THE CONDITION OF THE KALGAN RIVER FORESHORES 1992/93

Albany Waterways Management Authority, Oyster Harbour Catchment Group and the Department of Agriculture of WA

Waterways Commission
Report No 52
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SUMMARY

Large quantities of nutrients and sediment discharged into Oyster Harbour, principally from the Kalgan River catchment, are thought to be the main cause of massive algal growth which is smothering the seagrass meadows of the harbour. Recent research has highlighted the importance of streamline fringing vegetation in attenuating nutrient and sediment loss from agricultural areas into waterways.

Landcare groups in the catchment have called for the Kalgan River to be fully fenced, to protect the largest natural biofilter of the catchment and to prevent erosion of the riverbanks, which occurs when the supportive and protective fringing vegetation is lost through livestock grazing and trampling. In the spring and summer of the 1992/93, a survey was undertaken to assess the condition of the foreshores of 94km of the lower Kalgan River, most of which lies within narrow strips of Crown land.

This work graded the condition of sections of foreshore of each river bank into three categories: (A) pristine to slightly disturbed, (B) degraded and (C) erosion prone to eroded; on the basis of weed infestation, soil exposure and erosion. The extent of riverbank fencing, river valley form, the scenic quality of the river valley and the general quality of the fringing vegetation were also assessed.

Foreshore condition and fencing status were assessed in detail and results for specific sections and subsections are reported, along with fencing and rehabilitation needs and other information. Overall, about 26% of the river foreshores were A grade, 48% B grade and 26% C grade. About 64% of the river was fenced off, leaving about 68km of fencing needing to be done; of which 11km needed to be done urgently. About 145ha of foreshore required vegetation rehabilitation to stabilise the embankments, maintain the ecological corridor and protect river pools.

The lower half of the Kalgan River study area was very scenic and contained foreshores generally of a high quality, but points of severe erosion and subsidence and sections of extensive degradation were nonetheless common. The increasingly saline upper half of the study area, despite being mostly fenced off, was extensively degraded, exhibiting major erosion along firebreaks located within the floodplain of the river valley, major siltation and massive vegetation die-off as a result of increasing salinisation.

To protect riverine fringing vegetation and thereby maintain its biofiltering and erosion control functions, fencelines should be located above the river valley and, in the case of steep valley embankments, well above it.

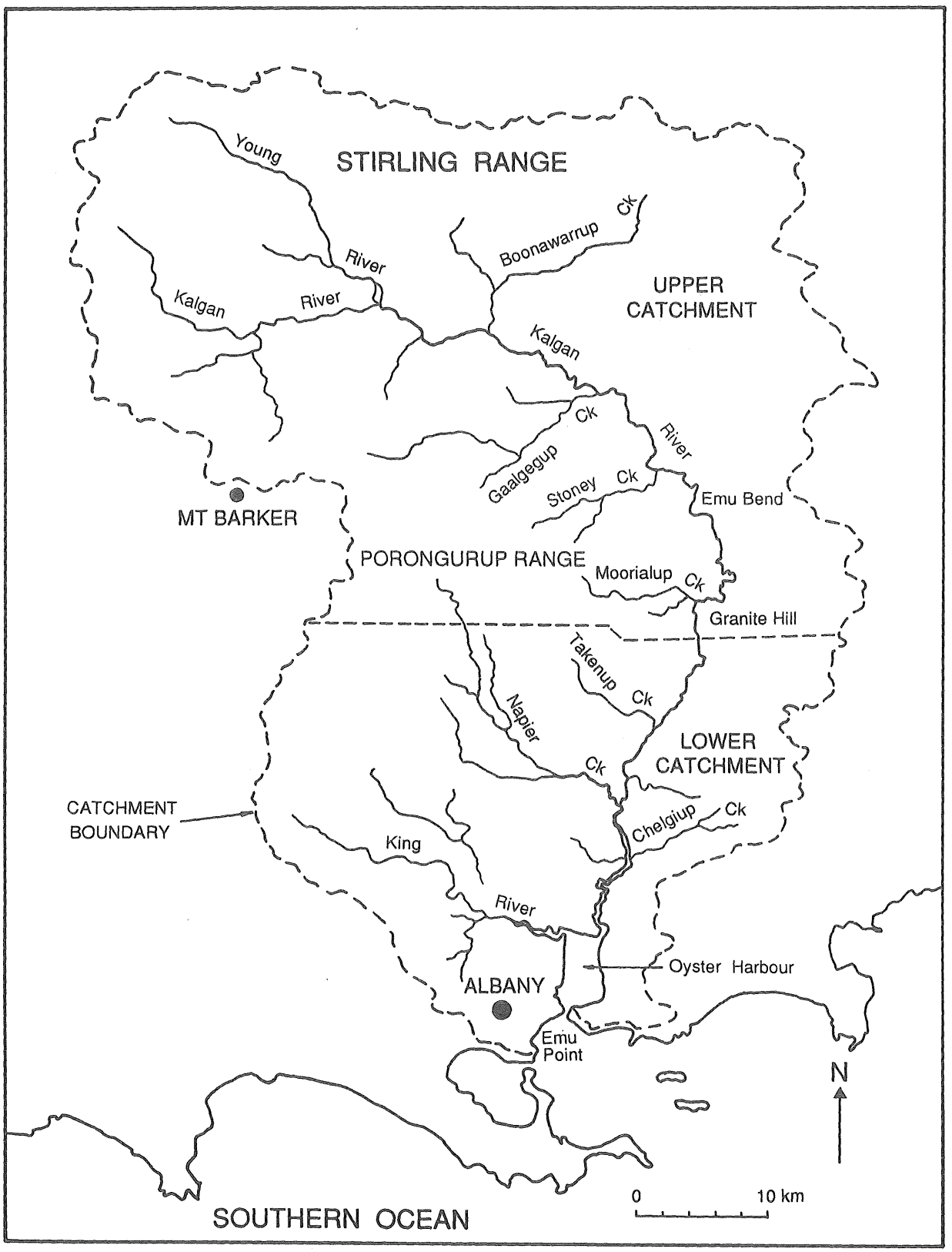

Figure 1.1: The Oyster Harbour Catchment and the Kalgan River system.

1. INTRODUCTION

1.1 Background

The Kalgan River is the largest tributary of Oyster Harbour, an inlet on the south coast of Western Australia, near Albany (Fig. 1.1). Studies carried out in 1987 and 1988 by the Environmental Protection Authority revealed that Oyster Harbour was becoming increasingly eutrophic and experiencing large growths of algae which were smothering the seagrass that once dominated the relatively shallow environment of the inlet (EPA, 1988, 1990).

The prime cause of eutrophication in Oyster Harbour is the input of nutrients from farmlands into the harbour via the Kalgan River system (EPA, 1990; SCEP, 1991). In 1988 and 1992, at least 42 and 39 tonnes, respectively, of phosphorus entered Oyster Harbour from the Kalgan River (SCEP, 1991; Prout and Weaver, 1992).

In an effort to control nutrient loss to Oyster Harbour, a catchment management strategy was developed, involving the urban and rural community, and government departments. In the general region of the Kalgan River catchment, four Land Conservation District Committees (LCDCs) work at a local level to arrest land degradation and reduce nutrient loss. In order to coordinate catchment management work by the LCDCs within the Oyster Harbour catchment, the Oyster Harbour Catchment Group (OHCG) was formed. It is supported by the South Coast Estuaries Project, Department of Agriculture, which investigates and promotes sustainable agricultural systems.

SCEP's research has shown that nutrient loss from the catchment reaches maximum levels during high intensity rainfall events in which massive runoff causes widespread erosion in the catchment (SCEP, 1991). Eroded soil from these events is usually richer in nutrients than the original field soil and large quantities are washed into the Oyster Harbour (SCEP, 1991). In most years, Oyster Harbour turns muddy brown following major storm events.

Among many actions to minimise nutrient loss to waterways, SCEP has emphasised the placement and maintenance of vegetative strips along streams. Such fringing vegetation acts to prevent erosion, filter out suspended solids during flood events and assimilate nutrients carried in runoff (SCEP, 1991; Weaver and Prout, 1993). This led the OHCG to call for the fencing of the Kalgan River in September 1992, as a first step towards managing all major streamlines. In response to this the Albany Waterways Management Authority, a community-based management agency and part of the Waterways Commission, undertook to carry out a survey of the condition of the Kalgan River foreshores. This report contains the results of that survey.

1.2 Description of the region

The Kalgan River system drains most of the catchment of Oyster Harbour, found in the extreme south-west of Australia, just north-east of Albany (Fig. 1.1). It drains an area of about 2450km^2 which extends some 75km inland from the coast. The area is mainly flat to broadly undulating plains, reaching about 200m ASL, but broken occasionally by minor ridges and by the relatively high Porongurup Range, which reaches 654m ASL. The larger Stirling Ranges, which reach 1096m ASL define the northern extent of the catchment (Fig. 1.1). The plains are developed on marine sediments and the soils are predominantly sandy duplex types with saline subsoils formed by the siltstone.

The climate of the catchment is temperate and mild, with rainfall, beginning at 900mm at the coast and declining inland to 600mm, mostly confined to the winter and early spring months. Evaporation is as high as 1400mm inland, but as little as 50-200mm on the coast (DPUD, 1991). As with virtually all south-west rivers, the Kalgan exhibits a discharge pattern which reflects the seasonal rainfall: strong flows over the winter/spring period and moderate to negligible flows over the summer/autumn period. Over recent years the magnitude of yearly discharges has varied greatly, and there have even been unseasonal floods, of tropical cyclonic origin, such as the one in January of 1982 (DPUD, 1991).

The catchment of the Kalgan River can be divided into an upper and lower region on the basis of climate and salinity. The upper region, which comprises 83% of the total catchment is relatively dry and prone to salinisation (DPUD, 1991; SCEP, 1991). Consequently, the river water ranges from brackish to saline. The lower Kalgan catchment is wet, with a number of major freshwater tributaries which render the brackish river water from upstream marginally fresh. The main natural vegetation form of the upper Kalgan catchment is woodland dominated by jarrah, wandoo, marri and yate, while that of the lower Kalgan is forest dominated by jarrah and marri, occasionally with yate and karri (DPUD, 1991).

Most of the Kalgan River catchment has been cleared of its natural vegetation and developed for agriculture, which is mainly cropping and sheep farming in the upper part, and sheep, beef cattle and some dairy farming in the lower part (DPUD, 1991). By 1991 about 66% of the upper Kalgan catchment and 88% of the lower Kalgan catchment had been cleared. The only large areas that retain significant stands of natural vegetation are that portion of the Stirling Range National Park which falls in the catchment and the Porongurup Range National Park.

1.3. Value of fringing vegetation in catchment management

1.3.1 Streambank stabilisation and soil conservation

The soils of the natural stream valley support a varied flora of trees, shrubs, sedges and herbs. In turn, the vegetation supports the streambank and protects it from erosion and subsidence. The vegetation does this in a number of ways. Firstly, fringing vegetation increases streambank roughness which acts to dissipate the energy of running water, with the effect of reducing the erosive capacity of the stream flow (Troeh *et. al.*, 1980). Secondly, roots and rhizomes bind and reinforce the soil of the embankments. The large roots of trees anchor the embankment in place and the smaller roots and rhizomes of shrubs, sedges and grasses hold the soil firmly in place at the surface of the ground between the large tree roots. In fact, the soil-root matrix can add extra cohesion of the order of ten times that of an unvegetated embankment (Thorne, 1990).

The roots and rhizomes also act to loosen and break up the soil, with the result that a well vegetated bank enables rapid infiltration of rain water (Riding and Carter, 1992; Thorne, 1990). Together with the abstraction of the water by the plants themselves, greater hydrological conductivity causes the bank to be drier than a similar unvegetated bank. In wet weather, this means that the vegetated embankment is less likely to become saturated with water, and thus is less prone to mass failure, such as subsidence and toppling caused by the added bulk weight of the water (Thorne, 1990).

Lastly, riparian vegetation is highly resilient, exhibiting quick regeneration and recolonisation following the effects of severe floods. In this way the vegetation helps stabilise the river system against the effects of severe erosion and siltation (DeBano and Smidt, 1990; Wissmar and Swanson, 1990).

1.3.2 Sediment and nutrient retention

Research being carried out in Europe, North America and New Zealand increasingly highlights the important function that riparian zone vegetation has in filtering out sediment and nutrients carried in flowing waters. Work on vegetated buffer strips along waterways or between waterways and agricultural land has shown that vegetation of many forms, including grasslands, sedgelands, woodlands and forests, can filter out and retain substantial amounts of sediment and nutrients (Peterjohn and Correll, 1984; Cooper *et al.*, 1987; Dillaha *et al.*, 1988, 1989; Heede, 1988; Knauer and Mander, 1989; Margette *et al.*, 1989). Dissolved nutrients, especially nitrate, are readily taken up and assimilated by plants (Yates and Sheridan, 1983; Peterjohn and Correll, 1984; Howard-Williams and Downes, 1984; Howard-Williams *et al.*, 1986; Pinay *et al.*, 1990).

By reducing stream flow, riparian vegetation promotes sediment deposition (Thorne, 1990). Sand can be deposited even when water is fast moving and silt will settle out where vegetation causes a marked reduction in flow. However, near-still water, such as that caught in densely vegetated floodplains, is required for the deposition of the very fine clay fractions (Troeh *et al.*, 1980). Over time, substantial streambank and floodplain accretion can occur in certain areas as a result of sediment deposition, and this can alter hydrological processes (Thorne, 1990). The removal of suspended sediment by vegetation is especially important, as water carrying sediment has a greater momentum and is more abrasive than clean water, and thus has an enhanced capacity to cause erosion (Troeh, 1980).

Much of the nutrients trapped in the vegetation of waterways or in buffer strips is assimilated by the vegetation (Odum, 1990). Generally, the longer the water is held by the vegetation, the greater the uptake of nutrients (Howard-Williams *et al.*, 1986). Of course, the nutrients are eventually released back into the water column when plant material decays, but much of this will once again be assimilated. In this way the riparian system retards the rate of transfer of nutrient particles downstream, in a process known as nutrient spiralling (Pinay *et al.*, 1990; Pieczynska, 1990).

Nitrogen can be removed from riparian systems completely. This occurs via the biochemical process of denitrification, which causes nitrate to be converted to gaseous nitrogen. This process can be the major form of nitrogen removal in certain riparian zones and during particular environmental conditions such as those which occur during and after flooding (Jacobs and Gilliam, 1985; Pinay *et al.*, 1990).

1.3.3 Ecological values

Streamline vegetation has natural resource value in its own right. But it also provides a range of habitats for a large variety of plants and animals, particularly species which are restricted to moist or aquatic environments. Furthermore, as stream systems are linear in form and cover large distances, their vegetation helps to create ecological corridors. In agricultural areas, where nearly all the native bush has been cleared, these natural corridors, along with unnatural ones such as the vegetated strips along road and rail reserves, enable plant and animal species to move between larger patches of remnant habitat (Hussey *et al.*, 1989).

1.4 Study area

The study area consists of the land along the Kalgan River between the lower Kalgan bridge near Oyster Harbour and the end of the Crown Reserve on the river near the western end of the Stirling Range (see Fig. 1.1). It includes the river channel embankments, the floodways and floodplains of the river and the river valley embankments which rise immediately above them and, for the most part, the land from the river to the first farm paddock (see Fig. 2.1 for an explanation of the terms used to describe river valley form).

1.5 Aims of the study

The aims of the study were as follows:

1. Survey the condition of the river valley and its fringing vegetation using the system outlined in Section 3.2;
2. Map points of serious erosion;
3. Map the extent of fencing along the river;
4. Provide a general description of the fringing vegetation and landscape; and
5. Assess the health of the vegetation along the river.

2. RIVER VALLEY FORM AND THE PROCESS OF RIVER DEGRADATION

2.1 River form

2.1.1 Cross sectional form

Figure 2.1 illustrates typical river valley form in south-west Western Australia and the nomenclature used to describe it.

A typical south-west river consists of a floodway which resides in a valley. Within the floodway, water generally flows along a main channel, which will wander from one side of the floodway to the other as water moves downstream. Sometimes there are two channels: a primary one, which always carries water, and a higher secondary one, which will carry water in times of flood. At times of heavy discharge the entire floodway will carry water.

When the floodway is contained within a shallow or steep valley, the embankments on each side will contain the water from even the most severe flooding and, therefore, the extent of the extra floodfringe is minor. Conversely, when there is no obvious valley form, the floodplain (i.e. floodway plus floodfringe) may extend over a very wide area.

Fringing vegetation seldom occupies the main channel but where water movement is very slow, due to the frictional effects of floodplain vegetation or stream debris, some aquatic species are able to take root. On the other hand the channel embankment and the floodway support dense vegetation, which may extend over a broad floodplain or up the river valley embankments. Floodplain and river valley embankments can support their own distinctive plant communities, which are often more open than those of the floodway.

2.1.2 Channels, riffles and deep pools

Length-wise, the typical south-west river can be divided into three distinct zones. These are the long narrow channels which meander along the floodplain, broad shallow riffle zones and deep broad pools. A typical channel is often no more than a few metres across, while the riffle can be 5 to 20 metres broad. Sometimes the riffle zones consist of open areas where shallow water passes over stones, while in other areas it can be densely vegetated, with shallow water passing between clumps of sedges and tree stems. For example, it is not uncommon for the river floodway to support a completely closed canopy of paperbark trees, where, in the absence of an understorey, the water passes freely between the tree stems.

Deep pools are dotted along the length of rivers and are formed as a result of the movement of water (Marsh and Dozier, 1981). In south-western Australia these pools are as long as 50 to 500 metres or more and are typically 20 to 50 metres across and from 3 to 9 metres deep. Ecologically they are integral to the south-western Australian river ecosystem, nearly always retaining water over the hot dry summer/autumn months when the channel and riffle zones dry up, thus providing refuge habitat in times of drought for many aquatic animals, including birds, turtles, water rats, fish, crayfish, shrimp and mussels.

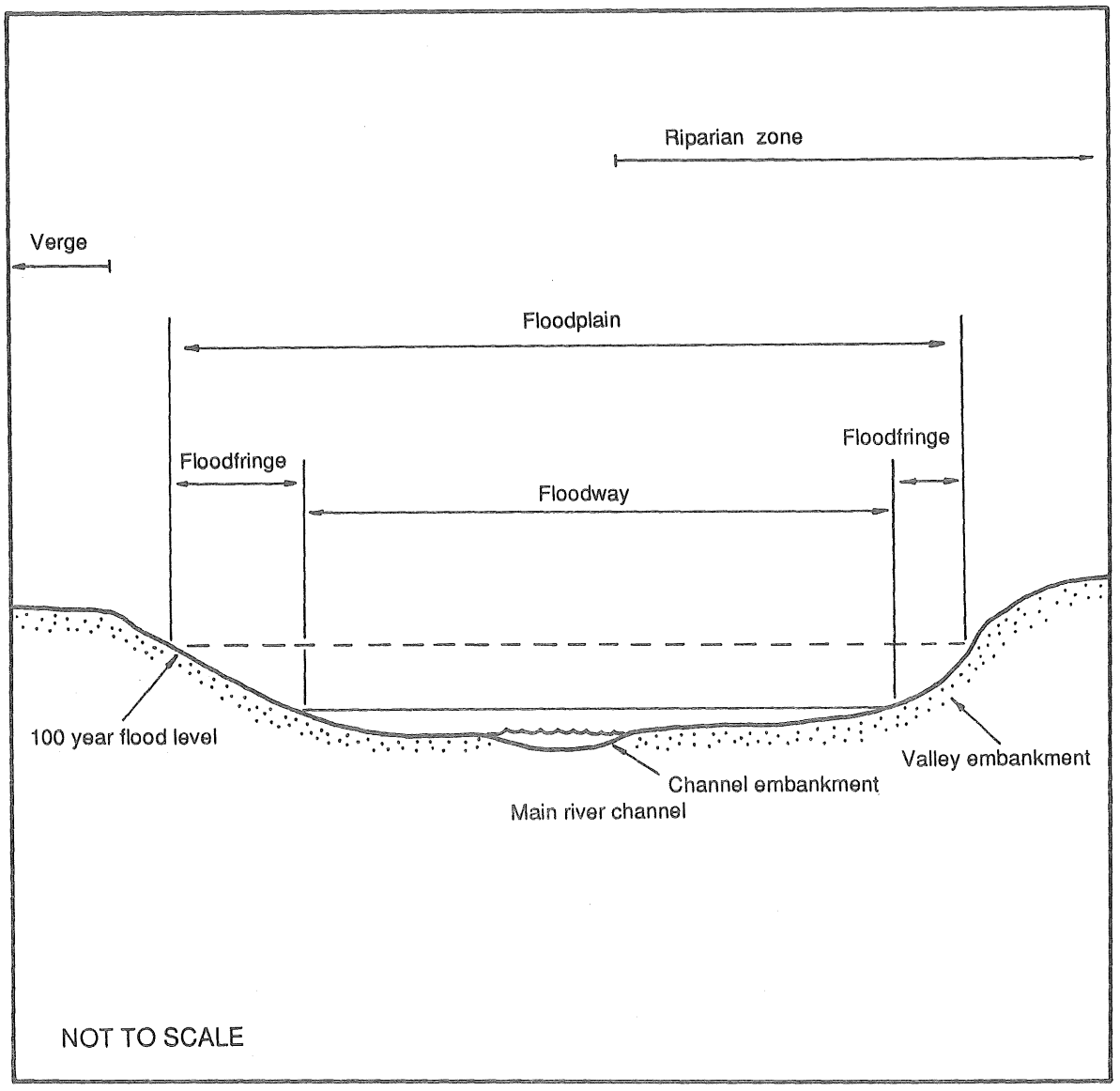

Figure 2.1: Terms used to describe river valley form.

2.2 River valley degradation: from river to drain

The author has worked in a number of river systems and has observed a number of states of degradation, most of which clearly fit into a pattern of degradation which would seem to describe the main form of river degradation in south-western Western Australia *(see Fig. 3.1).*

2.2.1 The healthy river valley

In a healthy river valley, native vegetation is dominant. Not only does it provide habitat for a huge range of animals, but it also supports the substratum that sustains it (Thorne, 1990). The large root systems of trees, which may extend as far as 50 metres, become interlaced and tangled to form a mesh or matrix of roots to a depth of two to three metres or more. This matrix of roots and soil, where trees become tied to each other and support each other, is found right along each side of the river and holds the river valley embankments securely in place. The smaller root systems of shrubs and rhizomes of sedges and the tiny root and rhizome systems of herbs, grasses and small sedges hold the soil firmly in place between the large tree roots and, most importantly, form dense masses of roots and rhizomes along the actual river channel.

In this way, the most powerful floods and heaviest rainfall cannot dislodge the soil of the river valley for virtually the entire length of the river. Only rarely does the action of water gain the upper hand and erosion occur. This usually happens at power bends along the river and would appear, in most cases, to be quickly arrested by the growth of abundant vegetation.

