Guidelines For Growing Phragmites For Erosion Control

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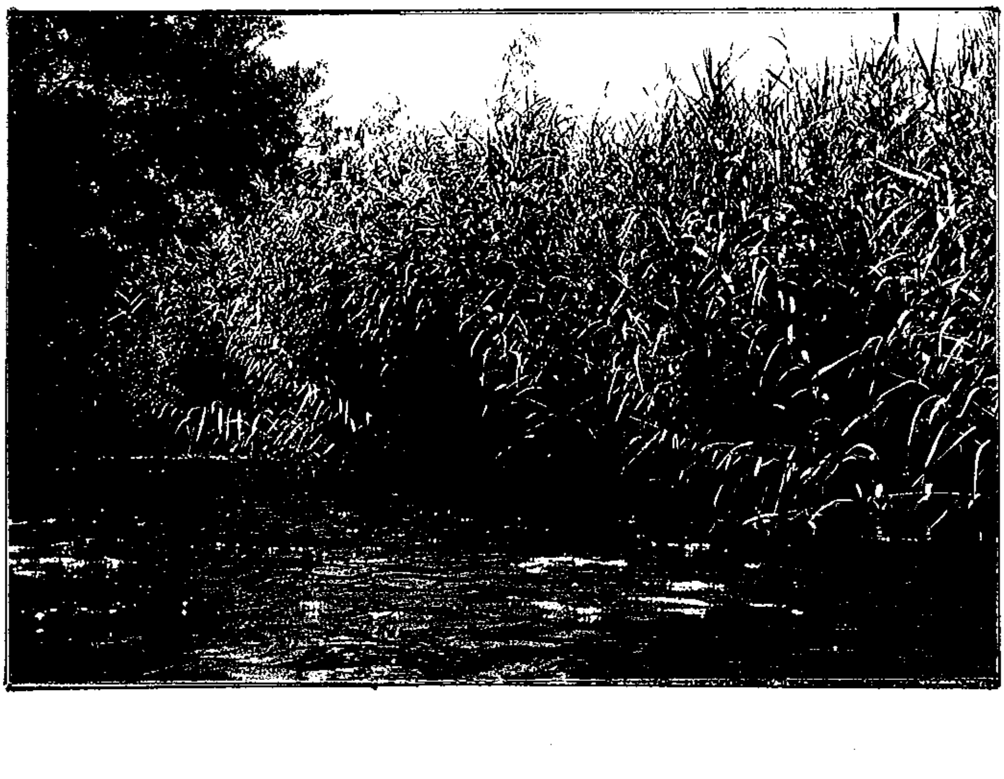

NATURAL RESOURCES MANAGEMENT STRATEGY
MURRAY · DARLING BASIN

COOPERATIVE RESEARCH CENTRE FOR FRESHWATER ECOLOGY

The Murray-Darling Freshwater Research Centre

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INTRODUCTION

The Common Reed, *Phragmites australis*, is a cosmopolitan species, with its major occurrence in Europe, Asia, Africa and Australia (Haslam 1973). It forms large monospecific stands in wetlands, and along lake and river margins, and dominates large areas on major river deltas (Hocking et al 1983). It is widespread in temperate Eastern Australia, being replaced by *Phragmites karka* in Queensland north of Mackay. Since settlement, the distribution of *P. australis* in Australia has undoubtedly been reduced in many areas by grazing and drainage.

Phragmites has been widely recognised as an important species for riparian habitat and bank stabilisation in Great Britain and Europe (Lewis and Williams 1984), (Bittmann 1953). It is also commonly used to trap silt and nutrients (Brown 1994). Investigations on the River Murray near Albury-Wodonga have shown that it can play a similar role on temperate Australian rivers.

The following guidelines for the use of Phragmites have been based on experience on the River Murray between Lake Hume and Lake Mulwala over a period of six years. Phragmites has been successfully grown and established on bare river banks along this section of the Murray River in trial plantings, and growth rates and bank stability are being monitored. The planted sites will continue to be monitored, and the guidelines may be amended as further experience and results are obtained.

PHYSICAL CHARACTERISTICS OF PHRAGMITES

Phragmites plants form dense clumps of annual vertical stems (canes), up to 4 metres tall, although often only 1.5 to 2 metres, rising from a network of underground stems (rhizomes). The rhizomes are often close to the soil surface, but can also grow to considerable depths, when the water table is below the surface. The below ground biomass is generally greater than the biomass of above ground parts (Westlake 1966).

A stand of reeds may be developed from a single original plant, which spreads vegetatively by the horizontal growth of the rhizomes, becoming a number of separate plants in the stand as the old rhizome connections die. New aerial stems are produced from the rhizomes each spring, and die off in late autumn, after flowering. The dead canes persist for one to two years, and provide an important function by aerating the submerged rhizomes during the winter. A large stand of Phragmites could therefore represent a single genetic entity (clone) if it has spread from one original plant.

Flowering occurs in autumn, and most stems produce a terminal flowering head. Large quantities of seed may be produced or in some years and localities the heads may be sterile. Successful reproduction from seed is probably a rare event (Haslam 1972). Newly germinated seedlings are very intolerant of desiccation, inundation or competition from other plants. Once well established, and with access to sub-soil moisture, Phragmites can survive without surface water, but usually occurs in permanently or seasonally flooded sites, where it may be the dominant species.

VALUE OF REEDS FOR BANK STABILISATION

Annual bank surveys on the River Murray have confirmed that reed-covered river banks are generally more stable than banks bare of vegetation. The combination of a dense network of rhizomes and tall stems protects the sediments from the erosive effect of current and wave action, and reduces the likelihood of slumping after rapid draw-down. Reeds can grow in water up to 2 metres deep, although generally 1 metre or less if permanently flooded, or subject to significant water current and wave action.

On the River Murray between Lake Hume and Lake Mulwala, river regulation causes a reversal in seasonal flows and a difference of 2 metres between summer (high) and winter (low) flows. It has been suggested that this flow regime makes the banks susceptible to erosion, by preventing the growth of vegetation which would protect the banks against the eroding forces of floods and slumping when the river falls (Anon 1977).

The reversed flow regime does prevent the growth of many herbaceous species which may naturally have covered the banks during summer and autumn. However there are still vigorous natural reed beds growing on the Murray despite the regulated water regime. During summer, bank-full irrigation flows of 25,000 ML/day will bend and damage the stems at the deepest edge of the reed beds, but the main stand remains unaffected. Erosion surveys on the Murray show that these reed beds stabilise the banks and prevent the erosion by attrition which occurs on most bare banks along this section of the Murray (Frankenberg et al 1995).

On a high steep bank, the greatest stability is achieved when the reeds can grow over the top of the bank as well as at and below the water line (see Figure 1). In the event of some undercutting, the reed bed will persist on the face of a steep bank because of the rhizome connections with the top of the bank. On the River Murray upstream of Lake Mulwala (rainfall >500 mm) and where protected from grazing, reeds can grow 2-3 metres above high water level up the bank and will spread onto the floodplain.

