murrumbidgee catchment soils in wet sieving and particle size settling experiments. The concentration of P on the < 2 µm fraction ranged from 0.025 to 0.157 wt% (Table 2); a maximum concentration factor of about 6 was observed compared to initial bulk concentrations. It should also be noted that the soils chosen for particle size analysis did not contain the highest phosphorus concentrations and it is possible that clay fractions from other soils within the catchment may have higher phosphorus concentrations than those reported here.

3.4 Phosphorus in tributary sediments

The P concentration of suspended sediments from the tributaries were analysed from samples collected using the CFC and rising stage samplers, (installed by N.S.W. Department Water Resources). A summary of these data are presented in Table 2 and all tributary values fall below the maximum concentration observed in the <2 µm fraction from the catchment soils.

3.5 Phosphorus in channel sediments

P concentrations were also analysed on 134 separate suspended sediment samples taken from the main Murrumbidgee channel between Burrinjuck Dam and Balranald (see Table 2). More than 94 % of these data had values lower than the maximum observed from the sieved soil. These data, as well as those from the tributaries, have been plotted against

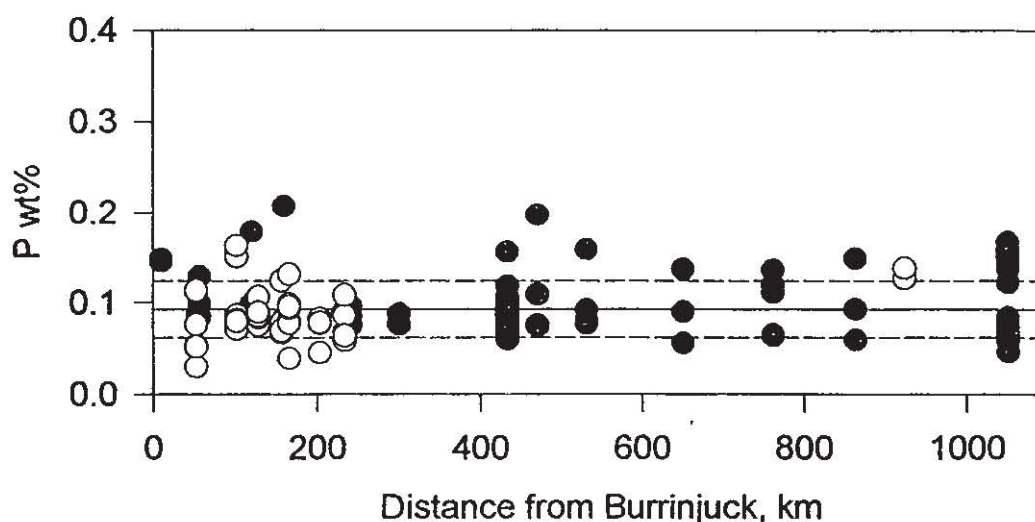


Figure 2: Phosphorus concentrations in suspended sediments from the main Murrumbidgee channel (closed circles) and its tributaries (open circles) plotted against sampling distance from Burrinjuck Dam.

river length to determine the possible influence from point sources (Figure 2). There is no systematic variation in the phosphorus concentrations with distance. In particular there is no increase in P concentration on these particles downstream of the Wagga Wagga sewage works, which used to enter the river at about 230 km on the scale in Figure 2. This lack of significant variation in concentration with river length indicates that inputs from point sources are not important compared to diffuse loads of P (eg. Olive et al., 1994b).

4. DISCUSSION

Concentrations of ^{137}Cs on suspended sediments derived from topsoil erosion processes alone are high. In contrast the concentrations observed on similar sized particles in the Murrumbidgee River and its tributaries are very low. The difference between the two is most probably due to dilution by a substantial amount of unlabelled subsoils derived from gully wall and channel bank erosion. The amount of contribution from surface soil (ie 0-10 cm depth) to total suspended sediment load is calculated to be less than ten percent. The ^{137}Cs concentrations measured in the channel are consistent with those from the tributaries between the dams and Wagga Wagga. This supports the evidence from flow and turbidity data which indicates that these tributaries are the main source of suspended sediment to downstream channel flow, (Olive et al., 1994b). The low ^{137}Cs concentrations at the tributary outlets also suggest that most of the subsoil contribution has occurred within these upland catchments prior to entering the Murrumbidgee River itself.

The concentrations of P measured in suspended sediments throughout the main channel and its tributaries are consistent with those from the fine fractions of a representative selection of catchment soils. Indeed, the mean phosphorus concentrations observed within the tributary and channel sediments are only factors of 2 and 3 respectively, above the mean bulk soil P concentration. Within our own limited number of fine samples extracted from bulk soils we have observed concentration factors up to 6 times. Others, (Sharpley and Menzel, 1987) report factors of up to 10. It must be concluded that the argument for a significant addition of particulate P by importation (eg fertilisers) to the catchment is weak. Further evidence for this is given by the uniform concentration of P observed along the length of the main river channel.

5. CONCLUSIONS

The data presented here strongly infer that the major source of particulate P to the Murrumbidgee channel is natural. The ^{137}Cs data also suggest that P is predominantly provided by erosion of subsoil material from channel banks and gully walls of the tributary catchments upstream of Wagga Wagga and below Burrinjuck Dam.

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