The dense vegetation also serves to retard the rate of flow of floodwaters and to filter out or cause the settling of suspended solids (Thorne, 1990). This action is enhanced by fallen branches which trap leaf litter and cause the formation of obstructions which dam the floodwaters, further reducing their velocity and capacity to erode and carry sediment. In a totally vegetated catchment floodwaters are held back by the frictional and damming effects of fringing vegetation along hundreds if not thousands of kilometres of streamline and much of the energy required to erode and to carry sediment has been dissipated by the time the waters have reached the estuary.

2.2.2 The degrading river valley

The earliest stage of degradation is the occasional presence of weeds. In near pristine vegetation, weeds are probably brought in by the wind or animals. This type of degradation is merely floristic and poses no threat to the integrity of the river valley, as the native vegetation remains dominant. However, where there are points of physical disturbance, such as along walking and vehicular tracks or where feral pigs or rabbits have turned over the soil, localised exposures of soil and infestations of weeds may occur. In this situation there is a small risk of severe water erosion.

Typically, severe degradation does not begin until livestock regularly enter the river valley to graze. Here they trample the native vegetation, eat out the more palatable species, trample the soil and bring in weed seed. This serves to encourage the establishment of weeds and to discourage the regeneration of native species. The longer the river valley is subject to livestock and the heavier the stocking levels, the quicker the native vegetation is replaced by weeds. The rate of weed invasion is accelerated by an increase in the frequency of fires, which favours species with short life cycles, which are mostly introduced grasses, over species with long life cycles, which are mostly native (Hussey and Wallace, 1993).

Eventually, the native understorey species are replaced entirely by weeds and the native trees begin to die out as the level of regeneration can no longer keep pace with mortality.

2.2.3 The eroding river valley

As weed invasion progresses, with continued livestock grazing and trampling and frequent fires, the deep root systems of native shrubs, sedges, grasses and herbs, which once had a firm hold on the soil between the large tree roots, are largely replaced by the shallow root systems of introduced annual grasses and other weeds. These new species do not bind the surface soil as well as the former native species, especially over the late summer/autumn period when most have senesced, and are quite easily dislodged by livestock trampling and surface water flow. In this scenario, the river valley is prone to severe erosion.

If the thin protection afforded by annual weeds is lost the soil between the large roots of trees and tall shrubs is easily washed away. Up on the valley embankment surface flow from adjacent pastured areas or high flood waters can dig long furrows, exposing tree roots and undermining trees and tall shrubs. Lower down, huge bites can be taken out of the river channel embankment and the valley embankment can be undermined, causing further sections to be undercut beneath the root zone and to collapse into the river. Where this occurs the remaining part of the embankment can be held in place by tree roots until further undercut, but if trees are not present to support the embankment, parts of the embankment can subside into the river. This would appear to occur in very wet weather where unsupported valley embankment becomes sodden (Thorne, 1990).

At first only the most prone areas will exhibit severe erosion. But gradually more and more areas will become eroded, until the river resembles a ditch. Not only will the river valley become increasingly prone to erosion as a result of loss of supporting native fringing vegetation, but as it does so the river can become smoother in parts, and the energy which was once dissipated by the vegetation will become available to erode and to carry sediment. There is also less vegetation to intercept the sediment, to prevent it from being washed downstream and ultimately into the estuary.

Ironically, coarse sediment lost from the streambanks can build up in places in the stream bed, which becomes wider and shallower as the material of the eroded embankments fills the floodway. In this situation, high bed sediment loads can have two effects: increased bed roughness can retard stream flow and cause upstream flooding; or conversely, large sediment accumulations can deflect flow into the adjacent streambank or even onto adjacent land, causing further erosion (Schmidt and DeBano, 1990; Thorne, 1990).

The progressive degradation of riparian vegetation has a compounding effect on the waterway, as the reservoir of sediment and nutrients filtered out and assimilated by downstream vegetation over many years begins to be released. This factor could be responsible for the sudden discharge of large quantities of sediment and nutrients into estuaries when parts of this reservoir of material are dislodged by severe floods.

3. MATERIALS AND METHODS

3.1 Vegetation description

Colour aerial photographs from 1989 at 1:20,000 scale, and black and white aerial photographs from 1991 and 1985 at 1:50,000 scale were obtained from the Department of Land Administration and the Department of Agriculture for the study area, and sketchmaps were produced using a Ziess Aerosketchmaster to 1:10,000 scale and 1:20,000 scales. Details of the aerial photographs used are given in Appendix 1. The sketchmaps were drawn to convey information on the distribution of vegetation and vegetation type, the river and land form. The photos were also viewed stereoscopically to observe landform in relation to vegetation.

These sketchmaps were then taken into the field and annotated with relevant information on landscape, plant communities, weed infestations, foreshore condition, points of severe erosion and fencing status. Transects of river form, along with the associated plant communities, were sketched at regular intervals.

The Kalgan River above the upper Kalgan bridge was surveyed over seven days between 15th October and 11th December 1992. The estuarine section between the lower and upper Kalgan bridges was surveyed on 19th February 1993.

Unknown plant species were identified at the Albany Herbarium with the help of local experts (see Acknowledgements) or at the Reference Herbarium in Perth. Species which were very difficult to identify were submitted to the WA Herbarium, the Manjimup Research Centre or the Australian National Herbarium for identification.

Vegetation was described on the basis of dominant species, projective foliage cover and height of the tallest stratum (Specht, 1981).

3.2 River foreshore condition assessment

3.2.1 System of assessment

The condition of a section of river foreshore or riparian zone was assessed using a simple system developed by the author from observations of river system degradation throughout the south-west of Western Australia. It consists of a number of stages or grades - A, B, C and D beginning at pristine and running through to completely degraded, following the general process of degradation outlined in 2.2. Each grade has three sub-levels which are easy to recognise. This system is described below.

A grade foreshore

A1. Pristine

The river embankments and/or channel are entirely vegetated with native species and there is no evidence of human presence, including livestock damage (Fig 3.1A). This category, if it exists at all, would be found only in the middle of large conservation reserves where the impact of human activities has been negligible.

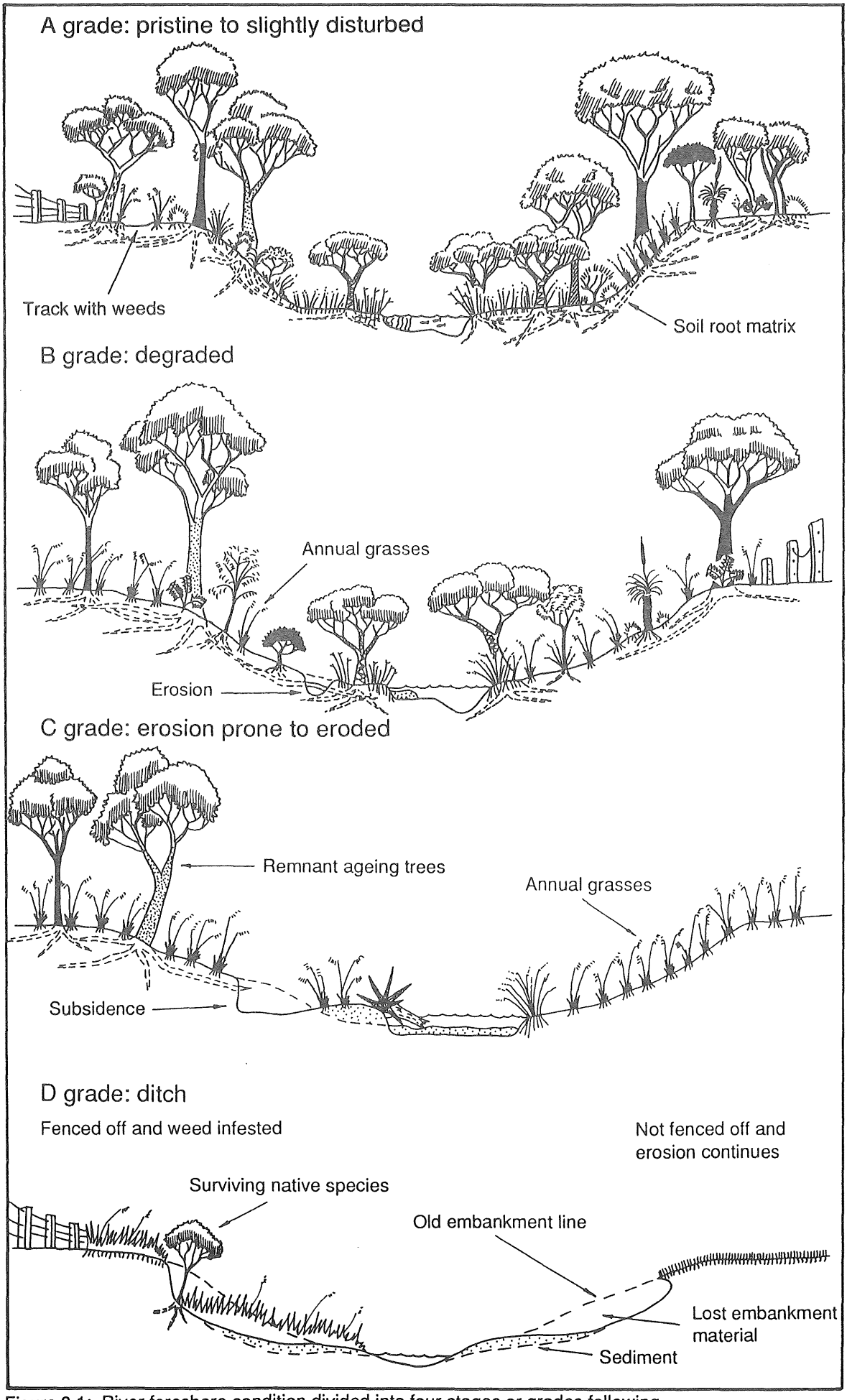

Figure 3.1: River foreshore condition divided into four stages or grades following the general process of river valley degradation, pristine river (A) to ditch (D).

A2. Near pristine

Native vegetation dominates but introduced weeds are occasionally present in the understorey, though not to the extent that they displace native species. Otherwise there is no human impact. A river valley in this condition is about as good as can be found today (Fig. 3.1A).

A3. Slightly disturbed

Here there are areas of localised human disturbance where the soil may be exposed and weed density is relatively heavy, such as along walking or vehicle tracks (Fig. 3.1A). Otherwise, native plants dominate and would quickly recolonise disturbed areas should human activity decline.

B grade foreshore

B1. Degraded - weed infested

In this stage weeds have become a significant component of the understorey vegetation (Fig. 3.1B). Although native species remain dominant, a few have probably been replaced or are being replaced by weeds.

B2. Degraded - heavily weed infested

In the understorey, weeds are about as abundant as native species (Fig. 3.1B). The regeneration of some tree and large shrub species may have declined.

B3. Degraded - weed dominated

Weeds dominate the understorey, but many native species remain. Some tree and large shrub species may have declined or have disappeared (Fig. 3.1B).

C grade foreshore

C1. Erosion prone

While trees remain, possibly with some large shrubs or grass trees, the understorey consists entirely of weeds, mainly annual grasses (Fig. 3.1C). Most of the trees will be of only a few resilient or long-lived species and their regeneration will be mostly negligible. In this state, where the soil is supported by short-lived weeds, a small increase in physical disturbance will expose the soil and render the river valley vulnerable to serious erosion.

C2. Soil exposed

Here, the annual grasses and weeds have been removed through heavy livestock damage and grazing, or as a result of recreational activities. Low level soil erosion has begun, by the action of either wind or water.

C3. Eroded

Soil is being washed away from between tree roots, trees are being undermined and unsupported embankments are subsiding into the river valley.

D grade foreshore

D1. Ditch - eroding

Fringing vegetation no longer acts to control erosion. Some trees and shrubs remain and act to retard erosion in certain spots, but all are doomed to be undermined eventually.

D2. Ditch - freely eroding

No significant fringing vegetation remains and erosion is completely out of control (Fig. 3.1D). Undermined and subsided embankments are common, as are large sediment plumes along the river channel.

D3. Drain - weed dominated

The highly eroded river valley has been fenced off, enabling the colonisation of perennial weeds (Fig. 3.1D). The river has become a simple drain, similar, if not identical, to the typical major urban drain.

3.2.2 Application in the field

A section of foreshore would be recognised for assessment on the basis of general homogeneity. For example, a section of foreshore which was fenced off was assessed separately from an adjacent section that was not fenced off and subject to sheep grazing. When the floodway and the valley embankment were in the same general condition they were assessed together, but when they were not they were assessed separately. The opposite banks of the river were always assessed separately and are referred to in the text as the right and left bank when facing upstream.

4. DESCRIPTION OF THE KALGAN RIVER

4.1 River form and environment

The study area of the Kalgan River can be divided into six sections, on the basis of landform and river salinity (Figure 4.1).

Section One: Estuarine

Section One is the most downstream stretch of the river, where it is in transition from estuarine to riverine, and for convenience falls between the lower and upper Kalgan bridges. It is a particularly scenic part of the river system, marked by broad stretches of water, 100 to 300m wide, flanked by tall steep embankments rising to 30 metres or more above the water. The lower parts of the embankments support estuarine fringing vegetation which gradually gives way to freshwater vegetation (see 4.2), while the upper embankments support forest dominated by jarrah and marri. Granite outcrops occur in places. The surrounding land uses are mainly cattle farming and hobby farming.

Section Two: Freshwater

The river channel in this section lies within a deep to shallow V-shaped river valley which is typically 20 to a few metres deep and as much as 150m across. The valley becomes shallower upstream. There are long winding channel and riffle zones, some of which are rocky, and long narrow pools, all fringed and overhung by dense freshwater forest which imparts a highly scenic quality to the river valley. The lower sections would rate as wild and scenic river (Taylor, 1988). The surrounding farmland, which is fresh and receives a relatively high rainfall, supports mainly sheep and cattle farming.

Section Three: High energy

This section begins at a point 4km downstream from the Mindijup Crossing and runs through to the Takalarup Bridge. It is marked by many high energy, fast flowing sections, such as high gradient river channels and broad stony cascades. The river valley is often deep and rocky, and mostly densely vegetated. There are broad rocky gorges, 200-350m across, exposed granite domes, steeply banked and narrow (20-50m across) "bath-tub" shaped floodways which support long narrow pools, and shallow stony river valleys. This section has the most scenic and floristically valuable sites in the study area and is mostly surrounded by remnant bush and scrub. The surrounding land uses are sheep and cattle farming.

Section Four: From fresh to brackish

Between the Takalarup Road and Chester Pass Road bridges, the river changes from marginally fresh to brackish. This is evident by the presence of salt-tolerant species, which are first seen just below the Takalarup Bridge. The river valley becomes increasingly shallow (3-5 m deep) and broad (generally 50-100m) with dense fringing vegetation occupying the floodway, although some stony and relatively open fast flowing sections are to be found. Large deep river pools are common. The surrounding land uses are sheep farming and cropping. Remnant vegetation above the valley embankments becomes increasingly sparse and open.

Section Five: Brackish

The brackish nature of the river, first encountered at the upstream end of Section 4, generally continues through to the Woogenellup[1] Road North bridge. The river valley is mainly shallow (2-3m) and broad (50-100m), with steep and sometimes high (5-10m) embankments being found only along deep river pools. Otherwise this section is similar to Section Four.

Section Six: Saline

Beyond the Woogenellup North Road bridge, the river becomes saline and many of the plant species, typical of the lower estuarine reaches of the Kalgan River, reappear. The river valley becomes increasingly shallow, but no broader than before. The surrounding land uses are cropping and sheep farming, and there is much evidence of salinisation.

4.2 Fringing vegetation of the Kalgan River

This section provides only a brief description of the fringing vegetation of the Kalgan River, using dominant species and structural nomenclature of Specht (1981). For a detailed floristic and structural description of the plant communities of the river, see Pen (In prep.).

4.2.1 Lower Kalgan: Section 1

Near the mouth of the Kalgan River, the wide floodway fans out slightly to create small tidal flats which support salt-marsh of samphire and shore-rush (*Juncus kruassii*). The saltmarshes back onto broad stands of estuarine low closed forest of salt-water paperbark (*Melaleuca cuticularis*) over shore-rush and coastal sword sedge (*Gahnia trifida*), which continue up the river as narrow fringing stands at the base of the steep embankments. Just below the cascades, which are found 1km downstream of the upper Kalgan bridge, the fringing estuarine forest gives way to closed forest of marri (*Eucalyptus calophylla*), WA peppermint (*Agonis flexuosa*) and greenbush (*Oxylobium lanceolatum*) over a variety of sedges, including the tall spreading sword sedge (*Lepidosperma effusum*) and the medium sedges twig rush (*Baumea juncea*) and shore rush.

The vegetation of the steep embankments mainly consists of closed forest of marri and jarrah (*Eucalyptus marginata*), broken in places, where the soil is thin over granite, by a dense heath dominated by one-sided bottlebrush (*Calothamnus quadrifidus*).

4.2.2 Lower Kalgan River: Section 2

The narrow floodway of the river supports a closed forest dominated by marri, swamp paperbark (*Melaleuca rhaphiophylla*) and flooded gum (*Eucalyptus rudis*). Yate (*Eucalyptus occidentalis*) and jarrah are occasionally present. The middlestorey largely consists of the large shrubs greenbush, Trimalium (*Trimalium floribundum*) and Astartea (*Astartea fascicularis*), with Hakea (*Hakea oleifolia*) and river Banksia (*Banksia seminuda*) being uncommon. A variety of rushes and sedges largely make up the understorey, along with bracken fern (*Pteridium esculentum*) and mats of sweet vernal grass (*Anthoxanthum odoratum*), which is most effective at stabilising sediment deposits. The spreading Sword sedge is the most conspicuous member of the understorey. The most common weeds are Yorkshire fog (*Holcus lanatus*) and sweet vernal grass.

[1]The spelling used here is as preferred by the Woogenellup community.

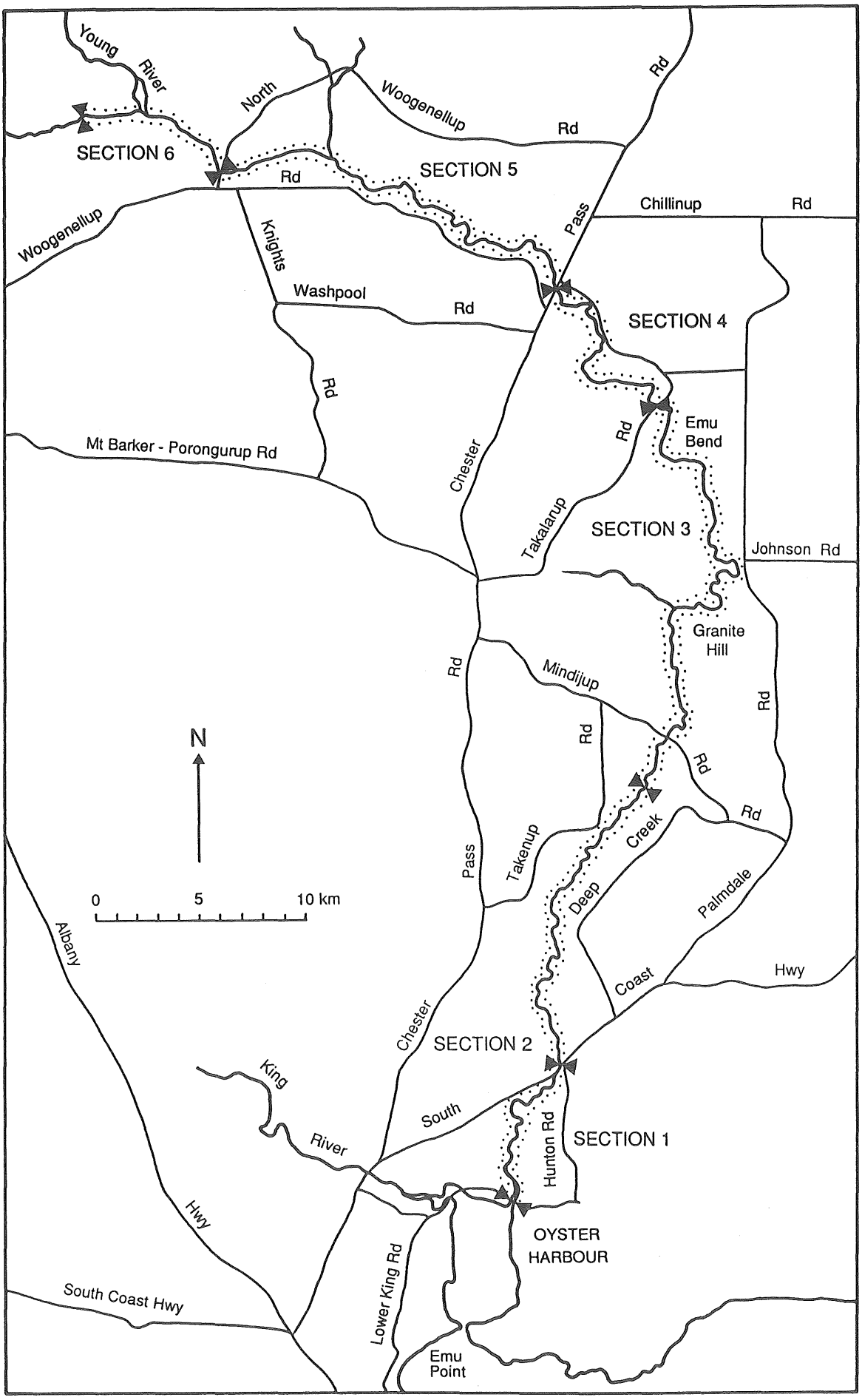

Figure 4.1: The Kalgan River Study Area.
Note that the area has been divided into six sections on the basis of landform and river salinity.

In Section 2, the river valley is deep and narrow and, the embankment areas moist and humid, creating an environment very different from the relatively dry environment above the valley. Consequently, the embankment vegetation is riparian in nature, unlike the jarrah-marri forests above the valley.

The steep sandy embankments generally support a closed forest of mostly marri, but with jarrah also being important. The largely open understorey mainly consists of tussocks of the sedge Cyathochaeta (*Cyathochaeta avenacea*), but clumps of small trees/large shrubs, such as river Banksia, Trimalium, Hakea, harsh Hakea (*Hakea prostrata*), Astartea and lemon scented Darwinia (*Darwinia citriodora*), are found here and there. Near the ground, bracken fern, hispid stinkweed (*Opercularia hispidula*), Loxocarya (*Loxocarya flexuosa*) and purple tassels (*Sowerbaea laxiflora*) are common. In the relatively open conditions of the understorey, weeds abound. Chief among them are bridal creeper (*Myrsiphyllum asparagoides*) and the grasses yorkshire fog, sweet vernal grass, the quaking grasses (*Briza maxima* and *B. minor*), annual veldt grass (*Ehrharta longiflora*) and great brome (*Bromus diandrus*).

In one small area, no larger than a hectare, there is a small stand of open tall forest of karri (*Eucalyptus diversicolor*), flooded gum and marri, mostly over the tall spreading sword sedge. The karri trees do not represent climatic relics as they are regenerating most successfully in the area, including upon the embankments.