The presence of trees and shrubs on the upper bank also adds to bank stability. On rivers and streams in higher rainfall zones (>800 mm), many species of trees and shrubs can effectively stabilise the banks. On the River Murray below Hume Dam, however, trees and shrubs alone without reeds are generally not effective, as the dominant river red gums (*Eucalyptus camaldulensis*) have a shallow open root system which is easily undermined on a steep bare bank. The stability of bank sediments generally depends on herbaceous species. The exclusion of grazing is therefore an important contribution to bank stability.

On the coastal streams in New South Wales, Phragmites is an effective bank stabiliser in estuarine areas where it provides protection from wave action and tidal fluctuation (A. Raine pers. comm.). Where dense-foliaged trees and shrubs occur in the riparian zone of streams, shading will probably reduce the importance of Phragmites as a stabilising species, but it would be a useful plant in cleared areas.

Willows have been used widely and with success for bank stabilisation in temperate Australia, but increasing concern about their impact on riparian habitat and morphology is raising questions about their continued use (Carr et al. 1992), (Frankenberg 1995). Control programs are in place in many catchments, and willow planting is now rarely recommended by river management authorities.

METHODS OF ESTABLISHMENT

Phragmites can be established from seedlings, cuttings or transplanted rhizomes. The method selected depends on the availability of suitable material and equipment. Where practicable, seed or plants should be collected from an area similar to the planting site. Phragmites populations tend to become adapted to a particular hydrological regime (season of flooding) (Haslam 1970) and reeds growing in estuarine conditions, or saline inland areas, will be more salt tolerant than those growing in freshwater conditions.

Transplanted rhizomes can give the quickest result, as the resulting plants are mature and robust and will spread rapidly. However they are bulky to transport and handle, and collection of the plants can have a considerable impact on the source area. The rhizomes must be handled carefully to avoid damage, or they may fail to establish. Planting is best done during winter and early spring, when the plants are dormant, but plants can be transplanted successfully at any time of year with care.

Stem cuttings taken in spring will root and grow if planted directly, or may be struck in water or grown in pots before planting out. These plants will also be physiologically mature and form robust flowering plants relatively quickly. The cuttings can be collected from existing stands without seriously damaging the reed beds. This can be particularly important if the only local reed beds are on river banks where excavation for rhizomes would present an unacceptable level of damage to the bank. The success of cuttings will depend on the water regime, as they have a limited tolerance to water level fluctuations until established.

Seedlings can be raised in large numbers, without the need for access or damage to existing reed beds. While seed set does not occur every year, one successful collection can provide large quantities of seed for several years propagation. Seedlings can be grown with slight modification to standard nursery techniques. The plants grown from seed and planted out at six months old will take a few years to develop into mature plants, so effective stabilisation of the bank may take a little longer than when using mature plant material.

PROPAGATION AND PLANTING TECHNIQUES

Rhizomes

In the past, transplanting rhizomes has been the most commonly used method of establishing new stands of Phragmites. A suitable supply of plants can be the greatest limitation to this method, particularly if large areas are to be planted. It should only be used if the environmental impact on the source of plants is minimal. Transport may also be a problem when using large quantities of bulky material if there is poor access to the planting site .

Source areas should be similar to the site to be planted. For example, clones of Phragmites from fresh water sites will not do well in saline situations, and plants from wetlands may take a few years to adapt to flowing waters. European experience suggests that adaptation to different growing conditions may be quite important (Haslam 1970), although no data is available for Australia.

If the machinery and source is available, a back-hoe can be used to dig rhizomes, which can be transported by the truck load and deposited on the planting site. This technique has been successful on the Mitchell River in Victoria (Ian Drummond pers. comm.) and the Williams River in NSW (Richard Gibson pers. comm.). Alternatively, plants can be dug by back-hoe, or shovel, then separated by hand and the rhizomes planted individually, or in small clumps.

Planting should be into wet mud or shallow water, and at least 1 metre of the existing live or dead stems left attached, to provide aeration for the rhizomes until new stems grow. Care should be taken not to damage the rhizomes and buds, which are very brittle.

Transplanting on the Murray River is most successful in late winter and early spring. This has also been the experience on the Edward River near Deniliquin (Jones 1992). On rivers regulated for irrigation, where water levels are low during winter, planting should be just below the expected summer water level, so that the new plants will not be too deeply submerged during high summer flows. On unregulated streams, planting could be earlier, in late autumn or early winter, to allow establishment before spring floods. New transplants will drown if the old attached stem is over-topped before the new stems grow above the surface of the water. The timing of planting therefore aims to allow establishment before the plants are subject to prolonged immersion.

Rhizome transplants produce vigorous, physiologically mature plants which can quickly reach full size.

Cuttings

Phragmites will grow readily from stem cuttings taken in spring, providing a means of obtaining a large number of plants without severe damage to the reed bed. Like rhizome transplants, cuttings have the advantage that they quickly develop into mature plants. Plants grown from cuttings are capable of flowering in their first year, while seedlings can take several years to reach maturity.

Cuttings are taken from young, vigorously-growing stems, 1-2 metres tall. The taller stems should be trimmed to 1 metre and the lower section used. The top section of 2 metre stems can also be used, with a somewhat lower strike rate, if the axillary buds are well developed. Well developed buds, at the node under the sheath of the leaf, should be plump and green (see Figure 2). The stems are inserted into the bank sediments at a water depth of 10-30 cm so that at least 2 nodes are buried. The top of the stem must remain exposed above water level, to maintain aeration for the growing points which develop at the lower nodes. Care should be taken not to bend or damage the stems. In firm banks, they should be placed in ready prepared holes, rather than forced into the sediment.

Alternatively, the cuttings can be struck in a bucket of water for three to five weeks, until roots and shoots have developed, then planted, or potted into soil and grown into larger plants.. Care must be taken at planting as the new growth is brittle and very easily damaged. Trowels and hands are generally better than shovels and boots.

Cuttings have been planted on the Murray River both directly and as rooted plants. Success has been mixed. Most failures have been due to bank erosion and water level movements. Plants which have established have spread well and produced a high stem density within 3 years. At one site, 6 rooted cuttings planted 50 cm apart, developed in 3 years into a reed bed 4.80 metres long containing over 150 stems, with stems to

1.5 metres tall). At another site, 85 rooted cuttings planted along 50 m of bank had reached a density of 7 stems per metre, with stems 2 metres tall and flowering, within 2 years.

More extensive plantings of cuttings were carried out by Allan Jones, of the Department of Conservation and Land Management, on the Edward River, during 1990-91. Jones observed that a major factor in the successful striking of the cutting was the condition of the axillary buds at the stem nodes. Only stems with green, well developed buds would strike well. The best results were obtained when stems were planted before the end of October, however satisfactory establishment could still be achieved until the end of December (Jones 1992). Success rates of about 50% were achieved on the Edward River.