4.2.3 Mid-Kalgan River: Sections 3 and 4

In the slower moving parts of the mid-Kalgan, flooded gum and swamp paperbark closed forest comes to dominate the floodway, with yate and marri occasionally present. The understorey is mostly composed of the large shrub Astartea and the sedge twig rush, with the sedges spreading sword sedge, shore-rush and twine rush (*Leptocarpus coangustatus*) being reasonably common. The mat grass form of sweet vernal grass is not common in this part of the river. The main weeds are sweet vernal grass, rye grass (*Lolium rigidum*) and ephemeral veldt grass.

On the shallow soils of the high gradient rocky sections of the river floodway, the small tree *Melaleuca viminea* mostly replaces swamp paperbark and joins stunted flooded gums to form a low open forest over the shrubs Trimalium, lemon scented Darwinea and Dodonaea (*Dodonaea ceratocarpa*). Occasionally, the shrubs one-sided bottlebrush and Thryptomene (*Thryptomene saxicola*), which are mostly found on the stony embankments, also occur on the fringe of the floodway. Common sword sedge (*Lepidosperma longitudinale*) is common in the understorey, with twig rush and spreading sword sedge being very uncommon. The main weeds are the quaking grasses, silvery hairgrass (*Aira* sp.) and annual veldt grass.

In Sections 3 and 5 the river valley is relatively open and, as a consequence, the embankments are mostly much drier than in Section 2. This means that the steep embankments mostly support the jarrah, marri, yate and limestone marlock (*Eucalyptus decipiens*) open forest, woodland or scrub typical of the surrounding land. Closed heath of one-sided bottlebrush and Thryptomene and small stands of low closed forest of limestone marlock and stunted jarrah are found on the stone embankments of the gorges.

Only in those few areas, where the river valley is narrow, are the moist conditions present which support true riparian vegetation on the embankments, rather than just along the fringes of the floodway. This vegetation mainly consists of a closed to open forest of marri, with some yate, jarrah and flooded gum over tussocks of Cythochaeta. Tall stands of the river Banksia are found in places. The main weeds are more or less as for the floodway, but with rye grass and flatweed (*Hypochoeris glabra*) becoming important.

4.2.4 Upper Kalgan River: Sections 5 and 6

The saline nature of these sections is reflected by the increasing presence of low closed forest of saltwater paperbark over shore-rush and saltmarsh vegetation of shore-rush and samphires, typical of estuarine regions, upstream. In the less saline sites, open to closed forests of swamp paperbark and flooded gum are found, with the occasional wandoo or yate. Two paperbark species (*Melaleuca thymoides* and *M. viminea*) are also common along the river in places. The main weeds are Atriplex (*Atriplex prostrata*) and rye grass.

In the relatively dry upstream areas it is not humidity which imparts a riparian environment to the embankments, but rather the shallowness of the river valley, which causes the embankments to be relatively close to the groundwater table and subject to flooding. Even so, the embankment vegetation largely consists of the wandoo and yate woodland typical of remnant bush of the surrounding land. The riparian character is provided by the presence of small paperbark trees, of which there are a number of species, including swamp paperbark, and two tussock sedges, one small (*Gahnia ancistrophylla*) and one large (*Cyathochaeta clandestina*). The main weeds are greater quaking grass (*Briza maxima*), wildoats (*Avena fatua*), annual veldt grass and veldt grass (*Ehrharta calycina*).

5. GENERAL CONDITION OF THE KALGAN RIVER

Table 5.1 provides details of river length, fenceline, riparian condition and actual fencing of the six sections of the study area. Note that 'right' and 'left' sides relate to facing upstream.

In all 94 km of the Kalgan River were surveyed, having a fenceline of slightly over 92km and 95km along the left and right banks, respectively. Of the total 188km of fenceline, about 64% was actually fenced. About one quarter of the riparian zone was A grade, nearly 50% B grade and the remaining area C grade. None of the Kalgan River valley in the study area was D grade. About 145ha of river valley embankment was so devoid of native plant cover as to warrant vegetation rehabilitation.

5.1 Section 1: Estuarine (9km)

On the left side of the river the condition of the steep embankment was mostly between B and C grade, with only 8% of the riparian zone fenced off from livestock, mostly cattle (Table 5.1, Maps 1 and 2). In fact, 67% of the left bank was C grade, representing the most extensively degraded embankment anywhere in the study area. There were some broad areas (4.3ha in total) of high embankment which had been substantially cleared and which required stabilisation with tree planting. Serious foreshore erosion was extensive in two main areas, near the waterski club and the Lower Kalgan bridge (Map 1), the latter probably being natural. Otherwise, there were a few points of severe erosion and subsidence, mostly near Elbow Island (Maps 1 and 2).

The right bank in this section contrasted greatly with the left bank. Seventy-five percent of the streambank was fenced off, much of it recently, and nearly half of the riparian zone was A grade, with the rest being B grade (Table 5.1). There was one area of extensive but probably natural erosion just below the waterski club at a power bend in the river (Map 1). Points of severe erosion and/or subsidence were more or less equally distributed along the river (Maps 1 and 2). Only one small area (1.1ha) required stabilisation with trees (Map 1).

Despite the increasing degradation, especially along the western bank, this estuarine section of the Kalgan River, with its steep forested and often stony embankments remains scenically attractive and retains much of its natural resource value. However, management to protect and rehabilitate the embankments should begin soon before erosion and weed infestation make serious impacts on the beauty and ecology of this section.

5.2 Section 2: Freshwater (16.7km)

The left and right hand sides of the river in this section were remarkably similar (Table 5.1). Between 26% and 29% of each side was in A grade condition and between 57% and 62% in B grade condition, with the remaining lengths C grade. Over half (59%) of the left side had been fenced off compared with well under half of the right hand side (38%). Large sections of the river on the right bank had been fenced off recently and the native plants were regenerating successfully.

Table 5.1: General condition of the Kalgan River study area, with details on river length, foreshore condition (grades A, B, C and D (see Chapter Section 3.3), fenceline, percentage fenced and fencing and vegetation rehabilitation requirements for each of the six sections of the study area.

Left bank

Section	River length (km)	Fenceline length (m)	River condition (%) A	B	C	D	Length Fenced (%)	Fencing required (m)	Veg. rehabilitation required (ha)
1	9	9850	6.8	25.9	67.3	0	8	9040	4.3
2	16.7	17760	28.8	57.1	14.1	0	59	7340	2.7
3	27	26020	60.4	17.1	22.5	0	78	6040	16.4
4	10.5	9140	0	60	40	0	21	7180	23
5	22	21060	2.7	61.6	35.7	0	63	7780	33.9
6	8.7	9100	0	64.8	35.2	0	80	1800	15.5
Total	**93.7**	**92930**	**23.7**	**44.6**	**31.6**	**0**	**58.2**	**39180**	**95.8**

Right bank

Section	River length (km)	Fenceline length (m)	River condition (%) A	B	C	D	Length Fenced (%)	Fencing required (m)	Veg. rehabilitation required (ha)
1	9	9560	47	53	0	0	75	2360	1.1
2	16.7	16960	26.8	61.6	11.6	0	38	9630	8.9
3	27	28260	57.3	26.7	16	0	68	9300	12.9
4	10.5	11200	0	67	33	0	76	2720	7.3
5	22	20740	5.4	66.2	28.4	0	77	4820	16.3
6	8.7	8540	0	60	40	0	99	80	3
Total	**93.7**	**95260**	**27.7**	**51.9**	**20.4**	**0**	**70**	**28910**	**49.5**
Grand total		**188190**	**25.7**	**48.3**	**26**	**0**	**64**	**68090**	**145.3**

The most serious point erosion to be found anywhere along the river was in this section, especially on the left bank (Maps 3, 4 and 5). Here, cattle grazing and trampling had exposed the soil over large areas, leading to serious sheet erosion or undercutting by floodwaters. In some places huge bites had been taken out of the river valley embankment, either by direct water erosion or by bank failure following undercutting of the root zone. Repair of these areas will be an expensive and time consuming process, but other areas of the embankment which had been cleared but which did not yet exhibit erosion, could be stabilised relatively easily with trees: 2.7ha on the left bank and 8.9ha on the right bank.

Some tributary creeks also exhibited severe erosion. With clearing, many creeks carry much greater volumes of water than previously and in some cases the creek beds had been eroded away, leading to deep cutting and gullying near the river. In the worst cases riparian vegetation had been undercut and had fallen into the deep creek valley.

Once again, despite severe degradation in places and widespread weed infestation, this section remained scenic over most of its length. In fact, some of the fringing forest was as pristine and beautiful as any which can be found in the south-west of Western Australia today. Tied to the scenic qualities of the steep forested embankments and the winding and fast flowing river this section, and Section 3 upstream, qualify the Kalgan as a wild and scenic river (Taylor, 1988).

5.3 Section 3: High energy (27km)

The lower 20km of this section contained the most near-pristine and scenic areas anywhere along the Kalgan River, where most of the river was flanked by broad remnant bushland on public and private land, nearly all of which was fenced off. Indeed, 78% and 68% of the left and right banks, respectively, of Section 3 were fenced off. This was reflected in the quality of the foreshores of which between 57% and 60% were A grade (Table 5.1).

Nearly all of the B and C grade foreshores of Section 3 were found in the upper 7km (Map 7), where relatively little of the river valley had been fenced off. Livestock grazing and probably frequent fires have rendered much of this area devoid of native understorey species and even tree cover in some places. The result is that whereas the lower 20km exhibit only a few points of severe erosion (Maps 6 and 7), most of which appeared to be semi-natural (see 6.5), the upper 7km were marked by either extensive soil exposure, sheet erosion and points of severe erosion, or a high potential for erosion, owing to the absence of perennial vegetation. Thus, over 16ha on the left bank and nearly 13ha on the right bank required vegetation rehabilitation to stabilise the embankments (Table 5.1, Maps 6 and 7).

5.4 Section 4: Fresh to brackish (10.5km)

About two thirds of the foreshores of this section were classified B grade, with the rest classified C grade (Table 5.1). No substantial A grade foreshore was found, even with 76% of the right bank fenced off. This suggests that very little of Section 4 has been fenced off continuously since the advent of agriculture and that grazing pressure and frequent fires have facilitated major weed invasions. Only 21% of the left bank was fenced off and there were large riparian areas with little or no perennial plant cover, necessitating about 30ha of vegetation rehabilitation to stabilise erosion prone sections of the river valley (Table 5.1 and Map 8).

There were seven points of severe erosion, of which three were major washouts along firebreaks or tracks (see 6.4). Large accumulations of coarse sediment from these washouts and others further upstream were occasionally evident amongst the vegetation of the river floodway and as saltating bed load in the main river channel.

Tree decline due to salinisation was evident in many parts of this section. In some areas salt-tolerant plants, such as sedges and samphire species, appeared to be replacing the more freshwater plant species, such as flooded gum and swamp paperbark (see 7.3). Overall, the effects of encroaching salinisation had made this section of the river scenically unattractive.

5.5 Section 5: Brackish (22km)

Some small areas of A grade foreshore remain in this section but generally the river valley is in a very similar condition to Section 4, except that the effects of salinisation are more pronounced and widespread. Many stands of fringing forest had died recently or were evidently dying from salinisation. Where forest and woodlands were healthy, tree species frequently showed no regeneration, giving rise to increasingly aged populations of trees. This decline in tree cover compounds the effects of frequent fires and livestock activity, where the more long-lived and tougher native trees are normally last to disappear. As a consequence, the river valley in Section 5, which is between 63% and 77% fenced off, may be losing its supporting vegetation at a faster rate than the unprotected downstream areas.

In the spring of 1992, between 61% and 67% of the foreshores were in B grade condition, compared with between 28% and 36% in C grade (Table 5.1). Some quite extensive sections of the narrow river valley had lost or were on the verge of losing their protective vegetation, requiring a total of about 50ha of vegetation rehabilitation works for riverbank stabilisation. Generally this was the case because clearing had been carried out right to the channel edge on many properties, resulting in serious erosion, including washouts along firebreaks. Points of severe livestock damage, threatening further serious erosion, were also evident.

5.6 Section 6: Saline (8.7km)

Although virtually the entire right bank and nearly 80% of the left bank were fenced off, all of the foreshore areas were either B or C grade, for reasons outlined in 5.4 and 5.5 and shown in Table 5.1. Large firebreak washouts were common in areas of cleared embankment and a total of 18.5ha requires rehabilitation.

6. TYPES AND CAUSES OF SOIL EROSION ON THE KALGAN RIVER

6.1 Livestock damage

Access of livestock into the river valley is a significant cause of soil loss along the Kalgan River in the study area. In some areas, particularly in Sections 1, 2 and 5, erosion was extensive and moderate, but at watering and crossing points where stock trampling is extreme, erosion could be quite severe. This was particularly the case where water draining from adjacent pastures flowed down to the crossing or watering point, causing further erosion. Crossing points which were made at fast flowing sections of the river, where embankments were of the non-cohesive type, also suffered heavy erosion.

6.2 Undercutting

Undercutting of the root zone and the subsequent undermining of trees was most prevalent in Section 2. Here, the steep sandy banks are particularly prone to undercutting and collapse at tight bends in the river. As the embankments are relatively high and non-cohesive in Section 2, the potential for serious erosion and subsequent sediment loss in this section is great, especially when floodways burst the main channel and occupy the entire floodway.

6.3 Subsidence

The steep high embankments of Sections 1 and 2 are prone to subsidence (Maps 1-4). In most cases subsidence has occurred where tree cover was nil or minimal, but there were three examples on the right bank in Section 1 (Map 2), where large sections of heavily forested embankment had subsided into the river. Furthermore, in certain areas of forested embankment in Section 2 tension cracks can be seen on the shoulders of the river, indicating imminent subsidence. These observations indicate that sections of embankment are not sufficiently fixed to adjacent ground by tree roots to overcome down slope gravitational pull. Thorne (1990) points out that the weight of large trees can be sufficient to cause bank failure. But the author can suggest another contributory factor: the added weight of water in the embankment due to rising water tables brought about by clearing.

6.4 Washouts

Erosion along firebreaks within the river valley of Sections 4, 5 and 6 was common. This type of erosion has occurred where clearing extends down to the main river channel rather than to the edge of the river valley. While the main channel and most of the floodway is protected from erosion by dense fringing vegetation, the upper embankments have been left unprotected. Therefore, floodwaters move swiftly and unopposed along the upper embankment and any exposed ground, such as tracks and firebreaks, is easily eroded. Many firebreaks and tracks have been only moderately eroded, losing a few centimetres of soil, but many others have been eroded to a depth of between 0.5m and 1m over tens and even hundreds of metres. In some cases deep washouts between one and four metres deep have been scoured out and continue to grow in size each year. Stock damage and wind erosion exacerbate the situation.

The presence of many tracks and firebreaks exhibiting various degrees of erosion suggests that this is an ongoing problem and not the product of particular flood events. For example, particular washouts in Sections 5 and 6 are not evident in aerial photographs taken in 1985. Nevertheless, the large floods of 1982, 1988 and 1991 would have been responsible for most of the damage.

Coarse sediment from these large washouts is evident downstream; as small accumulations behind sedge and grass tussocks just downstream from the washout, as large heaps of sediment near the channel or as huge "slugs" in the floodway, and finally as conspicuous deposits amongst the fringing vegetation along the main channel of the river for many kilometres downstream.

The same flood waters which have produced the washouts have also washed away or damaged fencelines. In many areas, farmers have been forced to move these fencelines to a level well above the river valley, where they should have been located initially. While this protects the fences, the former embankment remains unprotected and prone to severe erosion. Vegetation rehabilitation is a high priority in these areas.

6.5 Semi-natural erosion

Some of the points of severe erosion in Section 3, where embankments were well supported by fringing vegetation, can be considered to be semi-natural because, although the erosion was not the result of land degradation, the severity of floods has increased as a result of extensive clearing in the catchment. This means that in certain areas of the river, such as power bends, there is an increased risk of the supporting vegetation giving way and becoming undermined. However, in all cases where semi-natural erosion was observed it was highly localised and being controlled by surrounding vegetation.

7. MAJOR THREATS TO THE KALGAN RIVER

7.1 Loss of native riparian vegetation

Along most of the freshwater and brackish parts of the Kalgan River, the fringing vegetation is in transition from forest, woodland or heath, to grassland. Only in areas where the fringing vegetation is backed by substantial remnant bush, or where it has been fenced off for a long period of time, is the integrity of the riparian vegetation secure. Otherwise the native herbs, sedges, shrubs and trees of the river are slowly being replaced by introduced annual and perennial grasses and other weeds.

These introduced grasses and other weeds do not create the deep soil-root matrix required to support the river embankment. In the drier regions, the annual grasses or sparsely distributed tussock grasses, such as veldt grass do not even afford adequate superficial protection against water erosion. This means that many kilometres of the river valley are becoming increasingly prone to erosion.

Furthermore, introduced species do not provide the full range of habitat requirements for native fauna, while still supporting vermin such as rabbits. Riverine aquatic ecosystems depend on native fringing vegetation to provide shade, shelter, leaf litter and debris, and to stabilise pool embankments and riffle zones.

7.2 Breaks in the ecological corridor

The replacement of native plant communities with grasslands represents breaks in the ecological corridor. In Section 4, 5 and 6 long areas of embankment and floodway are devoid of native vegetation. These breaks not only retard the movements of mammals and birds, but fish are reluctant to move into open sunlit areas of water where they are prone to predation and heat stress (Olson and Skitmore, 1991).

7.3 Salinisation

Massive tree and shrub die-off due to salinisation is evident in many areas of Sections 4, 5 and 6. Dead and moribund trees are common around pools and along stretches of floodway. In a few areas floodplain forest has been replaced by salt-pan. In less salt-affected areas, many of the less salt tolerant tree species remain healthy but are not regenerating and, therefore, their populations are threatened by death from old age. This loss of trees destabilises the lower valley embankments and the channel embankments, and increases the risk of major erosion during flood events.

In Section 6, which is naturally saline, many salt-tolerant tree species are replacing less salt-tolerant species, the increasing level of salinity bringing about a successional shift rather than a simple die-off. There is potential downstream to augment this process by direct seeding with an appropriate suite of upstream plant species.

7.4 Erosion and siltation

Major bank failure threatens the entire river valley in some areas. From fence to fence the land given over to the river is often only tens of metres wide, which means that undercutting and subsidence can quickly bring the river back to the fenceline and eventually beyond it. In the case of Section 2, where the river valley is often deep and the river reserve is often narrow, this could occur in the near future.

The loss of large amounts of sediment from the river valley embankments threatens to fill the large pools which provide important aquatic habitat, especially in upstream areas where flow along the main channel may drop to very low levels over summer and autumn.

7.5 Major weed invasion

With respect to river management, major weed species are those which cannot be controlled by simply eliminating the disturbance regimes which facilitate the establishment and regeneration of common weeds. Major weeds can become established in relatively undisturbed vegetation and soon proliferate to become dominant species, even replacing the tall native trees in time. Examples include the giant grasses pampas grass (*Cortaderia selloana*) and giant reed (*Arundo donax*), the vines and creepers morning glory (*Ipomoea indica*) and dolichos pea (*Dipogon lignosus*), and the climbing shrub blackberry brambles (*Rubus* spp.). These species, and many more, infest large sections of the moist humid river valleys near Perth, Mandurah and Bunbury (Pen, 1992, 1993; Siemon *et al.*, 1993).

Similarly moist and humid conditions occur along the Kalgan, especially in Section 2 and 3. Therefore, these areas have considerable potential for infestations by major weed species. So far the Kalgan is remarkably free of such infestations, with only bridal creeper (*Myrsiphyllum asparagoides*) being a significant problem. This is mainly due to the low level of residential development along the river, as most major weeds would appear to be "garden escapees" (Pen, 1993).

8. KEY ATTRIBUTES OF THE KALGAN RIVER

8.1 Ecological corridor and remnant bush

The fringing vegetation of the river valley represents a significant ecological corridor connecting patches of remnant bush along the flanks of the river and, via road reserves, other more distant bush stands. Indeed, if the riparian vegetation were not entirely cleared in places, there would be a continuous corridor from the Stirling Range, via the Young River and Boonawarrup Creek, all the way to Oyster Harbour.

Large and small patches of remnant bush are found along the Kalgan River. Their proximity to water and connection to each other via the river corridor would enhance their value for the conservation of local native flora and fauna.

The river maps show those sections of the Kalgan River with native vegetation which represent good ecological corridors and associated patches of remnant bushland.

8.2 Riverine pools

The Kalgan River is dotted with many deep river pools (see river maps). The ecological value of these pools and the threats to their existence are discussed in 2.1.2, 7.1 and 7.3. However, it is worth mentioning that while most pools in Sections 2 and 3 were in a good state of repair and appeared healthy and scenically attractive, many further upstream were threatened by erosion and siltation, and were showing signs of eutrophication. Many of the pools in the more saline regions of the river were unhealthy and ugly, suffering from the combined effects of siltation, livestock damage, eutrophication and tree decline through salinisation. Nevertheless, healthy and aesthetically pleasing pools, of considerable ecological and recreational value, were found throughout the study area.

8.3 Areas of great aesthetic value

Sections 1, 2 and 3 of the Kalgan River have areas of great aesthetic value. These areas have heritage value and represent a largely untapped tourism resource.

Section 1 has high steep embankments supporting dense forest or heath, broken by granite outcropping on the eastern bank. Rich pastures or dense forest of jarrah and marri occur beyond the embankments. In downstream areas the broad river channel twists and turns and granite rocks are found in the channel or on the water's edge, creating stony foreshores. Ospreys and cormorants can be seen hunting in the more estuarine parts and jumping mullet are a common sight at times. Upstream the river becomes narrower and there are small forested islands and cascades of rapidly flowing water, especially near the upper Kalgan bridge. In this region the forested embankments remain high and steep, and often shade large stretches of the river.

In Section 2 the often steep and densely forested river valley which cradles the narrow, rapidly flowing main channel, gives the Kalgan River a wild and scenic quality. Although points of severe erosion detract greatly from the aesthetic value of some parts, it retains great beauty in others.

The grandest and most beautiful sections of the Kalgan River are to be found in the lower 20km of Section 3. Here, the river cuts deeply into the surrounding land, creating narrow valleys, with long deep pools shrouded in jarrah scrub and heath, or broad rocky gorges, with forest and heath of jarrah, limestone marlock and one-sided bottlebrush, often broken by large granite domes. In winter and spring the sound of cascading water on stone, mixed with bird calls, gently echoes up the valleys, while the numerous and exuberant bird life exploits a rich harvest of insects, nectar and fruit produced by a rich assemblage of abundant wildflowers.

9. REHABILITATION

9.1 Fencing

9.1.1 Fencing needs and priorities

The entire Kalgan River must be fenced off to protect the fringing vegetation of the river valley from the effects of livestock grazing and trampling, and to prevent the slow degradation of riparian vegetation, which eventually leads to severe erosion, downstream siltation, pollution and ultimately the loss of productive farmland. Protecting the vegetation will also maximise the natural biofiltering and energy dissipation function of riparian vegetation (see 1.3.2), which is needed to remove nutrients and sediment entering the river via tributary creeks and directly from farmland. Of course, work needs to be done to prevent nutrients and sediment from being lost from farmlands in the first place.

At the time of this study, 64% of the Kalgan River in the study area was already fenced off, leaving nearly 68km unprotected (Table 5.1). While fencing off any of the unprotected parts of the river will be beneficial to the river, there are areas which require fencing more urgently than others. Furthermore, as funding to build fences is limited, it is necessary that fencing needs are prioritised. There are four levels of priority, explained below:

Priority 1-urgent: Areas exhibiting severe erosion and/or stock damage which threatens to get worse in the short term.

Priority 1: Areas showing either limited erosion or the first signs of erosion or which are prone to erosion due to the absence of fringing vegetation.

Priority 2: Areas which retain substantial fringing vegetation which is becoming progressively degraded by livestock.

Priority 3: Areas which have healthy fringing vegetation or moderately degraded vegetation which are being degraded at a relatively slow rate and are therefore unlikely to become significantly further degraded in the short term.

The breakdown of fencing needs into the four priority levels for each of the six sections of the Kalgan River is given in Table 9.1. A detailed guide of where fencing is required and at what level of priority is given in Chapter 10 and Table 10.1.

Overall, nearly 32km of Priority 1 fencing is required, of which 11km is urgent. Twenty-three kilometres of Priority 2 and over 12km of Priority 3 fencing are also required (Table 9.1).

Table 9.1: General fencing and vegetation rehabilitation needs for the Kalgan River study area, divided into four levels of priority (see Chapter Section 9.1.1)

Left bank

Section	Level of priority								Total	Total
	1-urgent		1		2		3			
	Fencing (m)	Veg. rehab. (ha)	Fencing (m)	Veg. rehab. (ha)	Fencing (m)	Veg. rehab. (ha)	Fencing (m)	Veg. rehab. (ha)	fencing (m)	veg. rehab. (ha)
1	1270	2.5	800	0.2	4130		2840	1.6	**9040**	**4.3**
2	580		3260	2.1	2450	0.6	1050		**7340**	**2.7**
3	1460	1.5	1140	3.9	3440	10		1	**6040**	**16.4**
4	1620	9.7	3420	12.8	1460	0.5	680		**7180**	**23**
5	2280	24.3	4080	9.6	0		1420		**7780**	**33.9**
6	1800	11.5						4	**1800**	**15.5**
Total	**9010**	**49.5**	**12700**	**28.6**	**11480**	**11.1**	**5990**	**6.6**	**39180**	**95.8**

Right bank

Section	Level of priority								Total	Total
	1-urgent		1		2		3			
	Fencing (m)	Veg. rehab. (ha)	Fencing (m)	Veg. rehab. (ha)	Fencing (m)	Veg. rehab. (ha)	Fencing (m)	Veg. rehab. (ha)	fencing (m)	veg. rehab. (ha)
1					1850	0.5	510	0.6	**2360**	**1.1**
2			3300	8.9	2440		3890		**9630**	**8.9**
3	920		1520	4	4760	8.9	2100		**9300**	**12.9**
4	920	5	1240	0.5	560			1.8	**2720**	**7.3**
5			2740	16.3	2080				**4820**	**16.3**
6			80	3					**80**	**3**
Total	**1840**	**5**	**8880**	**32.7**	**11690**	**9.4**	**6500**	**2.4**	**28910**	**49.5**
Overall	**10850**	**54.5**	**21580**	**61.3**	**23170**	**20.5**	**12490**	**9**	**68090**	**145.3**

9.1.2 Placement of fences

Ideally, fences should be placed above the river valley (see Fig. 9.1). Depending on the steepness of the embankment, the fence should be placed 5m to 20m back from the edge of the river valley (Fig. 9.1A). Five metres is sufficient for a shallow valley a couple of metres deep but a broader zone, greater than ten metres, is required for valleys deeper than five metres. The purpose of fencing off the shoulders of the river is to enable trees on the upper part of the embankment and those above the river valley to anchor the embankments to the adjacent, land and thereby prevent subsidence. It should be mentioned that while much of the Kalgan River is fenced off, many fences are inappropriately placed to provide maximum support against subsidence.

In the case of shallow river valleys, there is little chance that embankments will subside. Nevertheless, fencelines should be located above the river valley (Fig. 9.1B). This is because fences and firebreaks located within the river valley will be damaged and eroded by floodwaters. As mentioned in Chapter 6.4, firebreak washouts can be very severe and contribute large quantities of sediment to the river system.

If the river valley is particularly broad and floodplains have been cleared for grazing, fencing them off may mean sacrificing good farmland. In this case it is necessary that only those areas that are prone to water erosion or stock damage, such as embankments and secondary river channels which only flow strongly at times of flood, need be fenced off (see Fig. 9.1C). Some of these fencelines will be prone to flood damage, but this can be minimised if fences run, as much as possible, parallel to the direction of floodwaters.

9.1.3 Types of fences

Needless to say, fencing should be appropriate to the livestock being grazed. In some cases this means purchasing expensive materials and much time-consuming effort. But fencing along a river need not be too expensive, especially if electric fences are used. Some farmers have found that a single strand of "hot" wire nailed from tree to tree is effective in keeping stock out of the river. While this is an excellent idea there are a number difficulties which require attention. Firstly, the nail used to attach the wire will wound the tree and open it to infection and, gradually, the tree will grow around and over the nail. A better idea is to tie the wire to the tree and to loosen the tie as the tree grows.

Another problem is that electric fences represent a hazard to people moving along a public river reserve. This can be dealt with easily by hanging small conspicuous notices on the wire, both to warn of a hazard and to make the wire conspicuous.

Another idea is the use of slack electric wire. The value of such a fence along remnant bush is that fallen limbs and trees will not break the wire and repairs are limited to the removal of debris. One farm in the Kalgan River catchment has solar-powered electric fences, which may serve to reduce maintenance costs in the long term.

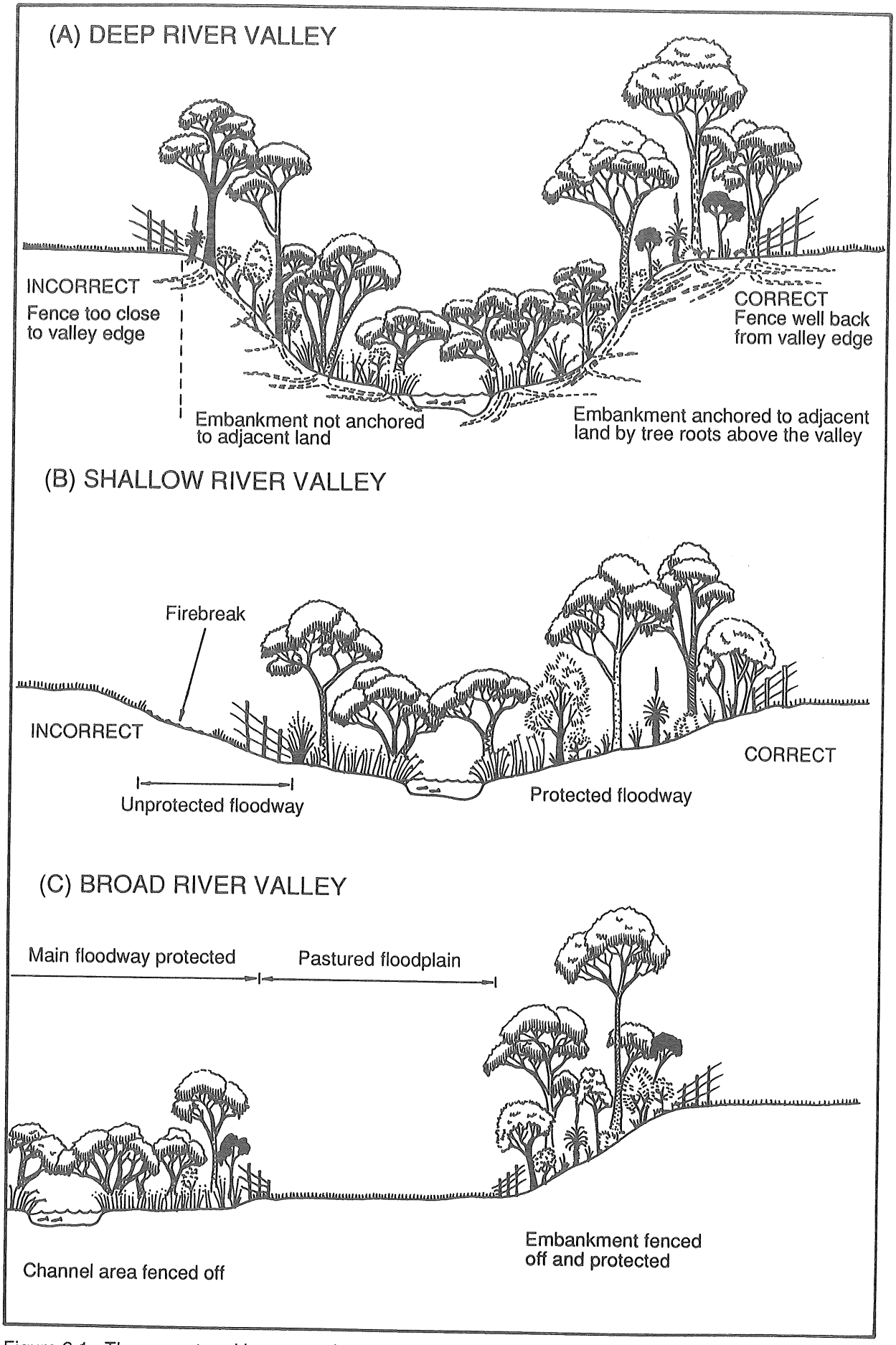

Figure 9.1: The correct and incorrect placement of fences in relation to the river valley: (A) the deep river valley, (B) the shallow river valley and (C) the broad river valley with broad floodplain.

9.2 Vegetation rehabilitation

The general subject of vegetation rehabilitation on cleared land is beyond the scope of this report and the reader is referred to the excellent publications listed in Appendix 2.

9.2.1 Planting along the river valley

Areas of exposed river embankment need to be planted to control erosion, by supporting the soil and by dissipating the energy of floodwaters. Actual sites of erosion cannot be planted until they are stabilised, as plantings would easily be washed away in the first winter. However, plantings can be carried out just upstream, on cleared non-eroded embankment, to retard flow rates and encourage sedimentation in the former erosion sites, which, in turn, will create sites which can be planted or will be recolonised naturally by plants. This process of rehabilitation is occurring naturally on some washouts in Section 6 of the study area, where trees and shrubs have regenerated upstream of the erosion sites.

Vegetation rehabilitation requirements along the Kalgan River are given in Table 9.1, Chapter 10 and Table 10.1, and are shown on the river maps. Areas for rehabilitation have been prioritised in the same way as for fencing needs (see 9.1.1).

9.2.2 Minor useful work

There is much useful work that can be done to accelerate regeneration of native riparian vegetation in those B grade areas of the river which have recently been fenced off. Tree and shrub seedlings can be protected from rabbit grazing by placing wire cages or old tyres around them, until the plants are large enough to fend for themselves. The cages or tyres can then be moved to other young plants. On a larger scale, small areas can be surrounded by enclosures to reduce grazing by rabbits and small marsupials. This method produces spectacular results on Rottnest Island where Quokka grazing is a major problem (*Pers. Obs*). Even clearing or spraying weeds around young plants will encourage growth.

The ground can be prepared below trees and tall shrubs to encourage seed germination and early growth can be encouraged by spraying weeds and by scarifying (shallow ripping) the soil. Deep ripping is not recommended within 20m of trees as it could damage root systems essential for the stability of the embankment and the trees themselves. Scarification has been observed by the author to produce good results along the Brunswick and Collie rivers. It should not be done in areas subject to swift flood waters, as severe washouts may result.

Even though these suggested activities are on a very small scale, taken across the whole river over many years, they will make a very useful contribution to river protection.

9.3 Stock crossings and watering points

Where properties cross the river, or where farmers own or manage both sides of the river, livestock crossings are required. The heavy livestock trampling associated with crossings often exposes the soil and initiates serious water erosion. However, simple river crossings, if located and managed properly, need not present an erosion hazard to the river banks. For example, a crossing point could be located just downstream of dense riparian vegetation, where flow rate, even during floods, is minimal, or it could be located in a stony area where erosion is not possible.

In areas where the soil is not cohesive and easily washed away, stones can be placed along the track to dissipate energy and buffer the soil against livestock trampling. At the embankments, where the soil is often worn down by livestock, large stones or logs can be placed over small ones to form revetments. Ideally, crossing points should be fenced off when not in use, to prevent livestock access to the river valley.

Because crossings run up and down the river valley embankments they are prone to erosion by water running off the paddocks and channelling down the tracks. To prevent this, tracks leading down to crossing points should not be aligned with the natural drainage lines of the adjacent paddocks.

9.4 Firebreaks and tracks

The practice of locating firebreaks within the shallow but often relatively broad river valley of Sections 4, 5 and 6 has led to the most severe form of erosion in the upper region of the Kalgan River (See 5.4). As a rule, firebreaks and even tracks running parallel to the river should be located well above the river valley.

9.5 Plant species for rehabilitation

Long term general rehabilitation of the fringing vegetation of the Kalgan River will be necessary to maintain the habitat, biofilter and ecological corridor functions of the river, to combat erosion and preserve the riverine landscape of the region. A list of native plant species suitable for the Kalgan River is given in Table 9.2. This list has been divided into the major sections of the study area, river valley zones (floodway and embankment) and certain environmental conditions (ie fresh, saline, moist, dry, rocky, etc).

Table 9.2: Recommended plant species for vegetation rehabilitation and where to plant them along the Kalgan River.

		Section and environment												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Tall trees														
	Eucalyptus diversicolor						*							
Medium trees														
	Eucalyptus wandoo													*
	Eucalyptus marginata				*		*			*	*			
	Eucalyptus calophylla		*	*	*		*	*		*				
	Eucalyptus rudis					*		*	*			*		
	Eucalyptus cornuta			*										
	Eucalyptus occidentalis					*		*		*				*
Small trees														
	Melaleuca rhaphiophylla					*		*	*			*		
	Agonis flexuosa			*										
	Agonis juniperina		*											
	Melaleuca viminea								*			*	*	*
	Melaleuca cuticularis	*											*	
	Eucalyptus decipiens										*			*
	Hakea oleifolia			*			*							
	Banksia seminuda						*			*				
	Banksia grandis									*				
	Oxylobium lanceolatum		*			*		*	*					
	Casuarina obesa												*	
Small trees/large shrubs														
	Acacia myrtifolia			*			*							
	Agonis parviceps			*			*							
	Agonis hypericifolia				*		*							
	Astartea fascicularis		*			*		*						
	Agonis linearifolia		*			*	*							
	Melaleuca densa					*								
	Melaleuca viminea											*	*	*
	Leptospermum oligandrum													*
	Hakea ruscifolia			*			*							
	Hakea prostrata				*		*							
	Trimalium floribundum					*			*					
	Dodonaea ceratocarpa								*					
	Allocasuarina huegeliana													*
	Actinostrobus arenarius													*
Shrubs														
	Hypocalymma angustifolium			*										
	Calothamnus quadrifidus				*						*			
	Thryptomene saxicola										*			
	Sollya heterophylla			*			*							
	Hakea trifurcata		*											
	Hakea undulata				*									
	Darwinea citriodora			*			*		*		*			
	Melaleuca thymoides												*	*

Table 9.2 cont.

		Section and environment												
		1	2	3	4	5	6	7	8	9	10	11	12	13
	Bossiaea linophylla			*			*			*				
	Bossiaea divaricata			*										
Large sedges														
	Gahnia trifida	*						*					*	
	Juncus kraussii													
	subsp. australiensis	*	*			*		*	*			*	*	
	Lepidosperma effusum		*			*		*	*					
	Lepidosperma tetraquetrum					*		*						
	Cyathochaeta clandestina				*					*				
	Juncus pallidas					*								
Medium sedges														
	Cyathochaeta avenacea			*			*	*		*				
	Baumea juncea		*			*		*	*					
	Isolepis nodosa						*	*						
	Leptocarpus coangustatu		*			*		*						
	Leptocarpus scariosus		*											
	Lepidosperma longitudinc		*	*						*				
Small sedges														
	Loxocarya flexuosa						*							*
	Anarthria laevis											*		
	Gahnia ancistrophylla													*
Samphires														
	Sarcocornia quinqueflora												*	
	Halosarcia lepidosperma												*	
Grasses														
	Stipa junceafolia												*	*
	Parapholis incurva												*	
	Key													
	1 - Section 1, saline foreshore													
	2 - Section 1, freshwater lower foreshore													
	3 - Section 1, moist embankment													
	4 - Section 1, sandy dry embankment													
	5 - Section 2, floodway													
	6 - Section 2, embankment													
	7 - Section 3, floodway													
	8 - Section 3, rocky floodway													
	9 - Section 3, embankment													
	10 - Secton 3, rocky embankment													
	11 - Sections 4, 5 & 6, fresh/brackish floodway													
	12 - Sections 4, 5 & 6, saline floodway													
	13 - Sections 4, 5 & 6, embankment													

10. DETAILED DESCRIPTION OF THE CONDITION AND REHABILITATION NEEDS OF THE KALGAN RIVER

Each of the six sections of the study area have been divided into a number of sub-sections, on the basis of foreshore condition (see Table 10.1 at the end of this Chapter). These sections are shown on the river maps. The prefix R denotes the right hand and L the left hand bank, relative to the view upstream.

10.1 Section 1: left bank

Subsection L1.1: 800m (Map 1)

Immediate foreshore is A2 and the upper embankment B2-3. None is fenced off. There is a 0.2ha area right on the water which requires vegetation rehabilitation at priority level 2. The downstream foreshore is extensively eroded along the water's edge, but this appears to be natural.

Subsection L1.2: 1800m (Map 1)

The entire steep foreshore ranges from B2 to C3, and only about 29% was fenced off at the time of the survey. There is one point of subsidence and an extensive area of very severe undercutting and subsidence opposite the waterski area. The cause of the erosion appears to be a combination of livestock damage, rabbit digging, flood damage and wave action from boat traffic, and is one of the worst examples of erosion anywhere along the Kalgan River. About 1270m of fencing and 2.5ha of vegetation rehabilitation are required urgently to protect and stabilise the embankments (about 350m of fencing and 1.6ha of plantings have been initiated recently, adjacent to the waterski area).

Subsection L1.3: 280m (Map 1)

The foreshore is all A2 and is fenced off.

Subsection L1.4: 390m (Map 1)

The steep foreshore is mainly A2, ranging to B2 in the vicinity of the small parkland at the end of Aldo Road. Apart from the parkland, the foreshore is fenced off. The park requires management to control vehicular movement and to protect surrounding vegetation. The priority level is 3.

Subsection L1.5: 700m (Map 1)

The steep foreshore, which is not fenced, is mainly B3 to C1, but ranges to C3 with points of livestock damage down to the water. About 700m of fencing and 1.6ha of tree and shrub planting are required at priority level 3.

Subsection L1.6: 4130m (Map 2)

The steep foreshore, which is unfenced, is mainly B3 to C1, but ranges to B1 or to C3 in areas. There are points of subsidence and one point of severe livestock damage. Fencing is required at priority level 2 (The landowner began fencing in late 1992).

Subsection L1.7: 580m (Map 2)

The steep foreshore is mainly A3, but ranges to B1 and it is not fenced off. The wider area of bush on the left bank, together with the rocky cascades of the floodway, make this part of the river particularly scenic. Fencing is required at priority level 3.

Subsection L1.8: 1170m (Map 2)

The steep foreshore is B1-3 and is not fenced off. Fencing is required at priority level 3.

10.2 Section 1: right bank

Subsection R1.1: 2140m (Map 1)

The lower foreshore condition is mainly A2, ranging to B3. The embankment is B2-3. The area is entirely fenced off. However, about 0.6ha of priority level 3 vegetation rehabilitation is required above the embankment. About 300m of extra fencing would be required to protect the plantings. An 0.2-0.3ha metre high mound of sand has been deposited in the salt-marsh vegetation and is being colonised by weeds. This mound should be removed and the resultant cleared area allowed to regenerate naturally.

Subsection R1.2: 2060m (Map 1)

The foreshore is generally A2, ranging to A3-B2, and is 100% fenced off. There are points of severe erosion (C3) and one area of extensive erosion at the water's edge just downstream of the waterski club. This latter erosion is most likely natural, as it is on the outside corner of a power bend in the river. A small area of beach has been exposed at the waterski club where boats are launched. Although it is not eroding, it should be bordered to prevent the beach from growing in size. Also, just downstream of the club, amongst the rushes, a sandy track has been put in recently which threatens to cause erosion and lead to weed infestation and should be closed off to allow the rushes to regenerate naturally.

Subsection R1.3: 620m (Map 2)

Foreshore condition is A2 and it is entirely fenced off. There is one point of past major subsidence which is now stabilising through natural vegetation regeneration.

Subsection R1.4: 1580m (Map 2)

The foreshore is mainly A2 to B1, but ranges to B2 and at one point to C3. The area is 100% fenced off. There is a point of recent subsidence, indicating that this area of the river valley embankment, which is very sandy, is prone to bank failure.

Subsection R1.5: 2650m (Map 2)

The lower foreshore is mainly A3 to B1 grade, but some small areas of A2 grade remain. The upper embankment is more degraded, being mainly B3 to C1, but ranging to A2, with points of C3. The river is generally very scenic in this section. However, there is a point of vehicular damage, an area of major subsidence, which is now mostly stabilising, and a point of minor erosion. Only 30% of the section is fenced, requiring 1850m of fencing. The very steep embankment requires vegetation rehabilitation in a number of areas (0.5ha in total), and particularly in the area of past subsidence. Here a number of large trees are positioned precariously close to the edge of the precipitous embankment, and one large pine tree is already leaning over the river. Should these trees fall over, further major subsidence may occur. Fencing and rehabilitation work are required at priority level 2.

Subsection R1.6: 270m (Map 2)

The immediate foreshore is A3, but the upper embankment is somewhat degraded at B2-3. None of this small area is fenced off, but as the adjacent land use is residential there is probably no need for fencing. However, there is a need to delineate the foreshore reserve so that property owners do not encroach on the river valley, and to guard against "garden escapees" infesting the foreshore reserve. The recreational area at the bridge is degraded and requires considerable repair works to prevent erosion, at priority level 3.

Subsection R1.7: 240m (Map 2)

The condition of the foreshore is A2, despite none of it being fenced off. Some fencing is required along the mouth of the Chelgiup Creek to protect the river. The priority level is 3.

10.3 Section 2: left bank

Subsection L2.1: 420m (Map 3)

The foreshore is mainly B2, but C1-2 where fringing vegetation has been cleared to the water's edge and near the lower Kalgan bridge. None of the foreshore is fenced. However, as the area is on the outside corner of a power bend in the river, and is prone to serious erosion 420m of fencing and 0.1ha of planting are required, at priority level 1.

Subsection L2.2: 240m (Map 3)

A2 grade foreshore, none of which is fenced. A large tributary enters the river here. Fencing is required at priority level 3.

Subsection L2.3: 390m (Map 3)

B1-2 grade foreshore, none of which is fenced. Fencing is required at priority level 3.

Subsection L2.4: 950m (Map 3)

The steep foreshore is mainly B2-3, with some A2-3 grade foreshore and one point of severe erosion (C3) where overflow water from an adjacent farm dam has cut a narrow but deep gully into the embankment. The water from the dam should be diverted to the natural drainage line on which the dam is located. The entire section requires fencing and 0.2ha of vegetation rehabilitation at priority level 2.