Success with cuttings depends on a steady water level for a period after planting. Either a rise or fall in level could be detrimental. New plants are susceptible to dehydration until the roots have developed sufficiently to follow as moisture retreats in the bank. The young plants will not survive complete inundation for more than a few days until they have developed rhizomes and a nutrient store which will enable regrowth.

Seedlings

Seed can be collected from the mature flowering heads during winter and early spring. The heads are not always fertile, and in some years no seed is produced. In Europe this is a frequent phenomenon but experience in the Albury-Wodonga area has been that seed can be collected in most years. In a good seeding year it would be prudent to collect enough for future needs, as viability is maintained for several years.

Viability can be confirmed by dissecting seed from the seed head under magnification (see Figure 3) or by a trial germination. At temperatures above 25^{o} C germination will occur in a week.

Seed can be germinated while still contained in the head, or the seed threshed out and concentrated by agitation in water (eg. in a blender). The seed and some husks will float to the top while stems will sink. Germination is carried out by spreading the seed, or the broken up flower head, on a tray of mud, which is kept wet with free water on the surface (5-10 mm deep). Germination is slow (3-4 weeks) at low temperatures, but rapid (6-7 days) at temperatures over 25^{o}C. Increased germination may occur if the seed tray is dried briefly and re-flooded. Seedlings are transplanted into individual pots when large enough to handle (3-4 leaves). Standard tree tubes, 4 cm x 4 cm x 14 cm are suitable.

Seedlings can be grown in normal potting mix, with a reasonable nutrient level. Nitrogen is the most important nutrient for increased seedling growth. Pots should either be watered frequently in high humidity glass house conditions, or kept in water-tight trays so that a high water table is maintained, halfway up the pots. Plants will be large enough to plant out when they are at least 30 cm tall, with more than 5 stems (see Plate 1). They will then be producing rhizomes, and be ready to spread. This can take up to 6 months, depending on the growth rate achieved. If grown in a glasshouse they should be hardened off outside before planting.

Advanced plants

On difficult planting sites, better establishment may be achieved by using larger plants. During trials on the River Murray, 10 litre buckets have been planted with 3-4 seedlings per bucket, in a high nutrient potting mix, and grown for a further 3-4 months, until the root mass fills the bucket. The same result could have been achieved with cuttings. The larger plants with a tangled mass of rhizomes are easier to plant securely into unstable bank sediments (see Plate 2). The plants can be pegged down with a stake driven deep into the bank to provide additional stability if necessary.

Fertiliser Use

Phragmites is very responsive to nutrients. Seedlings in pots will stop growing when nutrients become limiting, and then respond quickly to added fertiliser. On low fertility planting sites, the use of a slow release fertiliser in the planting hole will increase initial growth rate and establishment success. Tablets have been found to be easier to manage than granules. Once plants become dense enough to trap some silt from the stream flow, growth can be quite vigorous even on low fertility sites.

Planting Season

The most favourable planting season depends on the water regime at the site. Successful establishment depends more on moisture availability than season. While above ground growth occurs mainly in spring and summer, rhizomes and roots can grow in all seasons. Reasonably stable water levels for some weeks after planting, or, if the water level falls below the planting position on the bank, a reliable rainfall, will give the greatest chance of success. Aerial shoots cannot survive prolonged submersion. If the plants are fully inundated for more than a few days in the first season after planting there may not be sufficient reserves in the rhizomes to grow new shoots.

The weeks immediately following spring flooding are generally the most favourable time for planting seedlings, as this is the period of maximum growth rate. However if banks are likely to be very dry during summer, there may be a risk of losses as the moisture level in the bank retreats more quickly than the root systems can follow. Rhizome transplants are easier to manage in winter when the plants are fairly dormant, provided the water regime is favourable. Cuttings will only strike reliably in the late spring, but can been grown in pots for autumn planting.

Mature Phragmites is generally dormant above ground during winter, and grows rapidly in late spring. However roots and rhizomes continue to grow slowly during winter and seedlings tend to have a longer growing season. Autumn and winter planting can therefore be more successful than spring, if the spring floods are brief or unreliable.

Planting Density and Position

The chosen planting density will depend on the quantity of material available and the profile of the bank to be planted. On steep banks, it may only be possible to use one or two rows of plants at the water line, with a close spacing of 20-30 cm. On flatter banks, several rows with 50 cm spacing of plants and 50 cm between rows could give rapid development of a dense stand if sufficient material is available. Cuttings should be planted more densely than seedlings or rooted cuttings, to allow for failures.

Rhizomes and advanced 'bucket' plants could be more widely spaced, as more rapid growth and spread can occur. High density planting for quick effect must be traded against the amount of material available and length of bank to be covered.

The range of levels on the bank which can be planted depends on the potential rainfall and water regime, and the shape of the bank (see Figure 4). Plants need continual access to moist soil, without the risk of prolonged total immersion. When rainfall and water regime are unpredictable, planting at several levels spreads the risk and improves the chances of some plants surviving.

Rate of Spread.

The rate of spread of newly planted Phragmites will depend on the fertility of the site. On the River Murray, six plants, grown from cuttings, and planted 70 cm apart, after 3.5 years formed a stand 480 cm long and with a density of approximately 30 stems per square metre to 150 cm tall.

At another site, 20 seedlings were planted in two rows at 25 cm spacing, with slow release fertiliser. Five years later, a stand 9.6 metres long, nearly two metres wide, with a density of 90 stems per square metre, had developed (see Plate 1).

Both of these sites were on sandy banks and better rates of spread would be expected on more fertile sediments. In both cases some silt accumulation has occurred and the bank shape is becoming more convex. A convex bank shape generally indicates bank stability.

Competition from other species.

Phragmites seedlings are susceptible to competition from other species, and growth rate is poor in the presence of vigorous terrestrial grasses and herbs. Establishment is therefore often more successful in water, where terrestrial species are disadvantaged, or after a period of flooding, when the banks are bare. Once established, Phragmites will generally dominate and shade out most other herbaceous vegetation.

POTENTIAL PROBLEMS IN ESTABLISHMENT OF PHRAGMITES

Susceptibility to grazing.

Phragmites is very palatable and readily grazed by sheep and cattle. Unless stocking rates are very light, reed beds rarely persist except in sites where they are inaccessible to stock, such as on steep banks, or where protected by deep water. Re-introduction of reeds to the riparian zone is therefore not possible without stock proof fencing. Once well established, reed beds can be subjected to light grazing for short periods, provided that the stocking rate is not high enough to cause permanent damage to the stand. Fenced riparian zones wide enough to create small 'paddocks' can be grazed in a controlled manner when necessary for management purposes, while minimum width strips of only a few metres cannot be used usefully.