Subsection L2.5: 580m (Map 3)

The foreshore here has been severely degraded by livestock and is mostly C3 grade but ranges to C1. It is not fenced. A 100m section is the worst example of livestock damage anywhere along the Kalgan and is beyond any simple form of rehabilitation such as tree and shrub planting. The use of geotextiles or log walling may be necessary to effect repair. The area requires fencing off urgently.

Subsection L2.6: 800m (Map 3)

The steep embankment is mainly B2-3, ranging to A2-3. None of it is fenced. There is one point of severe undercutting and bank failure (C3), over about 100m near a sharp turn in the river. Large scale subsidence of the sandy embankment is prevented by tree support above the valley. The area needs fencing off and about 0.4 ha of planting urgently.

Subsection L2.7: 800m (Map 3)

The foreshore is mainly A2, ranging to A3, and backs onto dense vegetation along a tributary creek. About 62% is fenced off, leaving about 300m to be fenced at priority level 3.

Subsection L2.8: 1520m (900m along river) (Map 4)

The foreshore is A2 and all fenced off. A 260m length backs onto remnant bush.

Subsection L2.9: 260m (Map 4)

The foreshore is B1-2 and is all fenced off.

Subsection L2.10: 320m (Map 4)

The foreshore ranges between A2 and B1, of which about 62% is fenced off. About 120m of priority level 3 fencing is required.

Subsection L2.11: 1060m (Map 4)

The foreshore is mainly B2-3 and is all fenced. Napier Creek, of which the lower 4-5km lies on reserved land, enters the river here.

Subsection L2.12: 920m (Map 4)

The foreshore is mainly B2-3, with some C1-3 where stock frequently gain access to the river. There is a point of severe erosion at a sharp turn in the river. None of this section is fenced, requiring about 920m of priority 1 fencing to be carried out.

Subsection L2.13: 2080m (Map 4)

This section has been fenced off recently, and although it is mainly B1-3, with only patches of A3, the native vegetation is regenerating quickly.

Subsection L2.14: 1100m (Map 4)

The foreshore is mainly A2-3, with some B2-3, and is fenced off completely. There is a small crossing for a track on the eastern side of the river which connects with Deep Creek Road, and appears to be used to move stock occasionally.

Subsection L2.15: 460m (Map 4)

The foreshore is mainly B2-3, and is fenced off. Karri dominates much of this section, and despite the abundance of weeds, are regenerating very successfully. The small area is very scenic.

Subsection L2.16: 840m (Map 4)

The foreshore is all fenced off and is B3.

Subsection L2.17: 1420m (Map 4)

The foreshore is C1-2 and livestock graze to the river's edge, as none of the area is fenced. There is a point of severe erosion (C3) caused by livestock. A crossing point made of stones has created a weir which has killed trees through flooding. Fencing is required at priority level 1.

Subsection L2.18: 700m (Map 5)

The condition of the foreshore is mainly B1-3, ranging to A3. None of the area is fenced off and there is a livestock crossing point. Fencing is required at priority level 2. The Takenup Creek, of which the lower 5km lies on a narrow reserve, enters here.

Subsection L2.19: 500m (Map 5)

The foreshore is B3 to C3 and is unfenced. Most of the river valley embankment has been cleared completely and at one point it is slowly subsiding and being eroded away by floodwaters. This area requires fencing off and about 2 ha of planting, at priority level 1, to protect and support the embankment. There is a stable livestock crossing point at the upstream end.

Subsection L2.20: 440m (Map 5)

The foreshore condition is B1-2, and the whole area is fenced off.

Subsection L2.21: 1140m (Map 5)

The foreshore is A2 and is all fenced off. It backs onto a patch of remnant bush.

Subsection L2.22: 820m (Map 5)

The foreshore is B1-2 and is all fenced off. There is a crossing point at the upstream end.

10.4 Section 2: right bank

Subsection R2.1: 250m (Map 3)

The foreshore is A2-3 and backs onto large residential blocks, with some gardens encroaching into the native fringing vegetation. There is potential for "garden escapees" to infest the foreshore reserve. The whole area is fenced off or well delineated.

Subsection R2.2: 740m (Map 3)

The foreshore is A2, of which a 280m length backs onto jarrah forest. Only about 13% of the river is fenced off, leaving 640m of priority level 3 fencing to be done.

Subsection R2.3: 2290m (Map 3)

The steep foreshore is mainly B1-3, with some A2-3. Only 4.4% of the area is fenced off. There is some erosion and subsidence (C3) along minor tributary creeks and one point of subsidence at the top of the valley embankment. About 2200m of priority level 3 fencing is required.

Subsection R2.4: 1060m (Map 3)

The steep foreshore is mainly A2, but ranges to B2. The entire section requires fencing at priority level 3.

Subsection R2.5: 1340m (Map 4)

The river valley becomes shallower here, most of the land has been cleared to the channel and none has been fenced off. The foreshore is mainly B1-2, but with some points between B3 and C3, including one point of severe erosion. The foreshore requires fencing off and about 5ha of vegetation rehabilitation is needed to protect the embankment against subsidence at priority level 1. A patch of remnant bush connects with the river in this section.

Subsection R2.6: 1220m (Map 4)

The foreshore condition ranges between B3 and C2, ranging to C3 at points of severe erosion and subsidence. Most of the foreshore has been cleared to the river channel. Cattle have taken a heavy toll of many of the native plant species, leaving only flooded gum and swamp paperbark, which are typical survivors along rivers throughout the coastal areas of the south-west. The area requires fencing off and 2.9ha of planting at priority level 1.

Subsection R2.7: 860m (Map 4)

Mainly A2-B1 foreshore, ranging to A2 and B2. None of the foreshore is fenced off. The area requires fencing off at priority level 3.

Subsection R2.8: 2180m (Map 4)

Mainly A2-3 foreshore, ranging to B2. It has been fenced off recently and the native vegetation is regenerating. This stretch of the river is an excellent example of what fencing off B grade river foreshore can achieve.

Subsection R2.9: 1380m (Map 4)

The foreshore condition is mainly A2-3, with some B2-3. There is one small area of subsidence, but it is stabilising naturally. A crossing point, which appears to be used to move livestock very occasionally, connects to a track which leads to Deep Creek Road. The entire section backs onto a large area of remnant bush which is entirely fenced off.

Subsection R2.10: 680m (Map 4)

Mainly B2-3 foreshore, with tall karri trees (see Subsection L2.15). It is all fenced off.

Subsection R2.11: 740m (Map 4)

The foreshore is mainly C1-2, ranging to B3 at best, and has been cleared to the river channel. This represents the typical degraded river valley seen anywhere in the south-west. It requires fencing off entirely and about 1 ha of planting along the embankment at priority level 1.

Subsection R2.12: 1160m (Map 4)

Mainly B2-3 foreshore, which is not fenced off. There is a livestock crossing point. The area requires fencing off at priority level 2.

Subsection R2.13: 740m (Map 5)

The foreshore is mainly B1-3, ranging to A3 along the floodway. The whole area requires fencing at priority level 2.

Subsection R2.14: 540m (Map 5)

The foreshore is B2-3 and there is a stable livestock crossing point. Fencing of the section is required at priority level 2.

Subsection R2.15: 1780m (Map 5)

The foreshore is B1-3 and is all fenced off. Fringing vegetation had been degraded through past livestock damage, but is now regenerating successfully. There is a crossing point at the upstream end of this section.

10.5 Section 3: left bank

Subsection L3.1: 3220m (Map 5)

The broad river valley embankment and lower foreshore are A2-3, ranging to B2 in places on the embankment. The area is very scenic and is fenced off.

Subsection L3.2: 320m (Map 5)

The foreshore is B2-3 and it appears to be all fenced off.

Subsection L3.3: 860m (Map 6)

The foreshore ranges between B3 and C3. Although the area is rocky, heavy livestock damage is causing erosion of the shallow soils that support the floodway vegetation. The area requires fencing urgently.

Subsection L3.4: 3120m (1940m along river) (Map 6)

The very steep and scenic river valley is mainly A2, ranging to A3. The fringing vegetation backs onto a large area of remnant bush. It is all fenced off.

Subsection L3.5: 500m (Map 6)

The foreshore is A2 and fenced off. There is one point of severe "semi-natural erosion" (see 6.5).

Subsection L3.6: 1720m (1240m along river) (Map 6)

The foreshore is A2, ranging to A3, and all fenced off. The valley is quite scenic

Subsection L3.7: 3400m (Map 6)

The densely forested foreshore is A2 and all fenced off. There is one point of bank failure which is "semi-natural". Fringing vegetation backs onto a large area of remnant bush and there are high areas of granite with scenic views of the Porongurup Range and surrounding countryside. Moorialup Creek enters the river here.

Subsection L3.8: 2020m (2900m along river) (Map 6)

The foreshore is A2, and all fenced off. There is one point of "semi-natural" bank failure which is stabilising. The river valley is quite scenic.

Subsection L3.9: 600m (Map 7)

The foreshore ranges between B1 and C3. There is a point of severe livestock damage and erosion and a huge deposit of sand at the base of a creek which is slowly filling a section of a long river pool. The foreshore needs fencing off and 1.5ha of vegetation rehabilitation urgently.

Subsection L3.10: 1580m (Map 7)

The steep and often precipitous foreshore is A2 and all fenced off. The narrow river valley is quite scenic.

Subsection L3.11: 1860m (1300m along river) (Map 7)

The foreshore is B3 to C1 and is all fenced off.

Subsection L3.12: 960m (Map 7)

The often rocky foreshore is B3 and fenced off. It requires 1ha of planting at priority level 3 to stabilise the embankment in one cleared area.

Subsection L3.13: 1680m (Map 7)

The very rocky foreshore is B3 to C2 and is unfenced. The floodway is very rocky and there are many zones of rapidly flowing water over stones. The area would have been very scenic at one time, but is now degraded by livestock. Fencing and 3ha of planting are required at priority level 2.

Subsection L3.14: 1440m (Map 7)

Mainly B1-3, but ranging to C2, foreshore, which is not fenced off. The area requires fencing off and 7ha of vegetation rehabilitation at priority level 2.

Subsection L3.15: 720m (Map 7)

Mainly B1-3 foreshore, but with some parts ranging to C3. Although the area is well treed it is not fenced off and it is being heavily disturbed by vehicles, livestock and humans. There is some serious erosion of the valley embankment. The area requires fencing off and about 1.1ha of planting at priority level 1.

Subsection L3.16: 860m (Map 7)

Mainly B1 to C2 foreshore, ranging to C3. There is one point of severe erosion. About 51% of the periphery is fenced, leaving 420m of fencing to be done, along with 2.8ha of planting to support the high embankment of the large river pool which is virtually unprotected. This work has priority level 1.

Subsection L3.17: 160m (860m along river) (Map 7)

The foreshore is A2 and backs onto remnant bush, all of which is fenced.

Subsection L3.18: 1000m (780m along river) (Map 7)

The foreshore is B1-3, and all fenced off. There is evidence of salinisation.

10.6 Section 3: right bank

Subsection R3.1: 1780m (Map 5)

The rocky foreshore is A2-3, ranging to B2, with 89% of the area fenced off. The broad and deep rocky river valley is very scenic. About 200m of fencing is required at priority level 3.

Subsection R3.2: 1860m (Map 5)

Most of the foreshore is B2, ranging to B1 and B3, but C2 where it is cleared down to the river. Sixty percent of the foreshore is fenced off. About 2.2ha of vegetation rehabilitation is required on the cleared area, to protect the embankment and restore the landscape and scenic quality of this area, and 640 m of fencing is required to protect the plantings and foreshore. This work is at priority level 2.

Subsection R3.3: 100m (Map 5)

The foreshore is mainly B2-3 and is all fenced off. The area is quite scenic.

Subsection R3.4: 920m (Map 6)

The rocky foreshore ranges between B3 and C3. The area is not fenced and livestock are causing the erosion of the shallow soils and the undermining of the floodway vegetation. The area requires fencing off urgently.

Subsection R3.5: 2840m (Map 6)

The steep foreshore is mainly A2, ranging to A3, and is very scenic. Most of the vegetation of the river valley backs onto degraded remnant bush, but more than half is separated from it by a fenceline. The entire foreshore area is fenced off.

Subsection R3.6: 400m (Map 6)

The foreshore is mainly B1, with some areas of B2 to C3. Livestock damage is evident in the adjacent remnant bush. Both areas are not fenced off. There is a severe washout along a sandy track, but further damage is limited by adjacent dense vegetation. The foreshore requires fencing off at priority level 2.

Subsection R3.7: 1360m (Map 6)

Mainly A2 grade foreshore, but ranging to A3, none of which is fenced off. The river valley is quite scenic. Fencing is required at priority level 3.

Subsection R3.8: 5360m (4100m along river) (Map 6)

The foreshore is A2 and backs onto a large area of remnant bush which has significant floristic and habitat value. At the eastern end of this section, where the land rises to tall granite hilltops, there are magnificent views to the west, of the Porongurup Range and the river valley, and to the north, along the forest shrouded river valley. The entire area is fenced off.

Subsection R3.9: 2460m (Map 6)

The foreshore is A2 and all fenced off. The area is quite scenic.

Subsection R3.10: 2400m (3280m along river) (Map 7)

The foreshore is A2, ranging to A3, and backs onto remnant bush which is fenced off. There are some points of severe "semi-natural" erosion in high energy areas, one recreational area which has become degraded (ie BBQ debris, swimming beach and discarded refuse), and some livestock damage which is stabilising naturally.

Subsection R3.11: 1000m (580m along river) (Map 7)

The foreshore and the adjacent bush is B3, following a severe fire and bulldozing. While regeneration of native species is good, introduced weeds are becoming more abundant. The entire area is fenced.

Subsection R3.12: 780m (600m along river) (Map 7)

Mainly B1 to C1 foreshore, with many points of C2, and the area is not fenced off. Fencing is required at priority level 2.

Subsection R3.13: 840m (Map 7)

The entire foreshore is C2 and none of it is fenced off. Sheep have grazed heavily down to the river. Fencing and 1ha (at least) of planting are required at priority level 2.

Subsection R3.14: 1980m (Map 7)

The rocky foreshore ranges between B3 and C2, and 72% has been fenced off. This area would have been very scenic prior to being degraded by livestock. About 560m of fencing and 2.7ha of planting along the embankments are required at priority level 2.

Subsection R3.15: 1440m (Map 7)

The foreshore is B1-3, ranging to C2. None of it is fenced off. About 1440m of fencing and 3ha of planting along the embankments are required at priority level 2.

Subsection R3.16: 540m (Map 7)

The foreshore is mainly B1-3, but there is a small area of A3 swampy floodplain in the middle of the floodway. The foreshore backs onto degraded remnant bush. Fencing of the foreshore area is required at priority level 3.

Subsection R3.17: 1520m (Map 7)

The foreshore is mainly B1 to C2, ranging to C3 in some areas. Riffle zones between the pools are fenced off to prevent the stock crossing to the other side of the river, but the embankments of the large pool are completely unprotected and there are points of severe livestock damage. The area requires fencing off and 4ha of planting at priority level 1, to stabilise and protect embankments.

Subsection R3.18: 680m (Map 7)

The foreshore is mainly B3, but ranges to B1, and is all fenced off. Evidence of salinisation is indicated, by the presence of salt-tolerant shrubs.

10.7 Section 4: left bank

Subsection L4.1: 680m (Map 8)

The foreshore is B2-3, and not fenced. Fencing is required at priority level 3.

Subsection L4.2: 280m (Map 8)

The foreshore is C2-3 and not fenced. There is very severe erosion due to stock damage. Fencing and 1ha of planting are required at priority level 1.

Subsection L4.3: 560m (Map 8)

Mainly B3 to C1 foreshore, with some C2, and not fenced. Fencing and 0.3ha of vegetation rehabilitation are required at priority level 1.

Subsection L4.4: 400m (Map 8)

The foreshore is C2 and not fenced. Fencing and 1.5ha of planting are required at priority level 1.

Subsection L4.5: 580m (Map 8)

The foreshore is mainly B2-3, ranging to B1, and is fenced off.

Subsection L4.6: 2000m (Map 8)

Mainly B2 to C1 grade foreshore, but ranging to B1 and C2. About 27% of the foreshore has been fenced off and there is a point of severe erosion. Stony Creek enters here. The floodway is quite saline and dead trees are to be seen. About 1460m of fencing and 0.5ha of tree and shrub planting are required at priority level 2.

Subsection L4.7: 1700m (Map 8)

The foreshore is mainly B2 to C2, ranging to B1 and C3. None of the area is fenced off. The area requires fencing off and about 6.5ha of planting at priority level 1.

Subsection L4.8: 720m (Map 8)

The foreshore is mainly B3 to C2, ranging to B1 and C3. About 33% of the area is fenced off. There are many dead trees due to salinisation and much algal growth, and as a result the area is most unattractive. About 480m of fencing and 3.5ha of vegetation rehabilitation are needed at priority level 1.

Subsection L4.9: 840m (Map 8)

Mainly B3 foreshore, but ranging to B1 and C3. About 24% of the area has been fenced off. This section has the largest washout anywhere along the river, with a huge bite out of the cleared embankment. A huge "slug" of sediment lies just downstream in the floodway. The area requires 640m of fencing and 6ha of planting urgently. About 1.7ha of this planting is to support the embankment just above the large washout. An additional 200m of temporary fencing would be required to protect these trees from livestock until they are large enough to fend for themselves.

Subsection L4.10: 1380m (Map 8)

Mainly B2-3 foreshore, ranging to C3 in parts. About 29% of the foreshore has been fenced off. A large area (~2 ha) is exposed to erosion along the lower foreshore. This area is becoming increasingly saline as trees die back, giving way to broad bands of rushland and, in turn, samphire. Many dead trees and foul water make the area look very unattractive. The foreshore requires 3.7ha of planting, preferably with salt-tolerant species, and 980m of fencing urgently.

10.8 Section 4: right bank

Subsection R4.1: 640m (Map 8)

The foreshore is B2-3 and all fenced off. About 0.8ha of vegetation rehabilitation is needed at priority level 3.

Subsection R4.2: 1000m (Map 8)

The foreshore is mainly B3 to C1, ranging to C3, and is fenced off. There is a point of erosion which requires 1ha of planting to protect the embankment, at priority level 3.

Subsection R4.3: 2760m (1100m along river) (Map 8)

Mainly B2-3 foreshore, ranging to B1 and C1, and backing onto a large area of remnant bush. The whole area is fenced off.

Subsection R4.4: 1780m (Map 8)

The foreshore is mainly B2 to C1, ranging to B1 and C2. About 68% of the river is fenced off, leaving 560m to be fenced off at priority level 2.

Subsection R4.5: 1640m (Map 8)

Mainly B2 to C2 foreshore, ranging to B1 and C3. About 24% of the area, which is quite saline, is fenced off. About 1240m of fencing and 0.5ha of planting are required at priority level 1.

Subsection R4.6: 1060m (Map 8)

The foreshore is mainly B3 to C2, ranging to B1 and C3, and only about 13% has been fenced off. Livestock damage is undermining trees and some sections of the embankment are being undermined or are subsiding. There is also a large washout along a firebreak, which is getting worse. The embankment is largely cleared, requiring 5ha of tree planting and 920m of fencing urgently, before livestock damage leads to severe erosion and subsidence. (See Subsection L4.8 for additional comments).

Subsection R4.7: 420m (Map 8)

Mainly A3 to B1 foreshore, ranging to C3, backing onto a small area of remnant bush which, as it extends to the road, is effectively fenced off. There is a small washout along a track, but it is limited by surrounding supporting vegetation. Salt encroachment is a problem, with many dead and dying trees being replaced by samphire. Management need only involve securing fencelines, placing stones along the track to retard erosion and the scattering of seed of salt tolerant paperbarks, but at priority level 1.

Subsection R4.8: 460m (860m along river) (Map 8)

The river splits into two channels here, one of which comes very close to the road, effectively providing fencing. The condition of the foreshore and floodway island is generally B3, but ranging from B1 and C2. There are many dead and dying trees due to salt. Management need only involve securing fencelines and the scattering of seed of salt tolerant paperbarks, at priority level 3.

Subsection R4.9: 1440m (Map 8)

The foreshore is mainly B1-2, ranging to B3 occasionally. The reserve, which is entirely fenced off, would appear to be used as a stock holding area from time to time. If so, this activity should cease immediately. This action is a priority level 2. (See also comments for L4.10).

10.9 Section 5: left bank

Subsection L5.1: 1700m (Map 9)

The foreshore is B1-3 and backs onto a large reserve which, as it extends to the road, effectively fences off the river. The river is very saline, with stands of salt tolerant paperbarks and samphire.

Subsection L5.2: 1800m (Map 9)

The foreshore is B1-3 and none of it is fenced. There is a point of severe stock damage, a washout and three crossings. The area requires fencing and 2.8ha of vegetation rehabilitation at priority level 1.

Subsection L5.3: 960m (Map 9)

The foreshore is B3 grade and backs onto a road reserve, which effectively fences it off. Chergugup Creek enters here.

Subsection L5.4: 2520m (2280 along river) (Map 9)

The floodway is A3 to B2, but the embankment is of poorer condition, at B2-3. About 44% of the river is fenced off, which means about 1420m of fencing is needed at priority level 3. Pools are often surrounded by dead trees and there is no regeneration of less salt-tolerant tree species, probably due to the effects of salinisation. A broad, low rocky weir has been built across the river.

Subsection L5.5: 480m (Map 9)

The floodway is A3 to B2, while the embankment is B1-2. The river is fenced off. The vegetation is salt-affected as for L5.4.

Subsection L5.6: 600m (Map 9)

The floodway is A3 to B2, while the embankment is C1-2, ranging to C3. There is a point of severe erosion. The area requires fencing off and 1.5ha of planting to stabilise the embankment, at priority level 1. The vegetation is salt-affected as for L5.4.

Subsection L5.7: 2400m (Map 9)

The floodway is B1-3, the embankment is mainly C2, ranging to C1-3, and the periphery of the pools are C2. The pool embankments are badly exposed and there is a point of severe livestock damage. About 63% of the area is fenced. About 880m of fencing and 9ha of planting are required urgently. The vegetation is salt affected as for L5.4.

Subsection L5.8: 1540m (Map 10)

The very steep embankment is mainly B3, ranging to C3. About 37% of the area is fenced off. There is very extensive severe erosion, including a huge washout, over 400m or more and areas cleared right down to very steep embankments which are supported by only a few remnant trees. These trees support little black cormorant breeding. In one area sediment deposits caused by livestock damage and runoff from the adjacent pasture are gradually filling a pool. About 960m of fencing and 6.5ha of planting are required urgently. The river in this section is less salt-affected, and less salt-tolerant tree species are regenerating.

Subsection L5.9: 1120m (Map 10)

The floodway is A2-3, while the embankment is B3 to C1, ranging to C3. About 76% of the river is fenced. There is a point of severe livestock damage. About 260m of fencing and 0.8ha of planting are required urgently. The vegetation is salt-affected as for L5.8.