High Flow Velocities

While established reed beds can tolerate some current and wave action, turbulent water movement will damage young stems and limit growth. If the flows are strong enough to bend and submerge the stems on the outer edge of the reed bed, the spread of the reeds into the stream will be limited and their growth may be confined to the shallow margins. On banks exposed to strong currents Phragmites is unlikely to develop a dense stand below the water line. The effectiveness of the reeds as stabilisers will then depend on the morphology of the bank and the hydrological regime. If a stream is spatey, and rises quickly for a short period, from a steady low flow base, reeds will quickly recover from damage and still be able to provide effective protection from flood related erosion. The reed bed can provide little protection to banks subject to undercutting by turbulent flows below the level at which the reeds can grow.

On the Murray River reeds can grow to a depth of 1.5 metres in summer regulated flows on straight reaches, when the flow will bend stems at the outer edge, and to 2 metres in back-waters. Banks are effectively protected by the dense mass of rhizomes which cover the bank, even if when some stem damage occurs. Existing stands can survive in conditions under which establishment would be difficult.

Nutrient Requirements

The resilience of the reeds also depends on the vigour of the stand, which will reflect the nutrient status of the sediments. Weakly growing stems will be more susceptible to damage by strong currents, and the stand will have fewer resources with which to regrow. At the other extreme, very high nutrient levels can also result in a weakening of the reed stems and increased susceptibility to damage from wave action. This has been a concern in Europe, where decline or loss of reed beds from lake shores has been attributed to eutrophication (den Hartog et al 1989), but is not likely to be an issue on most Australian streams. The accumulation of silt and organic matter by a reed bed as it develops will improve the nutrient supply to the plants, and increase the vigour and density of the stand. Existing vigorous stands on sand-bed streams indicate that sufficient nutrients can be trapped this way.

Need for stability for initial establishment

Phragmites plantings require a few years to develop into dense reed beds which can provide effective bank stability. Initial establishment can therefore be difficult on very unstable sediments, and protection of newly planted banks for a short period may be necessary until the reed plants are well established. Depending on the site, brushing, some form of matting, or current deflectors such as groynes or retards may be suitable.

On very unstable banks, structural works which deflect flow away from the bank are commonly used for erosion control, in conjunction with vegetation. On the River Murray, needle groynes have been used to stabilise banks where previous efforts to establish reeds had failed. Subsequent planting with advanced plants (in autumn 1994), has been successful to date (see Plates 2 and 3).

Reeds successfully established on stable sections of bank will spread, and provided that the banks are fenced so that dense growth can develop on the upper bank, the reeds will gradually invade the unstable sections.

There is a limit to the depth to which reeds will grow, which diminishes with increasing current. Therefore on large rivers, where bank instability is associated with a major meander movement and undercutting at the toe of the bank, or deepening of the stream bed, reeds will not be effective in halting erosion. Erosion of this type requires understanding of the morphological processes involved, more robust engineering solutions and appropriate river management along the whole reach of the stream. Reeds can only be useful in conjunction with other works.

Reeds are likely to be most effective where the erosion is due to exposure of unstable bank sediments to wave action or flows, or slumping of the bank because of water seepage and/or soil structural failure. A combination of reeds, shrubs and trees will provide the most secure bank stabilisation at these sites.

OTHER BENEFITS OF PHRAGMITES ESTABLISHMENT

Riparian Habitat

Phragmites was formerly a major component of the natural riparian vegetation of many rivers and streams in South-eastern Australia, but has been removed by grazing stock over much of its former range. It provides important habitat for riparian fauna, such as Reed Warblers and Moorhens, and shelter for aquatic species. Being an indigenous species, it is not likely to become an environmental weed in any area where it is planted. Occasional crash grazing can be used as a tool to prevent excessive spread.

On river banks where a dense stand of Phragmites alone is not desirable, the shade cast by most indigenous riparian trees will reduce the vigour and density of the reeds, and increase the species diversity while not losing all the benefits of bank stability. The dense shade of willows will exclude Phragmites completely, and degrade the riparian habitat.

Nutrient Control

The silt trapping capacity of a reed bed contributes to the nutrient controlling function of riparian vegetation. The understorey species, rushes, sedges and reeds, are the significant component of the vegetation which achieve this. Bare banks under dense trees and shrubs would have little effect in removing the nutrient-carrying silt in over-bank flows.

Phragmites also has a valuable role to play in nutrient management further up the catchment, where nutrients should be held before reaching the river system. Its frequent use in constructed wetlands, both in Australia and in the Northern Hemisphere, is testimony to its efficiency in this role. It has been successfully used to trap silt and raise the bed of gullies. This reduces the movement of sediment down the catchment, and siltation and turbidity of streams. As the major mechanism of phosphorus movement into streams is by attachment to soil particles, (Cullen 1991) reed beds can therefore contribute to the reduction of phosphorus loads in rivers and streams.

Groundwater Discharge Sites

Phragmites has potential, as yet untested, for use in groundwater discharge sites which are at risk of salinisation. Once established, it will persist with access to a shallow water table, will provide useful grazing if carefully managed, and has some salt tolerance

POTENTIAL FOR ADVERSE EFFECTS

Uncontrolled Spread

There has been some concern expressed about the potential for invasion by Phragmites into rice crops and irrigated pasture if its distribution along river banks is increased.

It has been recorded as a pest of irrigation channels and flood mitigation channels (Hocking et al 1983), and control measures are routinely used in some areas. The palatability of the green shoots suggests that it is unlikely to be a significant problem in pastures which are subjected to normal grazing pressures in spring and summer.

There is a possibility of Phragmites invading rice fields which are continually cropped, as the conditions would be very suitable, but it should be easy to control in fallow or ley pasture rotations, and is unlikely to become a problem under appropriate management. It is readily controlled by herbicides (Hocking et al. 1983).

Impact on Small and Shallow Streams.

Phragmites is not appropriate for use on shallow streams and rivers where flooding is likely to be a result of obstructions in the stream. This is particularly important if the stream is 'perched' above its floodplain, and at risk of changing course on the floodplain. The presence of a dense stand of reeds along the bank of a flood prone stream may build the natural levees on the banks by trapping silt, and increasing the height of the stream above its floodplain, so that a course change becomes inevitable.

When the stream is incised, Phragmites will be of value in trapping sediment and restoring a more natural cross section. The presence of Phragmites in a small stream will generally be less obstructive than Cumbungi (*Typha spp*). Provided that the stream is fenced, the Phragmites will tend to grow on the banks, concentrating the flow in the centre of the stream. Cumbungi will grow only in the centre, and will push the flows against the banks. This tends to have the effect of making the stream wider and shallower. Unfenced Phragmites will have the same effect.

MANAGEMENT

The fenced riparian zone in which Phragmites is established should be wide enough to be crash-grazed, generally in spring, allowing regrowth during the summer. This can be done without damaging the reed beds if managed correctly, and will reduce the build up of dry matter, while re-exporting trapped nutrients back up into the catchment.

Winter burning is commonly used as a method of reducing the bulk of accumulated dry matter in reed beds. This increases the density of the subsequent growth and may remobilise the nutrients accumulated in the reed-bed, allowing them to move back into the stream. It would also leave the bank more susceptible to erosion by spring floods. Grazing is probably a more effective way of removing bulk and nutrient, provided that it is not so prolonged as to do permanent damage to the stand.

PREVENTATIVE RIVER MANAGEMENT

Phragmites can be used to reduce or prevent existing bank erosion in many situations, but the most desirable objective is to maintain river and stream banks in a well vegetated condition so that erosion does not begin. While some erosion is the result of major morphological changes in the river channel, in many cases it may be caused by occasional events such as a flood on a susceptible bank. Sound fencing to enable the management of riparian vegetation by appropriate grazing control is probably the most important single river management practice that a land owner can carry out. Once the bank is fenced, the planting of reeds, trees and shrubs can be carried out as necessary. No planting may be needed for many herbaceous species as natural regeneration will be sufficient to maintain or restore a healthy riparian environment. Phragmites is the exception, as it does not spread easily to a new site, and will have to be planted where required, as is the case for many tree and shrub species.

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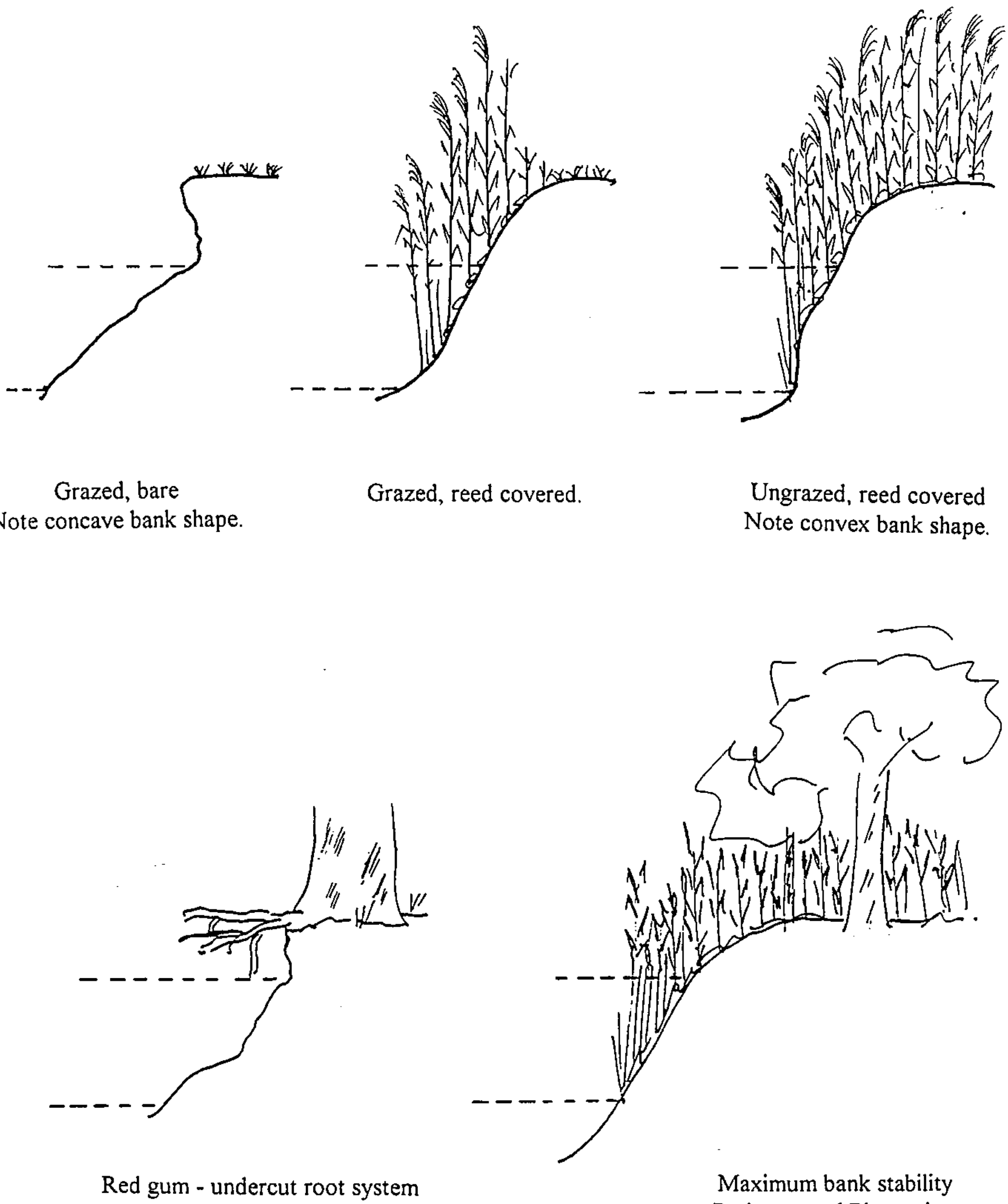


Fig. 1 Bank shape and vegetation cover.