Subsection L5.10: 740m (Map 10)

The foreshore is B3 to C1, ranging to C3, where there is a washout along a firebreak. About 240m of the foreshore reserve extends to the road, effectively fencing off 32% of the river. About 500m of fencing and 1ha of planting are required at priority level 1.

Subsection L5.11: 560m (Map 10)

The very steep foreshore is A2 to B1 and backs onto remnant bush which extends to the road. Fencing is not necessary along the road.

Subsection L5.12: 2240m (Map 10)

The foreshore is B3 to C1, with some C3 where there are large firebreak washouts, and about 92% is fenced off. There is one crossing point. About 180m of fencing and 6ha of planting are required urgently.

Subsection L5.13: 2340m (Map 10)

The foreshore is B2-3, with some C3 where there are large firebreak washouts (not present in 1985). All of the river is fenced off. There are patches of dead trees, but there is moderate regeneration of less salt-tolerant tree species. The foreshore requires 2ha of planting urgently. About 400m of fencing may be required to protect plantings beyond the fenceline.

Subsection L5.14: 660m (Map 10)

The foreshore is B1-2 and is all fenced off. Salt effects are as for L5.13.

Subsection L5.15: 1400m (Map 11)

The foreshore is mainly B2-3, ranging to C2. About 16% of the river is fenced off. Erosion is very superficial along tracks and firebreaks, but there is potential for a severe washout. About 1180m of fencing and 4.3ha of planting are required at priority level 1.

10.10 Section 5: right bank

Subsection R5.1: 1180m (Map 9)

Mainly B2 foreshore, ranging to B1 and C3, of which about 39% is fenced off. There is one point of severe livestock damage. About 720m of fencing and 4ha of planting along the embankment are required at priority level 1.

Subsection R5.2: 2840m (Map 9)

The foreshore is B1-2, of which 26% is fenced off. There are three livestock crossings. About 2080m of fencing is required at priority level 2.

Subsection R5.3: 3160m (Map 9)

The floodway is A3 to B2, while the embankment is B3 to C1. The foreshore is fenced off. There is a low rock weir. About 3ha of planting is required at priority level 1. The vegetation is salt-affected as for L5.4.

Subsection R5.4: 460m (Map 9)

The floodway is B1-3, while the embankment is C1. The river is not fenced off. The foreshore requires fencing and about 2.3ha of planting at priority level 1. The vegetation is salt-affected as for L5.4.

Subsection R5.5: 2000m (Map 9)

The floodway is B1-3, the embankment C2, ranging to C1-3, and the pool embankments C2. The area is 22% fenced off. About 1560m of fencing and 2.5ha of planting are required at priority level 1. The vegetation is salt-affected as for L5.4.

Subsection R5.6: 2020m (1480m along the river) (Map 10)

The floodway is B1-3 and the precipitous embankment A3, and backs onto an area of remnant bush which is fenced off. The river is quite scenic in this section.

Subsection R5.7: 1120m (Map 10)

The foreshore is A2-3 and all fenced off. The less salt-tolerant tree species are regenerating.

Subsection R5.8: 3420m (Map 10)

The foreshore is mainly B1 to C1, with some C2-3, and all fenced off. There is a point of severe erosion and a livestock crossing. About 1000m of fenceline maintenance and 4.5ha of planting are required at priority level 1.

Subsection R5.9: 3140m (Map 10)

The foreshore is B2-3 and fenced off. There are large sandy deposits at the base of Boonawarrup Creek and patches of dead trees, but the less salt-tolerant trees are still regenerating. There is a washout near Yarralla road.

Subsection R5.10: 1400m (Map 11)

Mainly B2-3 foreshore, but ranging to C2 in places. The entire foreshore is fenced off.

10.11 Section 6: left bank

Subsection L6.1: 3200m (Map 11)

The floodway is B3 to C2, while the embankment is B3 to C3, with many extensive severe washouts along firebreaks. About 44% of the river is fenced off. There is an area of sheet erosion just upstream of Woogenellup Road North, a pool being filled with sediment and a salt-pan where once there was fringing forest. About 1800m of fencing and 9.5ha of planting are required urgently.

Subsection L6.2: 1920m (Map 11)

The floodway is B1-2, while the embankment is B1-3. Although the river is all fenced off, about 4ha of vegetation rehabilitation is required at priority level 3.

Subsection L6.3: 680m (Map 11)

The foreshore is B1-3, ranging to C3, and all of it is fenced. There is one large firebreak washout which was not present in 1985. About 2ha of planting is required urgently to control erosion in the area of the washout. An additional 200m of fencing may be required to protect plantings beyond the fenceline.

Subsection L6.4: 3300m (Map 11)

The very saline foreshore is B1-2 and backs onto a large area of degraded remnant bush. Aerial photographs indicate that the whole area is fenced off.

10.12 Section 6: right bank

Subsection R6.1: 3420m (Map 11)

The floodway is B1-2 and the embankment B3 to C2, ranging to C3, and all but about 2% is fenced off. There are points of severe erosion and subsidence, and one pool is being filled with sediment. About 3ha of planting and 80m of fencing are required at priority level 1.

Subsection R6.2: 1380m (Map 11)

The floodway is B1-2 and the embankment is B1-3. The river is fully fenced off.

Subsection R6.3: 880m (Map 11)

The foreshore is B1-3 and all fenced off. The Young River enters here. Note that the main channel of this river lies in a reserve which connects with the Stirling Range National Park.

Subsection R6.4: 2860m (Map 11)

The floodway is B1-2 and the embankment B2-3. The river is very saline in this section, with salt-marshes and fringing forest, typical of estuarine floodplain.

Table 10.1: Summary description of foreshore condition (A, B, C and D (see Section 3.3), fenceline and fencing and rehabilitation needs and their level of priority for the left and right banks of each subsection of the Kalgan River study area.

Sub-section	Map no.	Priority level	River foreshore condition			Gen.	Fenceline (m)	Fenced (m)	Percent fenced	Fencing needed (m)	Veg. Rehab. (ha)
L1.1	1	2		A2	B2-3	B	800	0	0	800	0.2
L1.2	1	1-urgent	B2-C3			C	1800	530	29.3	1270	2.5
L1.3	1	OK	A2			A	280	280	100		
L1.4	1	3	A2,to B2			A	390	0	0	390	
L1.5	1	3	B3-C1, to C3			C	700	0	0	700	1.6
L1.6	2	2	B3-C1, to B1-C3			C	4130	0	0	4130	
L1.7	2	3	A3, to B1			B	580	0	0	580	
L1.8	2	3	B1-3			B	1170	0	0	1170	
Totals							9850	810	8.2	9040	4.3
R1.1	1	3		A2, to B3	B2-3	B	2140	2140	100	0	0.6
R1.2	1	OK	A2, to A3-B2, C3			A	2060	2060	100	0	
R1.3	2	OK	A2			A	620	620	100	0	
R1.4	2	OK	A2-B1, to B2,C3			A	1580	1580	100	0	
R1.5	2	2		A3-B1, to A2	B3-C1,to A2, C3	B	2650	800	30	1850	0.5
R1.6	2	3		A3	B2-3	B	270	0	0	270	
R1.7	2	3	A2			A	240	0	0	240	
Totals							9560	7200	75.3	2360	1.1
L2.1	3	1	B2, to C1-2			B	420	0	0	420	0.1
L2.2	3	3	A2			A	240	0	0	240	
L2.3	3	3	B1-2			B	390	0	0	390	
L2.4	3	2	B2-3, to A2-3, C3			B	950	0	0	950	0.2
L2.5	3	1-urgent	C3, to C1			C	580	0	0	580	
L2.6	3	2	B2-3, to A2-3, C3			B	800	0	0	800	0.4
L2.7	3	3	A2, to A3			A	800	500	62.5	300	
L2.8	4	OK	A2			A	1520	1520	100		
L2.9	4	OK	B1-2			B	260	260	100		
L2.10	4	3	A2-B1			A	320	200	62.5	120	
L2.11	4	OK	B2-3			B	1060	1060	100		
L2.12	4	1	B2-3, C1-3			B	920	0	0	920	
L2.13	4	OK	B1-3, to A3			B	2080	2080	100		
L2.14	4	OK	A2-3, B2-3			A	1100	1100	100		
L2.15	4	OK	B2-3			B	460	460	100		
L2.16	4	OK	B3			B	840	840	100		
L2.17	4	1	C1-2, C3			C	1420	0	0	1420	
L2.18	5	2	B1-3, to A3			B	700	0	0	700	
L2.19	5	1	B3-C3			C	500	0	0	500	2
L2.20	5	OK	B1-2			B	440	440	100		
L2.21	5	OK	A2			A	1140	1140	100		
L2.22	5	OK	B1-2			B	820	820	100		
Totals							17760	10420	58.7	7340	2.7

Table 10.1 cont.

Sub-section	Map no.	Priority level	River foreshore condition		Embankment	Gen.	Fenceline (m)	Fenced (m)	Percent fenced	Fencing needed	Veg. Rehab.
			Overall	Floodway							
R2.1	3	OK	A2-3			A	250	250	100		
R2.2	3	3	A2			A	740	100	13	640	
R2.3	3	3	B1-3, A2-3, C3			B	2290	100	4.4	2190	
R2.4	3	3	A2, to B2			B	1060	0	0	1060	
R2.5	4	1	B1-2, B3-C3			B	1340	0	0	1340	5
R2.6	4	1	B3-C2, to C3			C	1220	0	0	1220	2.9
R2.7	4	3	A3-B1, to A2-B2			B	860	0	0		
R2.8	4	OK	A2-3, to B2			A	2180	2180	100		
R2.9	4	OK	A2-3, B2-3			A	1380	1380	100		
R2.10	4	OK	B2-3			B	680	680	100		
R2.11	4	1	C1-2, to B3			C	740	0	0	740	1
R2.12	4	2	B2-3			B	1160	0	0	1160	
R2.13	5	2	B1-3, to A3			B	740	0	0	740	
R2.14	5	2	B2-3			B	540	0	0	540	
R2.15	5	OK	B1-3			B	1780	1780	0		
Totals							16960	6470	38.1	9630	8.9
L3.1	5	OK	A2-3, to B2			A	3220	3220	100		
L3.2	5	OK	B2-3			B	320	32	0		
L3.3	6	1-urgent	B3-C3			C	860	0	0	860	
L3.4	6	OK	A2, to A3			A	3120	3120	100		
L3.5	6	OK	A2			A	500	500	100		
L3.6	6	OK	A2, to A3			A	1720	1720	100		
L3.7	6	OK	A2			A	3400	3400	100		
L3.8	6	OK	A2			A	2020	2020	100		
L3.9	7	1-urgent	B1-C3			C	600	0	0	600	1.5
L3.10	7	OK	A2			A	1580	1580	100		
L3.11	7	OK	B3-C1			C	1860	1860	100		
L3.12	7	3	B3			B	960	960	100		1
L3.13	7	2	B3-C2			C	1680	0	0	1680	3
L3.14	7	2	B1-3, to C2			B	1440	0	0	1440	7
L3.15	7	1	B1-3, C3			B	720	0	0	720	1.1
L3.16	7	1	B1-C2, to C3			C	860	440	51	420	2.8
L3.17	7	OK	A2			A	160	160	100		
L3.18	7	OK	B1-3			B	1000	1000	100		
Totals							26020	20300	78.0	5720	16.4

Table 10.1 cont.

Sub-section	Map no.	Priority level	River foreshore condition Overall	Floodway	Embankment	Gen.	Fenceline (m)	Fenced (m)	Percent fenced	Fencing needed	Veg. Rehab.
R3.2	5	2	B2, to B1-3, C2			B	1860	1120	60	740	2.2
R3.3	5	OK	B2-3			B	100	100	100		
R3.4	6	1-urgent	B3-C3			C	920	0	0	920	
R3.5	6	OK	A2, to A3			A	2840	2840	100		
R3.6	6	2	B1, to B2-C3			B	400	0	0	400	
R3.7	6	3	A2, to A3			A	1360	0	0	1360	
R3.8	6	OK	A2			A	5360	5360	100		
R3.9	6	OK	A2			A	2460	2460	100		
R3.10	7	OK	A2, to A3			A	2400	2400	100		
R3.11	7	OK	B3			B	1000	1000	100		
R3.12	7	2	B3-C1, to C2			C	780	0	0	780	
R3.13	7	2	C2			C	840	0	0	840	1
R3.14	7	2	B3-C2			C	1980	1420	72	560	2.7
R3.15	7	2	B1-3, to C2			B	1440	0	0	1440	3
R3.16	7	3	B1-3, A3			B	540	0	0	540	
R3.17	7	1	B1-C2, to C3			B	1520	0	0	1520	4
R3.18	7	OK	B3, to B1			B	680	680	100		
Totals							26480	17380	65.6	9100	12.9
L4.1	8	3	B2-3			B	680	0	0	680	
L4.2	8	1	C2-3			C	280	0	0	280	1
L4.3	8	1	B3-C1, C2			C	560	0	0	560	0.3
L4.4	8	1	C2			C	400	0	0	400	1.5
L4.5	8	OK	B2-3, to B1			B	580	580	100		
L4.6	8	2	B2-C1, to B1-C2			B	2000	540	27	1460	0.5
L4.7	8	1	B2-C2, to B1-C3			C	1700	0	0	1700	6.5
L4.8	8	1	B3-C2, to B1-C3			C	720	240	33	480	3.5
L4.9	8	1-urgent	B3, to B1-C3			B	840	200	23.8	640	6
L4.10	8	1-urgent	B2-3, to C3			B	1380	400	29	980	3.7
Totals							9140	1960	21.4	7180	23
R4.1	8	3	B2-3			B	640	640	100		0.8
R4.2	8	3	B3-C1, to C3			C	1000	1000	100		1
R4.3	8	OK	B2-3, to B1-C1			B	2760	2760	100		
R4.4	8	2	B2-C1, to B1-C2			B	1780	1220	68.5	560	
R4.5	8	1	B2-C2,to B1-C3			C	1640	400	24	1240	0.5
R4.6	8	1-urgent	B3-C2, to B1-C3			C	1060	140	13	920	5
R4.7	8	1	A3-B1,to C3			B	420	420	100		
R4.8	8	3	B3, to B1-C2			B	460	460	100		
R4.9	8	2	B1-2,to B3			B	1440	1440	100		
Totals							11200	8480	75.7	2720	7.3

Table 10.1 cont.

Sub-section	Map no.	Priority level	River foreshore condition				Fenceline (m)	Fenced (m)	Percent fenced	Fencing needed	Veg. Rehab.
			Overall	Floodway	Embankment	Gen.					
L5.2	9	1	B1-3			B	1800	0	0	1800	2.8
L5.3	9	OK	B3			B	960	960	100		
L5.4	9	3		A3-B2	B2-3	B	2520	1100	44	1420	
L5.5	9	OK		A3-B2	B1-2	B	480	480	100		
L5.6	9	1		A3-B2	C1-2, to C3	C	600	0	0	600	1.5
L5.7	9	1-urgent		B1-3	C2, to C1-3	C	2400	1520	63	880	9
L5.8	10	1-urgent	B3, to C3			C	1540	580	37	960	6.5
L5.9	10	1-urgent		A2-A3	B3-CI, to C3	B	1120	860	76	260	0.8
L5.10	10	1	B3-C1, to C3			C	740	240	32	500	1
L5.11	10	OK	A2-B1			A	560	560	0		
L5.12	10	1-urgent	B3-C1,C3			C	2240	2060	92	180	6
L5.13	10	1-urgent	B2-3, C3			B	2340	2340	100		2
L5.14	10	OK	B1-2			B	660	660	100		
L5.15	11	1	B2-3,to C2			B	1400	220	16	1180	4.3
Totals							19360	11580	59.8	7780	33.9
R5.1	9	1	B2, to B1-C3			B	1180	460	39	720	4
R5.2	9	2	B1-2			B	2840	760	26	2080	
R5.3	9	1		A3-B2	B3-C1	B	3160	3160	100		3
R5.4	9	1		B1-3	C1	C	460	0	0	460	2.3
R5.5	9	1		B1-3	C2, to C1-3	C	2000	440	22	1560	2.5
R5.6	10	OK		B1-3	A3	B	2020	2020	100		
R5.7	10	OK	A2-3			A	1120	1120	100		
R5.8	10	1	B3-C1, C2-3			C	3420	3420	100		4.5
R5.9	10	OK	B2-3			B	3140	3140	100		
R5.10	11	OK	B2-3, to C2			B	1400	1400	100		
Totals							20740	15920	76.8	4820	16.3
L6.1	11	1-urgent		B3-C2	B3-C3	C	3200	1400	43.8	1800	9.5
L6.2	11	3		B1-2	B1-3	B	1920	1920			4
L6.3	11	1-urgent	B1-3, to C3			B	680	680	100		2
L6.4	11	OK	B1-2			B	3300	3300	100		
Totals							9100	7300	80.2	1800	15.5
R6.1	11	1		B1-2	B3-C2, to C3	C	3420	3340	98	80	3
R6.2	11	OK		B1-2	B1-3	B	1380	1380	100		
R6.3	11	OK	B1-3			B	880	880	100		
R6.4	11	OK		B1-2	B2-3	B	2860	2860	100		
Totals							8540	8460	99.1	80	3

Key to code: B1-3, to A3-C1, C3 means mainly B1 to B3 grade, ranging to A3 and C1 grades in places, with some points of C3 (ie severe erosion or subsidence)

A1 = pristine
A2 = near pristine
A3 = slightly disturbed

B1 = degraded - weed infested
B2 = degraded - heavily weed infested
B3 = degraded - weed dominated

C1 = erosion prone
C2 = soil exposed
C3 = eroded

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APPENDICES

Appendix 1: Aerial photographs used to map the condition of the Kalgan River.

Section 1: Between the lower and upper Kalgan bridges

Albany and Denmark Areas 1:20,000 27.3.1989 Job no. 880249

WA2715 (C)	Run 2	Numbers 5001-5002
WA2714 (C)	Run 3	Numbers 5198 -5199

Section 2: Upper Kalgan Bridge to the Mindijup Rd Crossing

Albany and Denmark Areas 1:20,000 27.3.1989 Job no. 880249

WA2715(C)	Run 1	Numbers 5077-5078
WA2715 (C)	Run 2	Numbers 5001-5002

King/Kalgan Catchment Area 1:50,000 20.2.1991 Job no. 900575

WA2957	Run 3	Numbers 5053-5055
WA2957	Run 4	Numbers 5036-5037

Section 3: Mindijup Rd Crossing to Takalarup Rd bridge

King/Kalgan Catchment Area 1:50,000 20.2.1991 Job no. 900575

WA2957	Run 2	Numbers 5059-5061
WA2957	Run 1	Numbers 5079-5080

Section 4: Takalarup Rd bridge to Chester Pass Rd bridge

Mt. Barker 1:250,000 1:50,000 8.12.85 Job no. 830481

WA2368	Run 9	Number 5049

Sections 5 and 6: Chester Pass Rd bridge to the end of the study area

Mt. Barker 1:250,000 1:50,000 8.12.85 Job no. 830481

WA2368	Run 8	Numbers 5016-22

Appendix 2: Recommended books and other literature on bush management and native vegetation rehabilitation

Bradley, J. 1991. Bringing Back the Bush. The Bradley Method of Bush Regeneration. Ure Smith Press, NSW.

Buchanan, R. A. 1989. Bush Regeneration: Recovering Australian Landscapes. TAFE Student Learning Publications, NSW.

Heinjus, D. 1992. Farm Tree Planting. Inkata Press, South Australia.

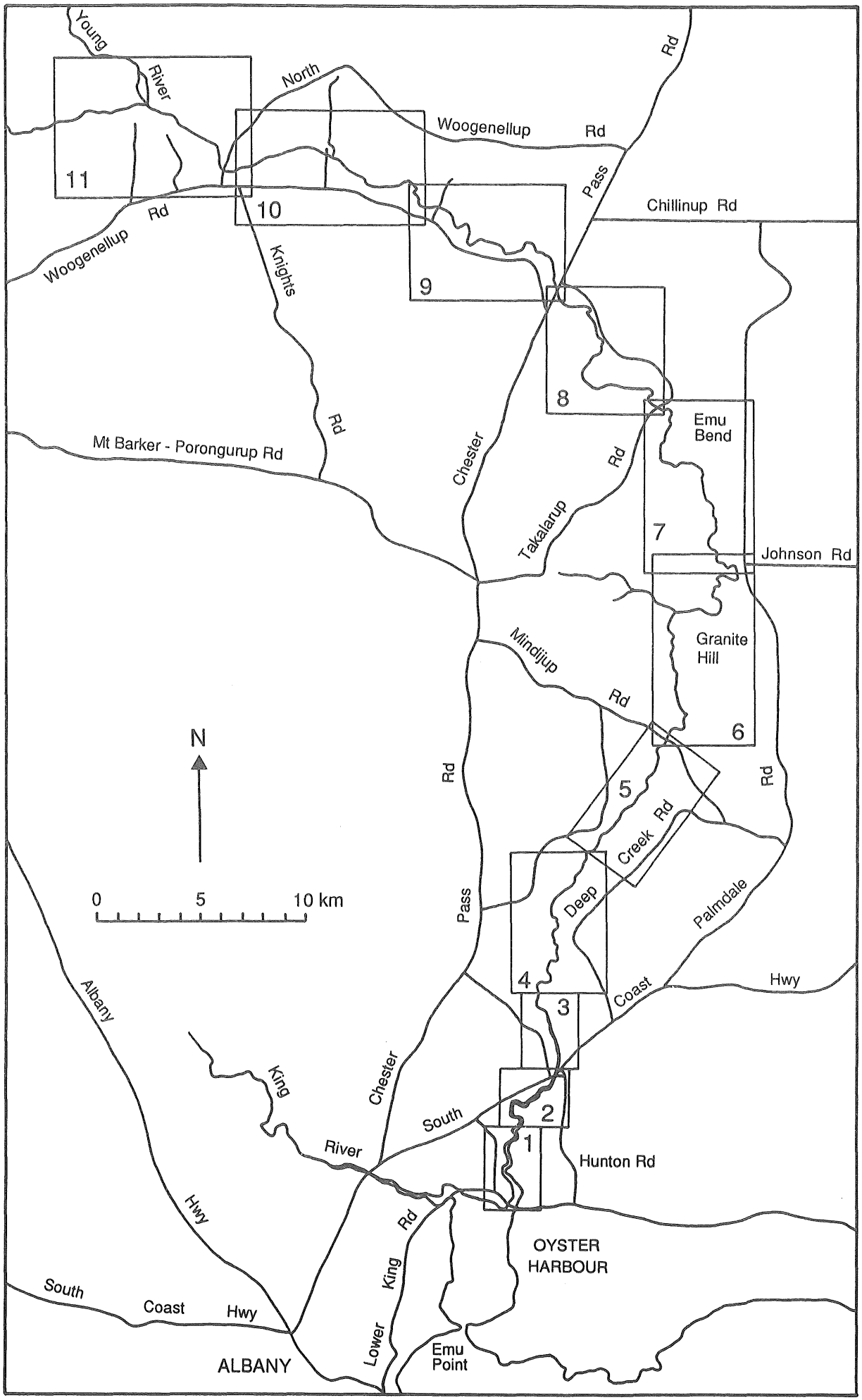
Hussey, B. M. J. and Wallace, K. J. 1993. Managing Your Bushland. Department of Conservation and Land Management.