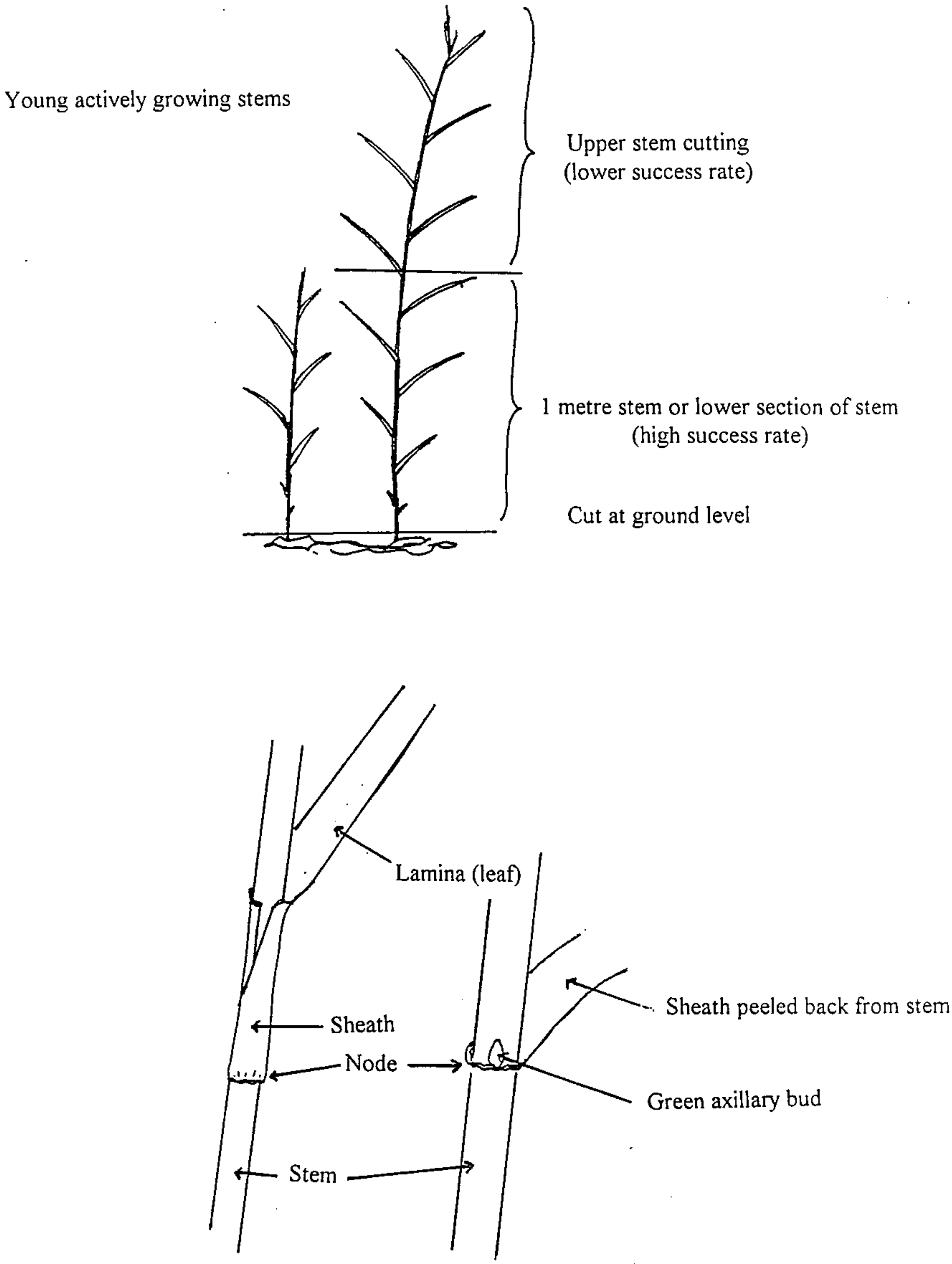
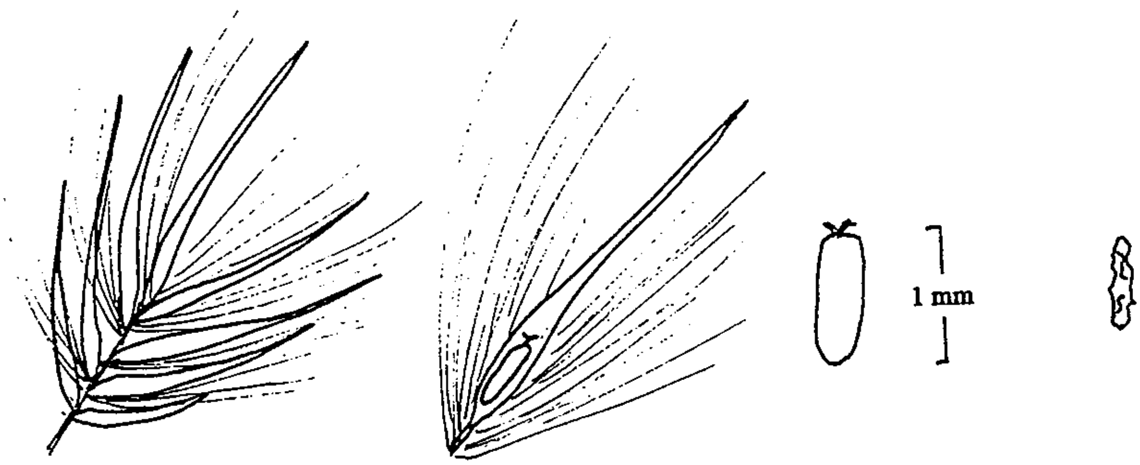


Fig. 2 Taking reed cuttings.



(a) x 5 (b) x 10 (c) Viable seed (d) Non-viable seed

Fig. 3. Phragmites flowers and seed

(a) Spikelet with several flowers and hairs. (b) Individual flower.
(c) Well developed, viable seed. (d) Poorly developed, non-viable seed.
Figure 1. Bank shape and reed cover