Jones, D. and Elliot, R. 1990. Pests, Diseases and Ailments of Australian Plants. Lothian Publishing Company, Melbourne.

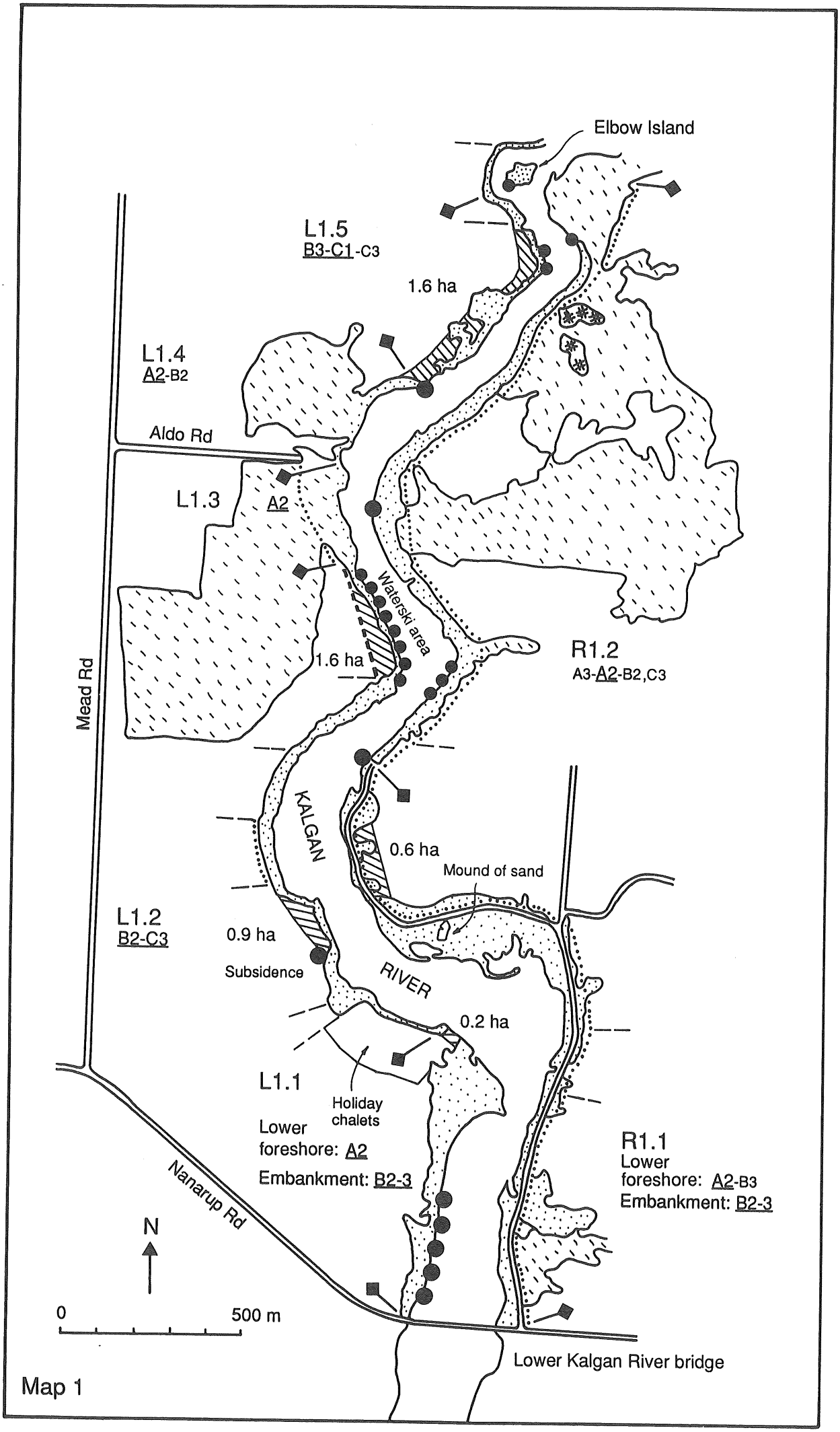
Main Roads Department. Summary of direct seeding techniques. Albany division of the Main Roads Department.

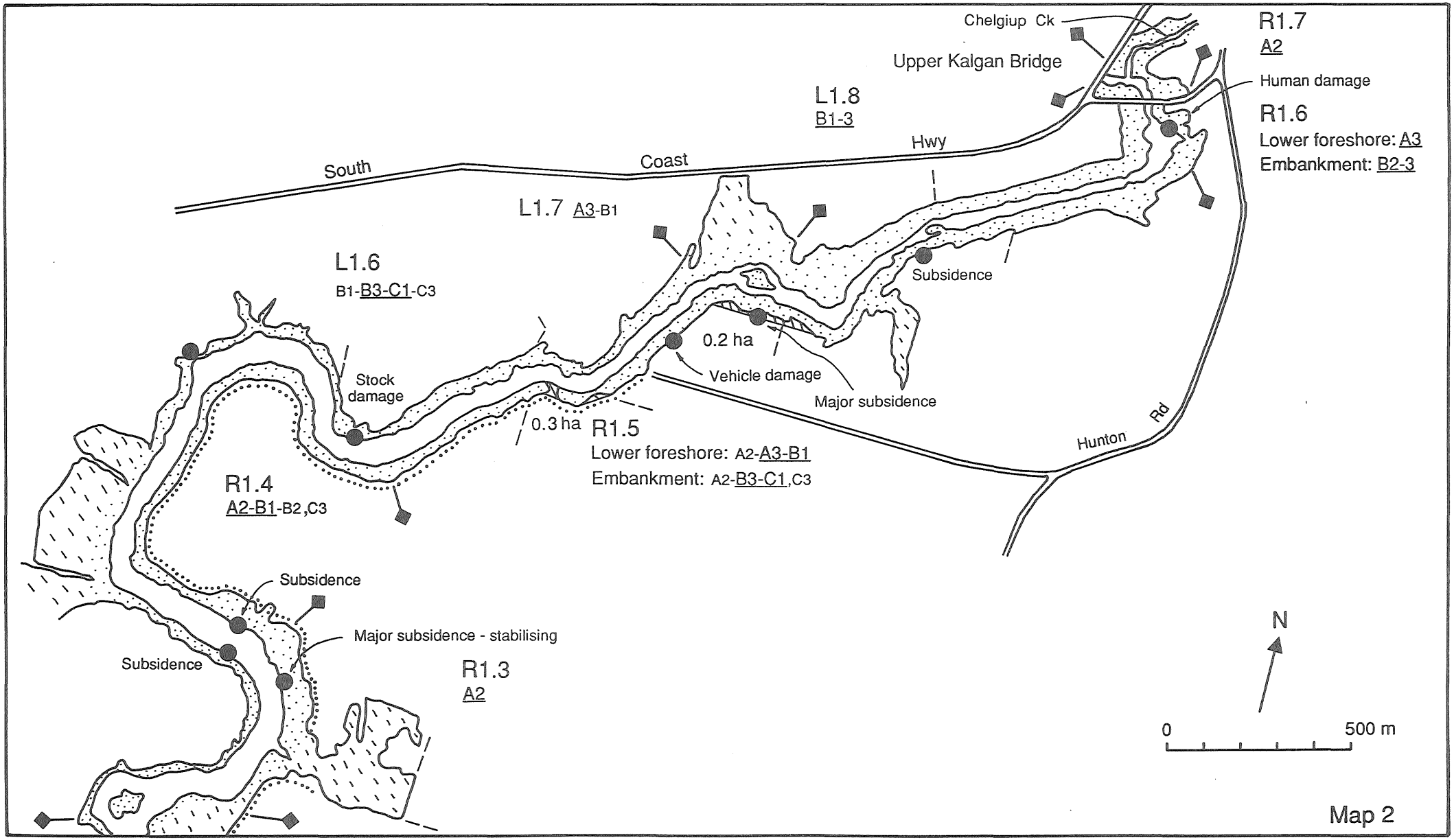
Native Seed Collection and Storage. Information Sheet No. 5, Department of Conservation and Land Management, Perth 1987.

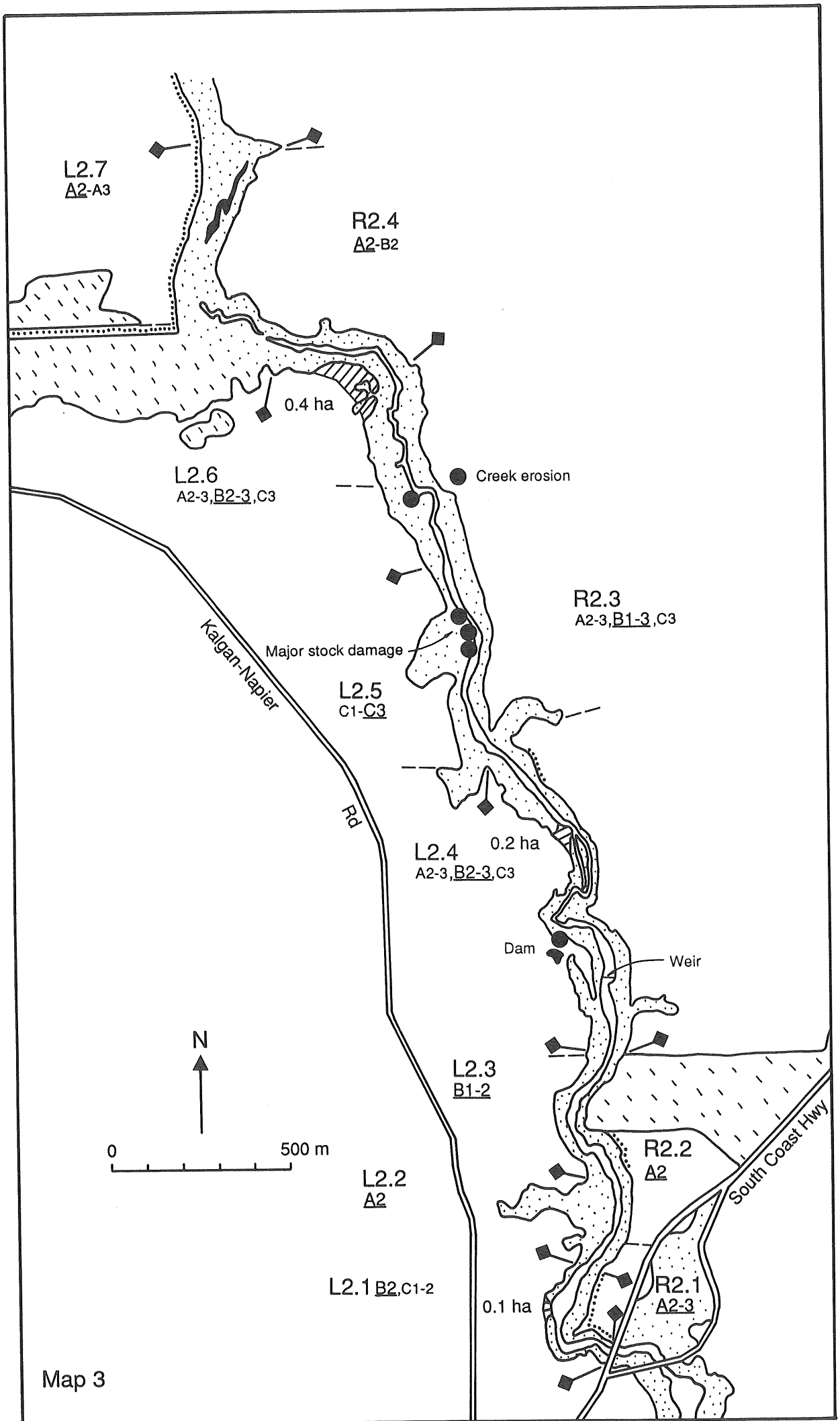
Powell, R. 1990. Leaf and Branch: Trees and Shrubs of Perth. Department of Conservation and Land Management.


Young
River
North
Woogenellup
Rd
Rd
11
10
9
8
7
6
5
4
3
2
1
Pass
Chillinup Rd
Woogenellup Rd
Knights Rd
Mt Barker - Porongurup Rd
Chester Pass Rd
Takalarup Rd
Emu Bend
Johnson Rd
Granite Hill
Mindijup Rd
N
0
5
10 km
Deep Creek Rd
Palmdale
Albany Hwy
Coast Hwy
King River
South
Hunton Rd
OYSTER HARBOUR
King Lower Rd
South Coast Hwy
ALBANY
Emu Point

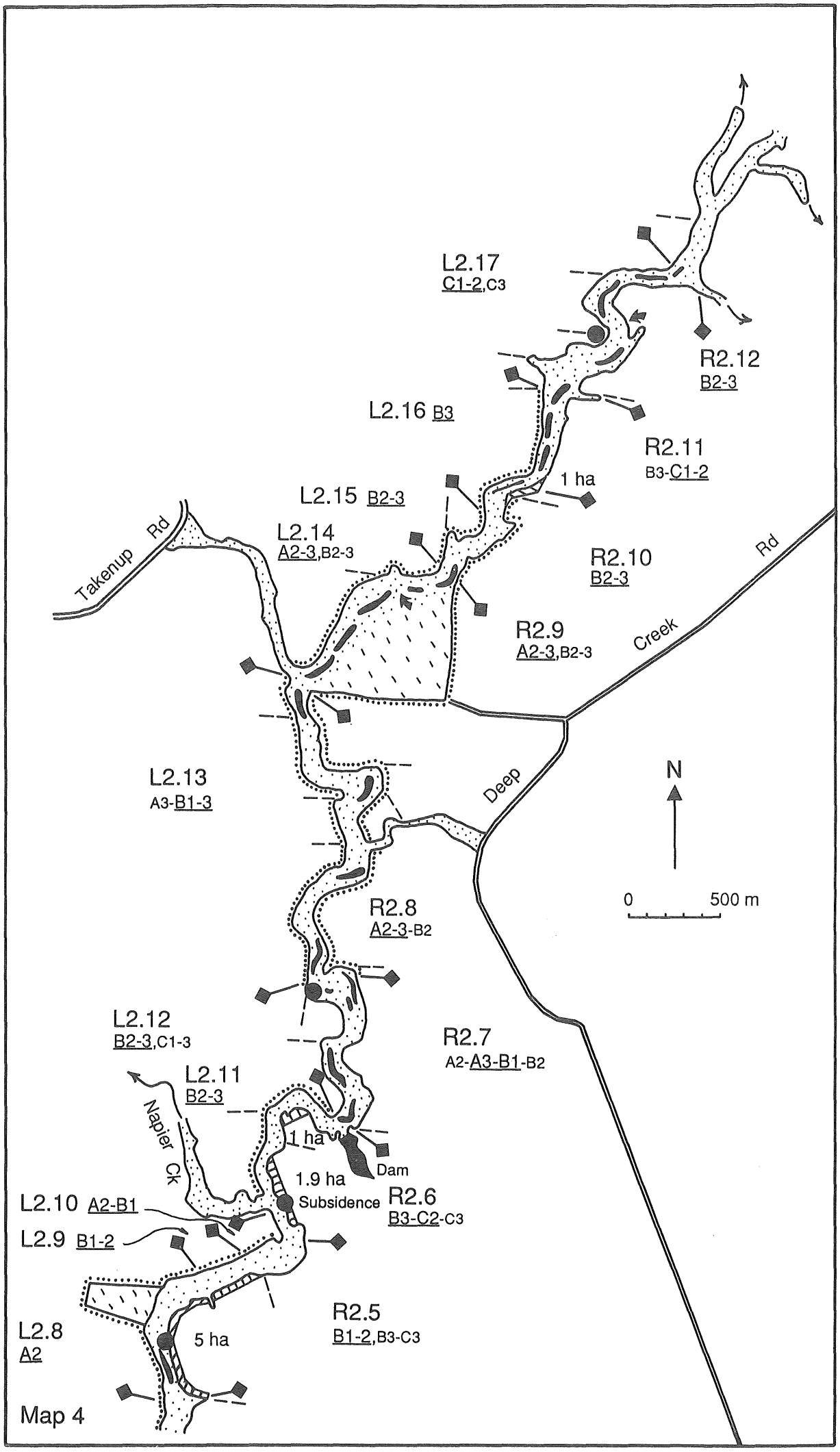
MAP INDEX

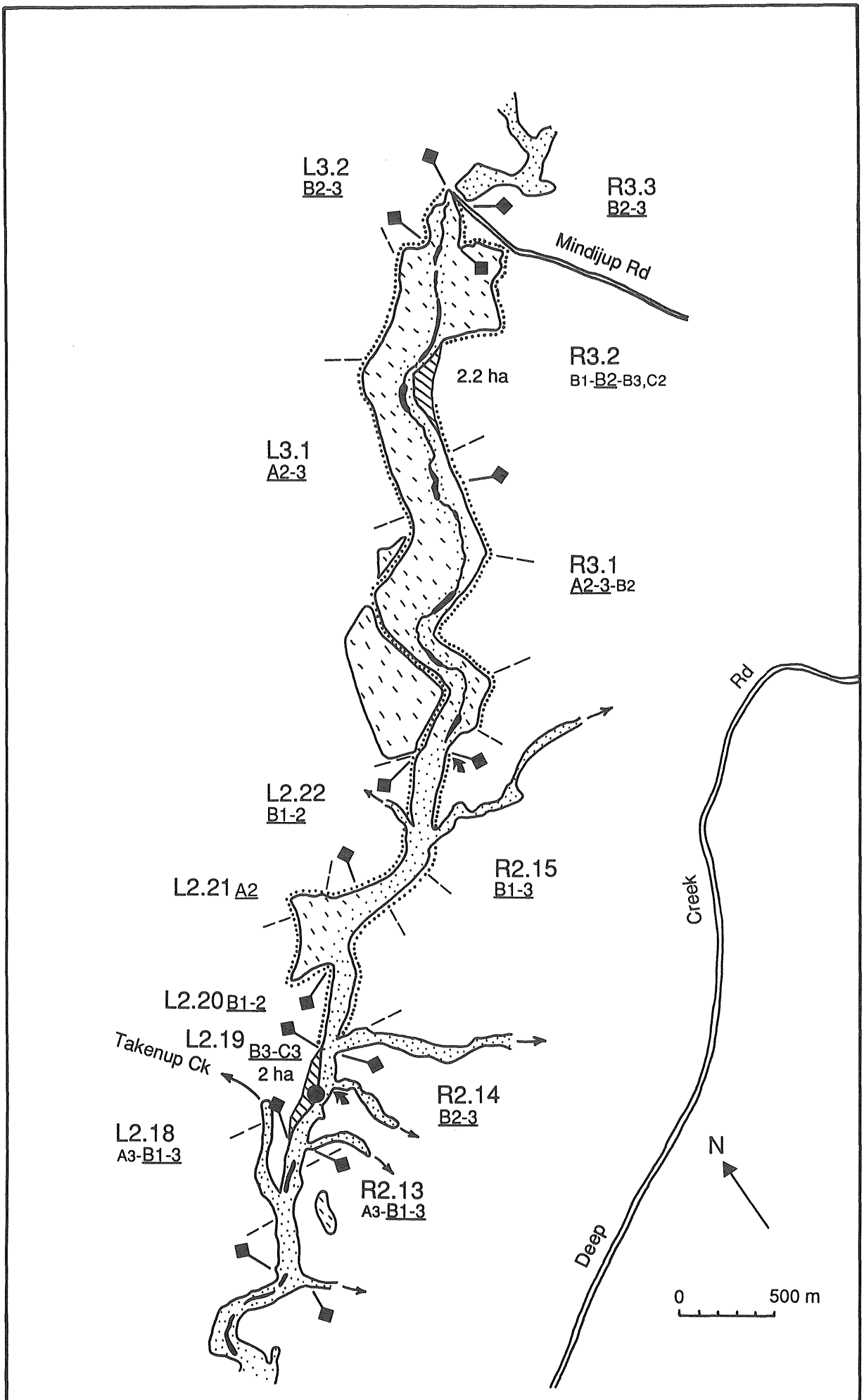

Elbow Island
L1.5
B3-C1-C3
1.6 ha
L1.4
A2-B2
Aldo Rd
L1.3
A2
Waterski area
1.6 ha
R1.2
A3-A2-B2,C3
Mead Rd
KALGAN
0.6 ha
Mound of sand
L1.2
B2-C3
0.9 ha
Subsidence
RIVER
0.2 ha
L1.1
Holiday chalets
Lower foreshore: A2
Embankment: B2-3
R1.1
Lower foreshore: A2-B3
Embankment: B2-3
Nanarup Rd
N
0
500 m
Lower Kalgan River bridge
Map 1


Chelgiup Ck
R1.7
A2
Upper Kalgan Bridge
Human damage
L1.8
B1-3
R1.6
Lower foreshore: A3
Embankment: B2-3
Hwy
South
Coast
L1.7 A3-B1
L1.6
B1-B3-C1-C3
Subsidence
0.2 ha
Vehicle damage
Major subsidence
Stock damage
0.3 ha
R1.5
Lower foreshore: A2-A3-B1
Embankment: A2-B3-C1,C3
Hunton Rd
R1.4
A2-B1-B2,C3
Subsidence
Major subsidence - stabilising
Subsidence
R1.3
A2
N
0
500 m
Map 2