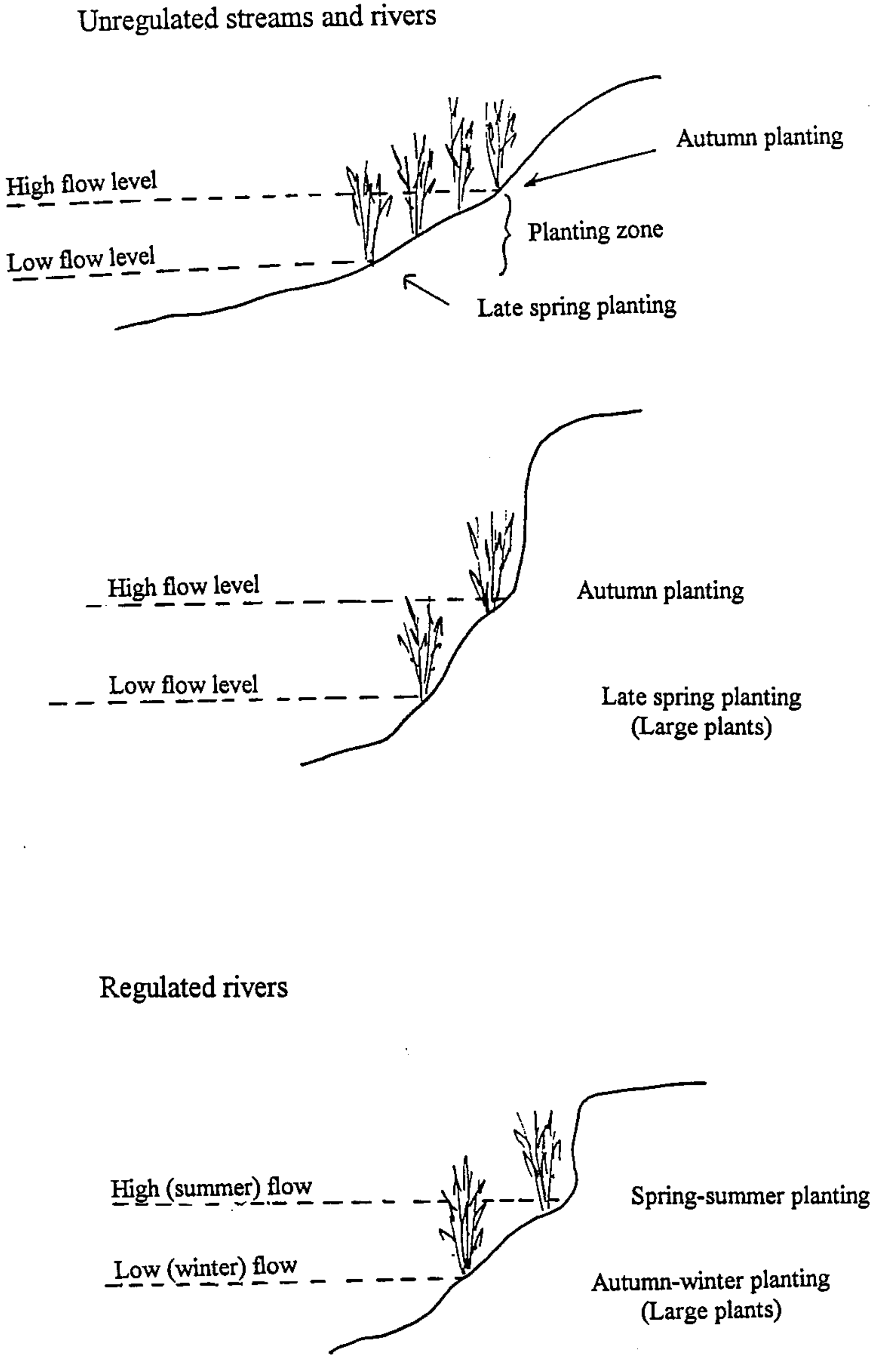


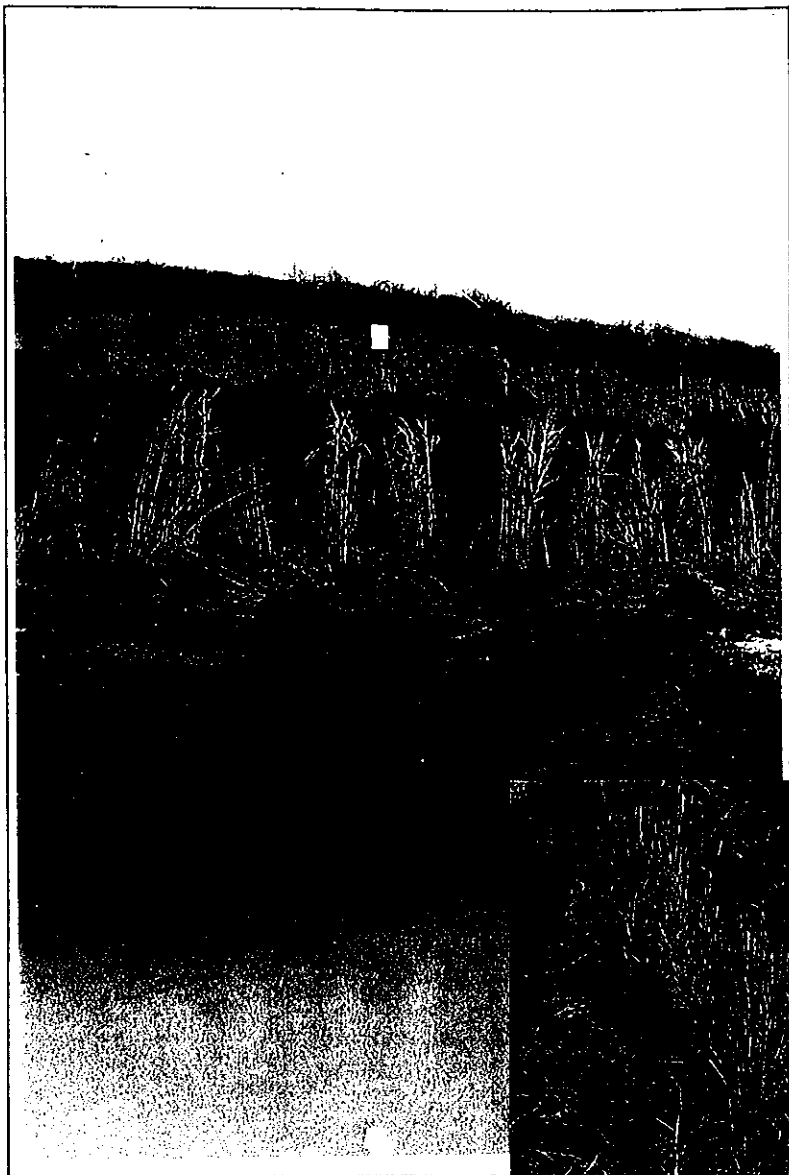
Fig. 4. Suggested planting position on bank of regulated and unregulated rivers and streams

(a)

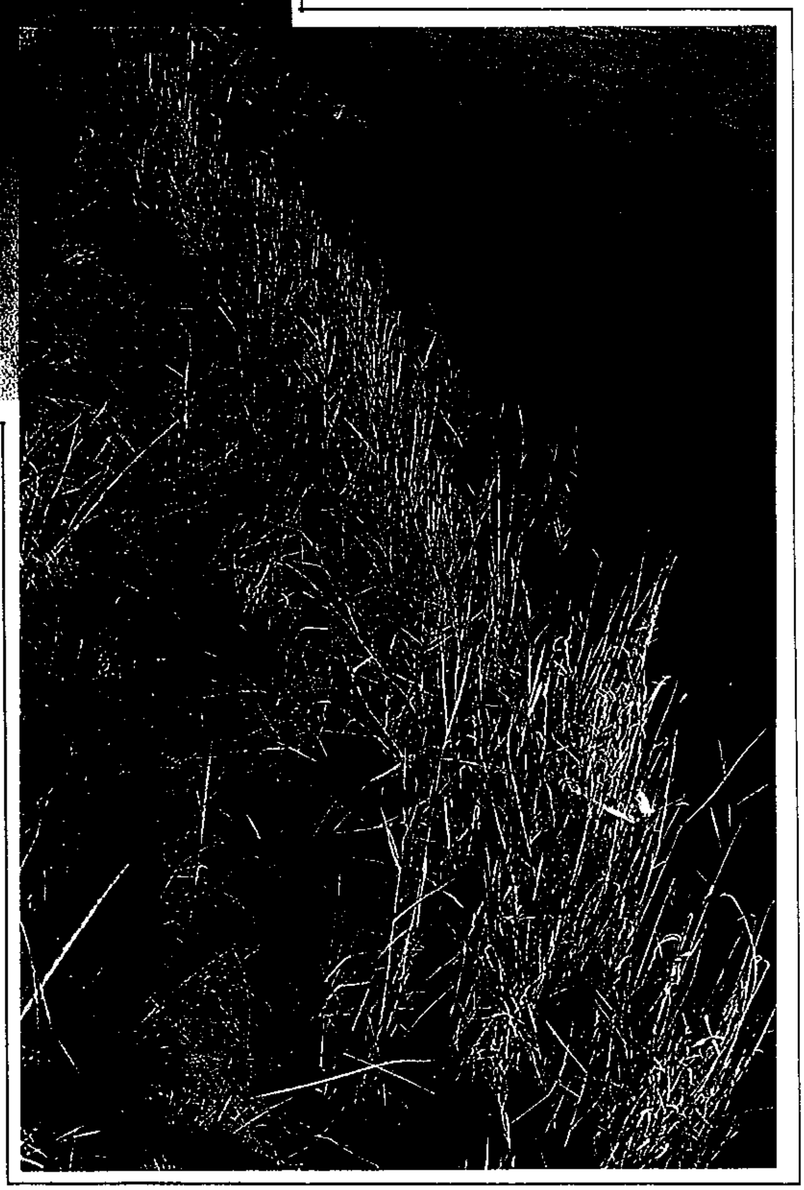
(b)

(c)

Plate 1. Seedlings planted on River Murray
(a) and (b) March 1989, (c) March 1992.



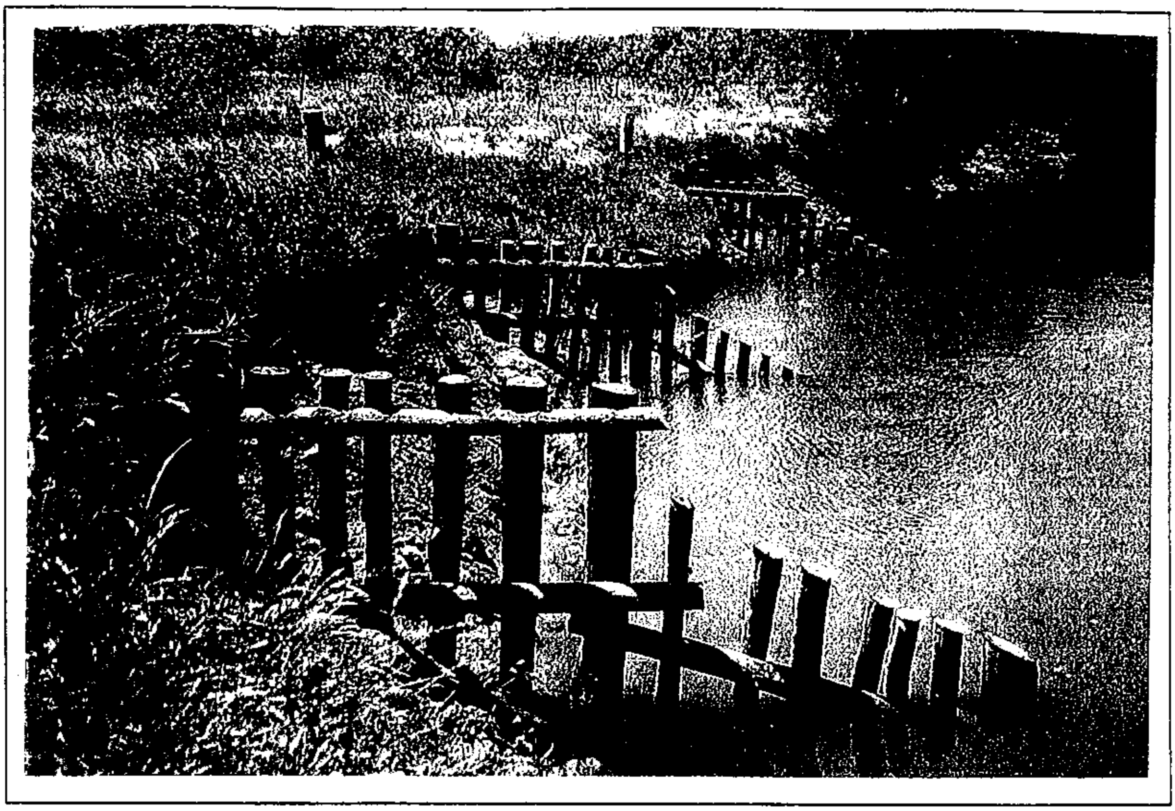
(a)



(b)

Plate 2. Advanced plants for difficult sites.
River Murray, (a) July 1994, (b) February 1996

(a)



(b)

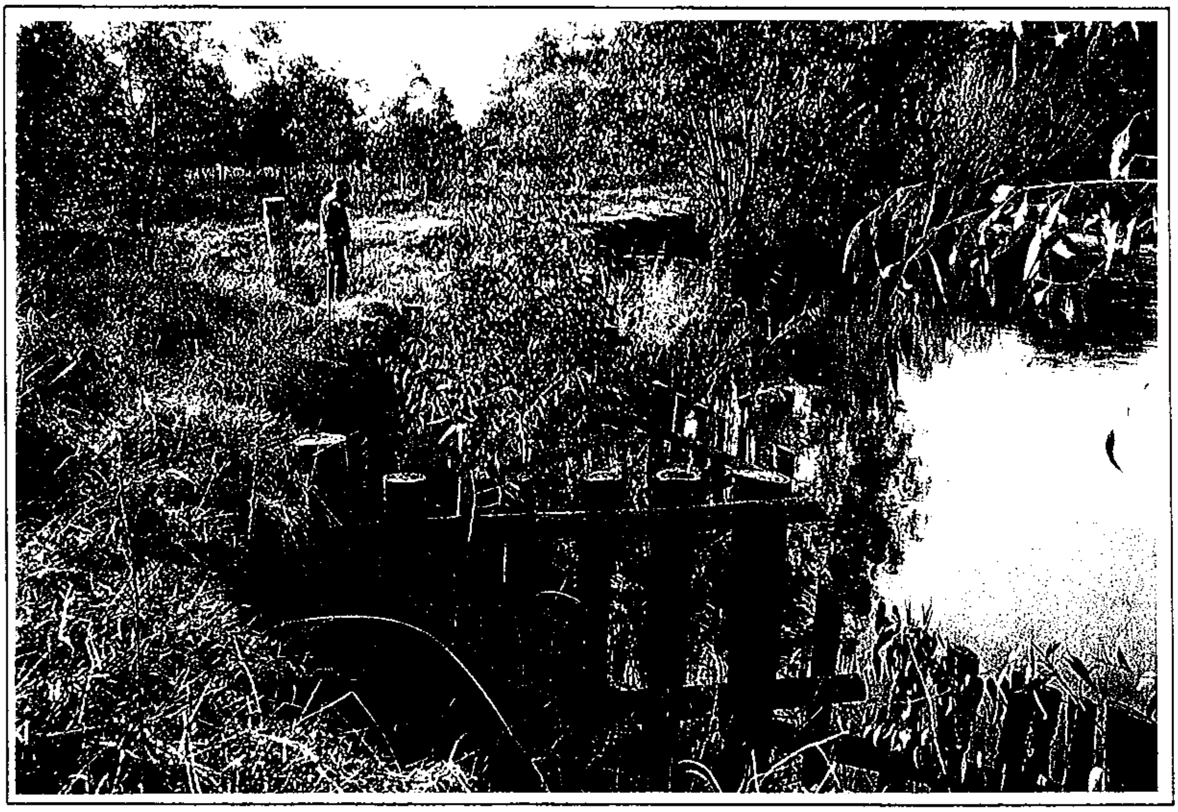


Plate 3. Groynes to aid establishment on actively eroding bank.
Mungabareena Reserve, River Murray. (a) November 1992, (b) July 1995.