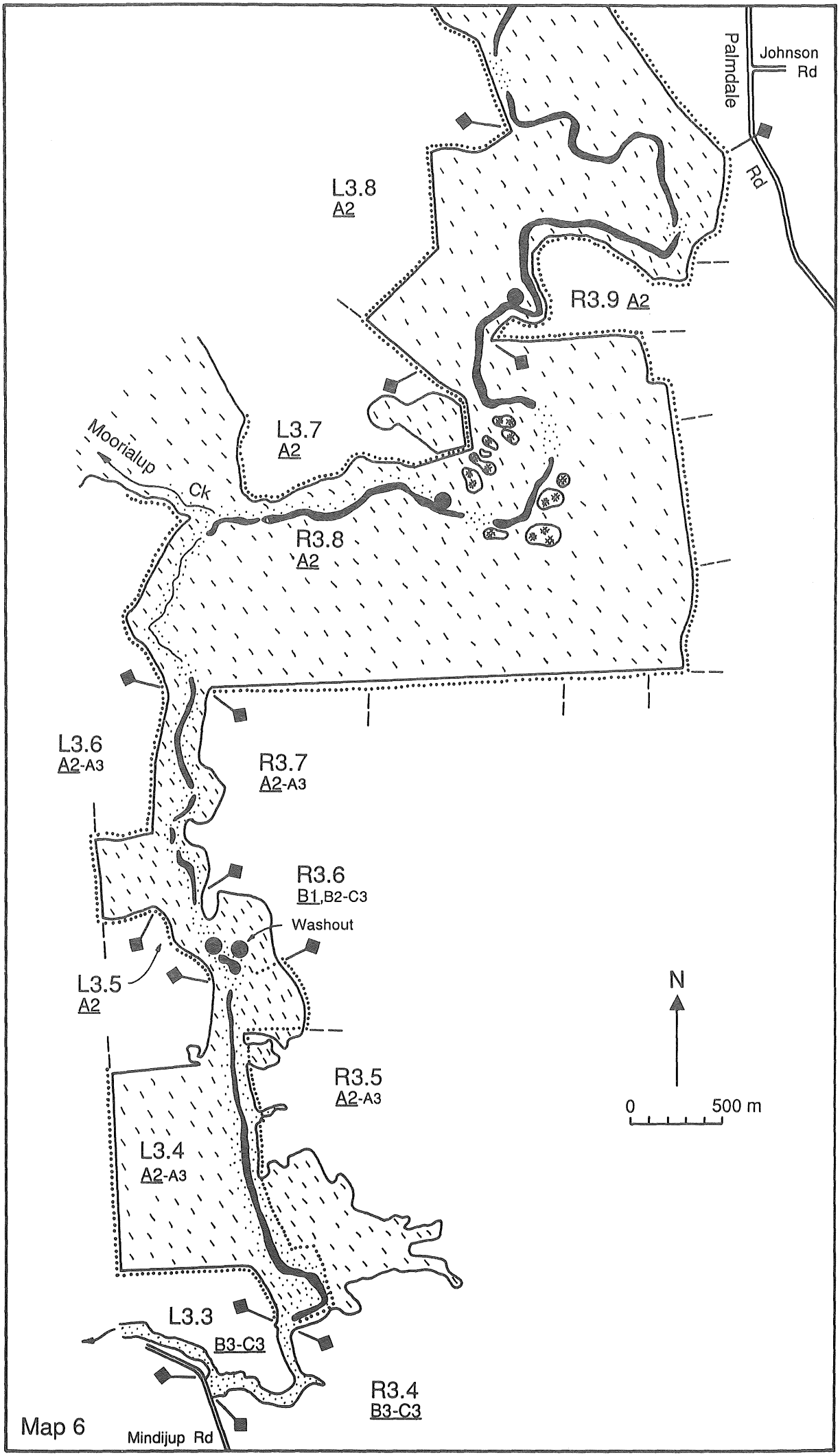

L2.7
A2-A3
R2.4
A2-B2
0.4 ha
L2.6
A2-3,B2-3,C3
Creek erosion
R2.3
A2-3,B1-3,C3
Major stock damage
Kalgan-Napier
Rd
L2.5
C1-C3
L2.4
A2-3,B2-3,C3
0.2 ha
Dam
Weir
N
0
500 m
L2.3
B1-2
R2.2
A2
South Coast Hwy
L2.2
A2
L2.1 B2,C1-2
0.1 ha
R2.1
A2-3

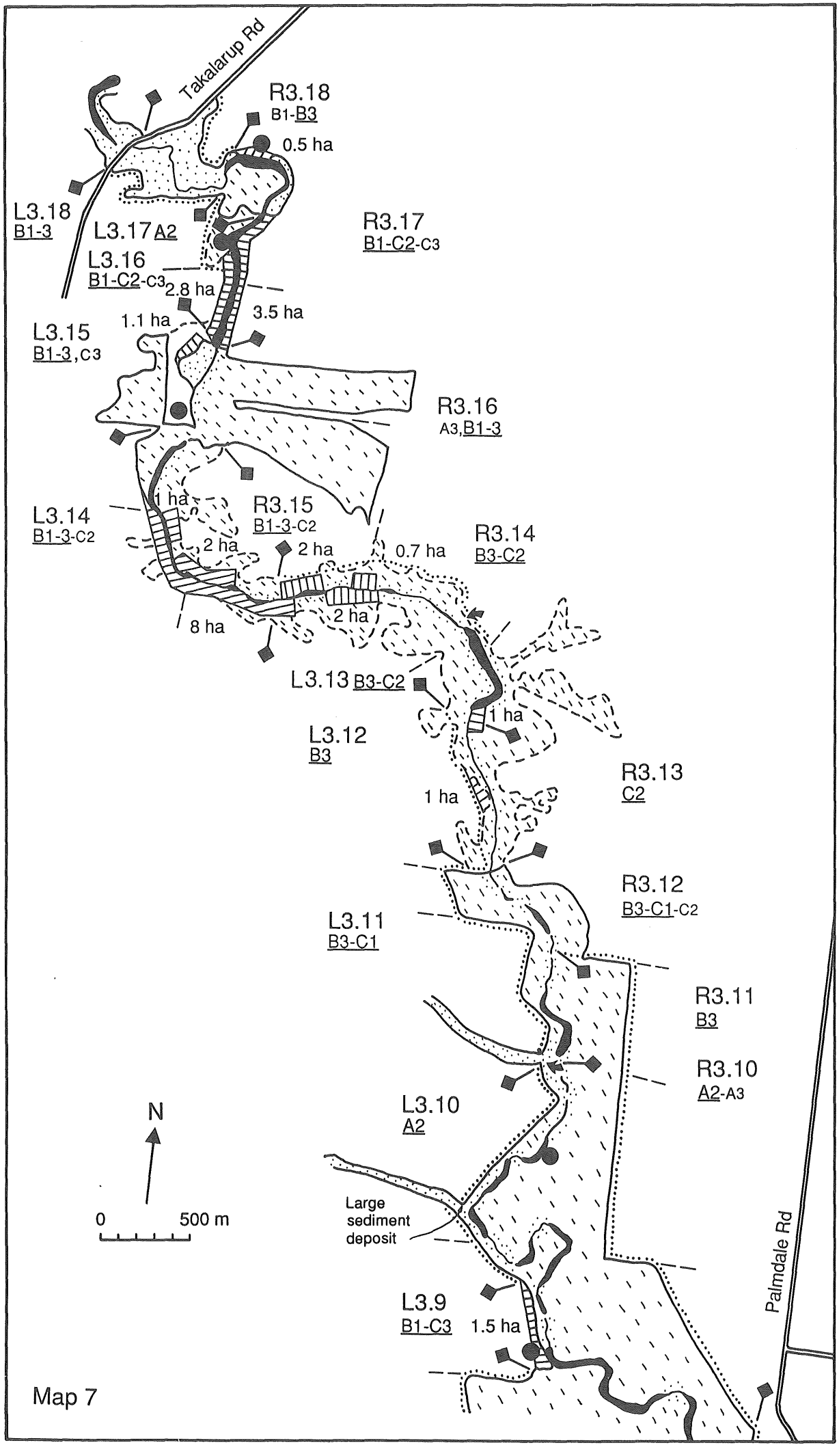
Map 3


L2.17
C1-2,C3
R2.12
B2-3
L2.16 B3
R2.11
B3-C1-2
1 ha
L2.15 B2-3
L2.14
A2-3,B2-3
R2.10
B2-3
Takenup Rd
Rd
R2.9
A2-3,B2-3
Creek
Deep
N
L2.13
A3-B1-3
0
500 m
R2.8
A2-3-B2
L2.12
B2-3,C1-3
R2.7
A2-A3-B1-B2
L2.11
B2-3
Napier Ck
1 ha
Dam
1.9 ha
Subsidence
L2.10 A2-B1
R2.6
B3-C2-C3
L2.9 B1-2
R2.5
B1-2,B3-C3
L2.8
A2
5 ha
Map 4

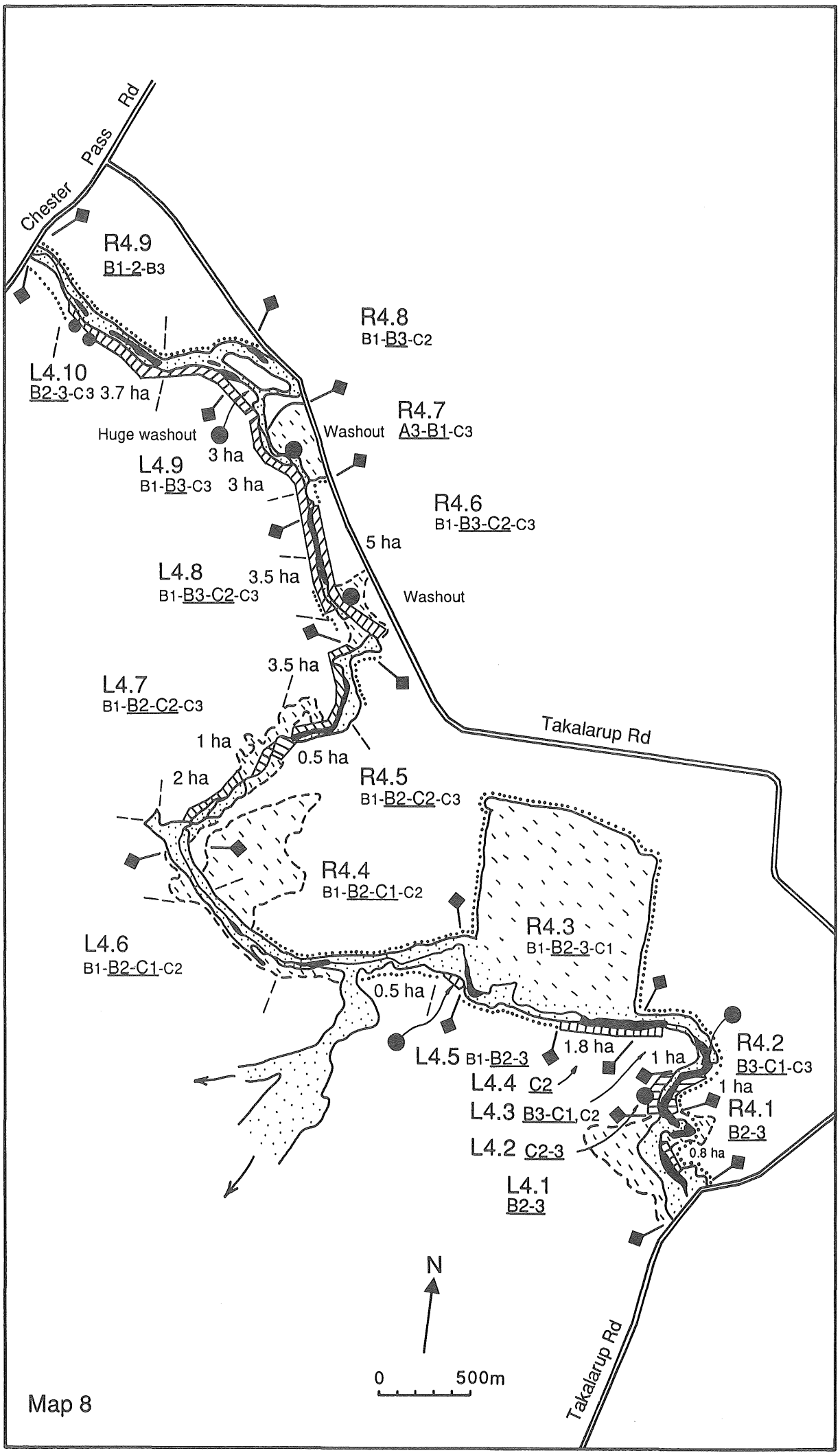

L3.2
B2-3
R3.3
B2-3
Mindijup Rd
R3.2
B1-B2-B3,C2
2.2 ha
L3.1
A2-3
R3.1
A2-3-B2
L2.22
B1-2
R2.15
B1-3
L2.21 A2
L2.20 B1-2
L2.19 B3-C3
2 ha
Takenup Ck
R2.14
B2-3
L2.18
A3-B1-3
R2.13
A3-B1-3
Rd
Creek
Deep
N
0
500 m

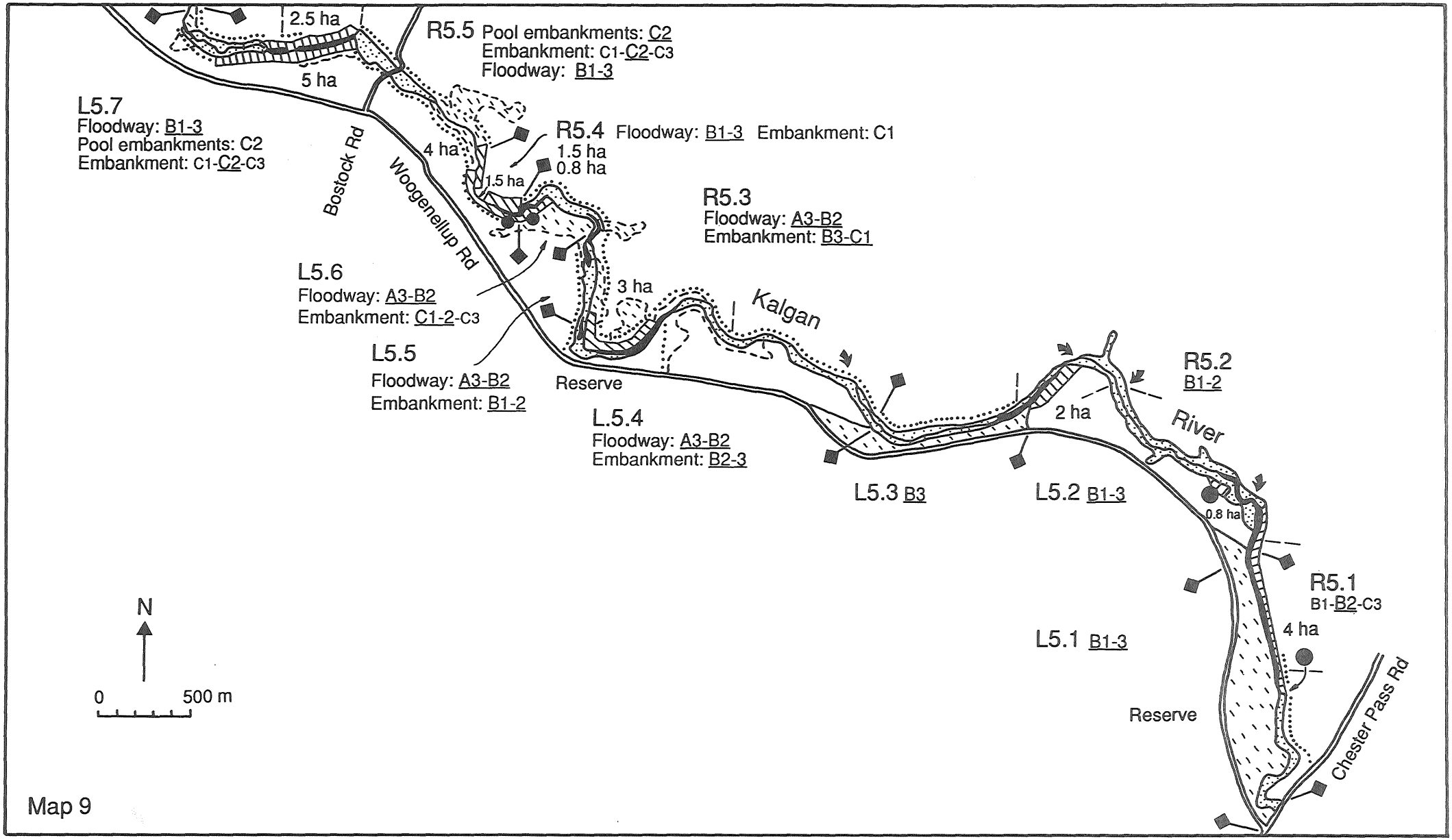
Map 5

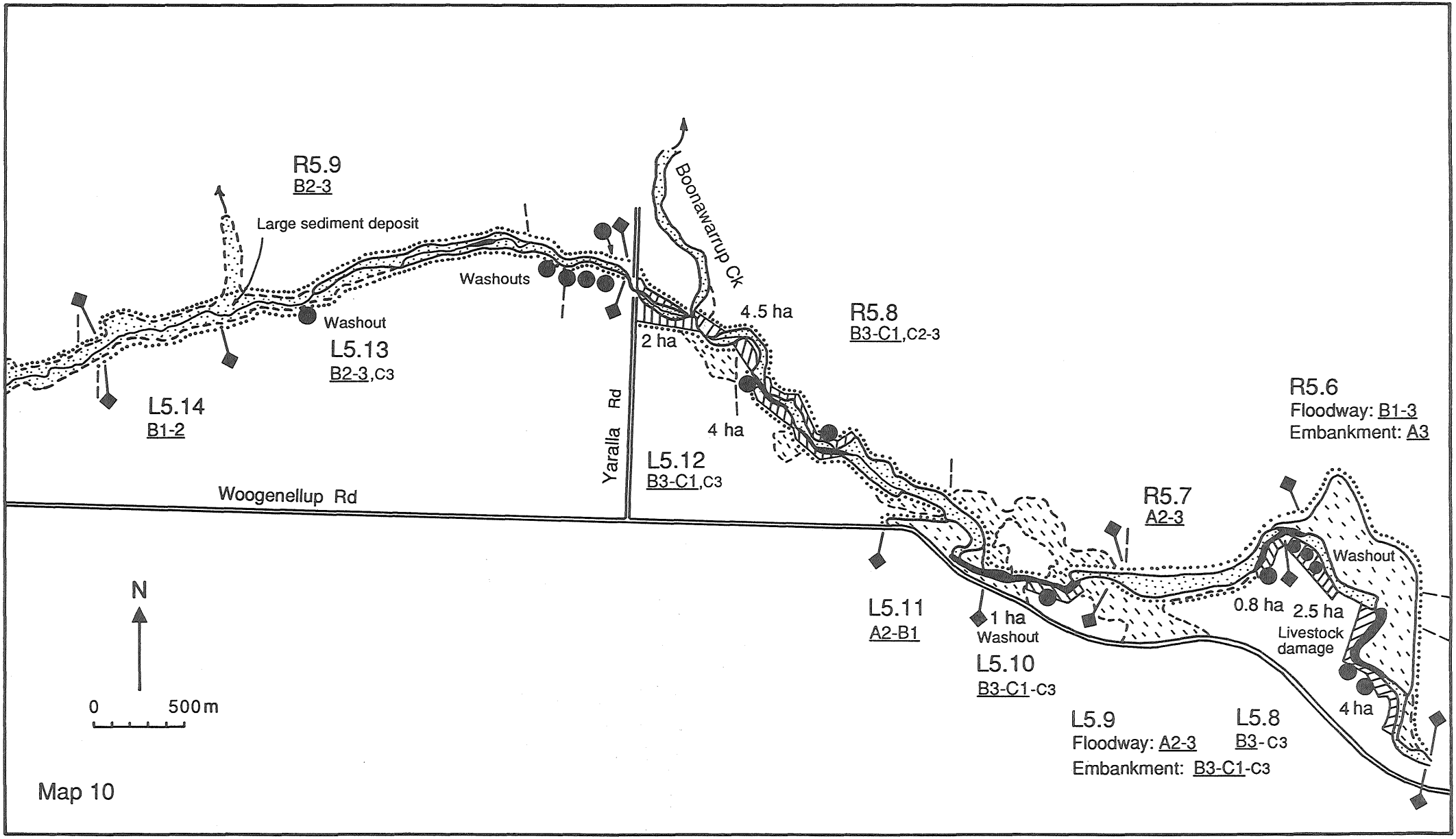

Palmdale Rd
Johnson Rd
L3.8
A2
R3.9 A2
L3.7
A2
Moorialup Ck
R3.8
A2
L3.6
A2-A3
R3.7
A2-A3
R3.6
B1,B2-C3
Washout
L3.5
A2
R3.5
A2-A3
L3.4
A2-A3
L3.3
B3-C3
R3.4
B3-C3
Mindijup Rd
N
0
500 m
Map 6

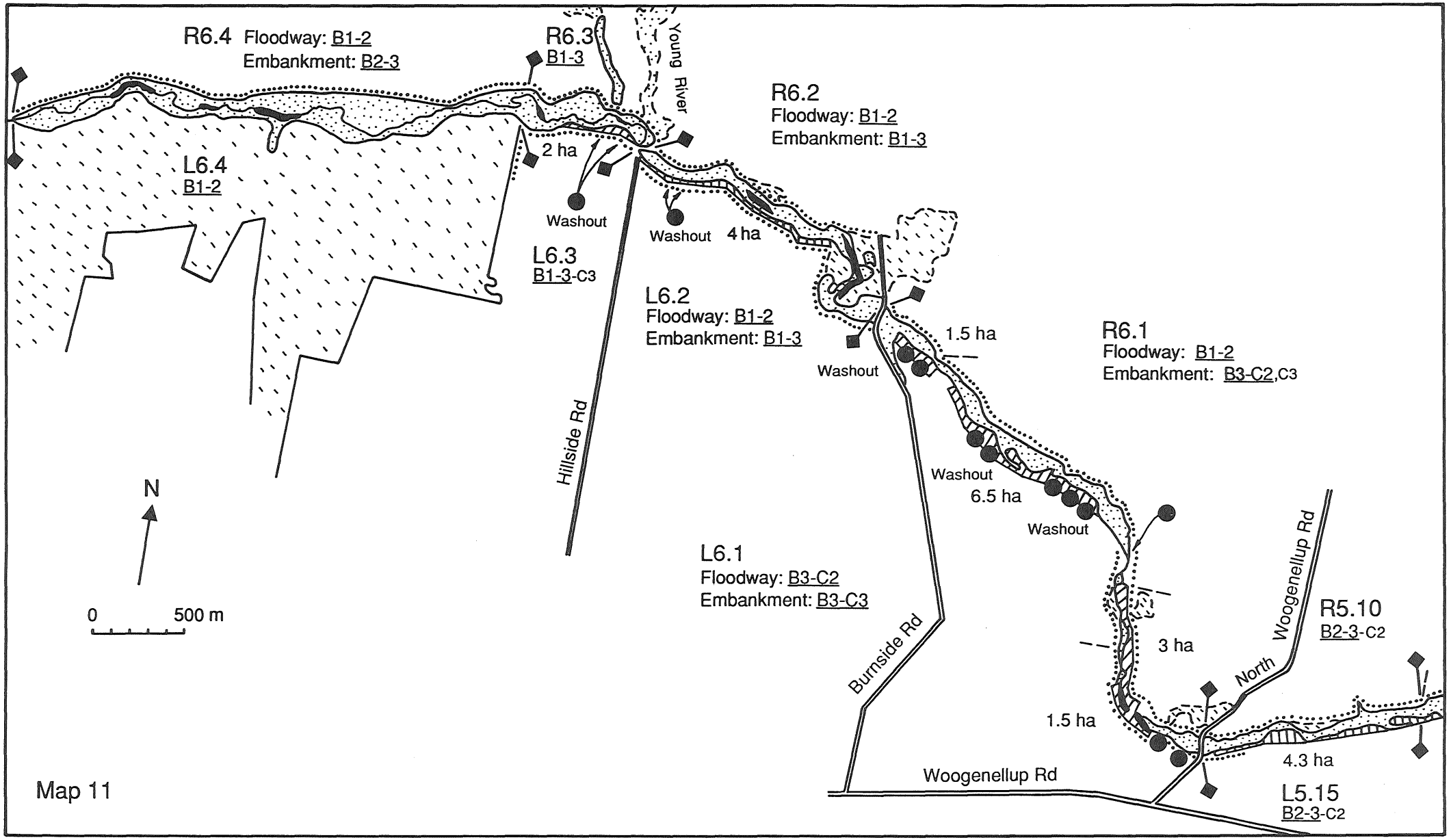

Takalarup Rd
R3.18
B1-B3
0.5 ha
L3.18
B1-3
L3.17 A2
R3.17
B1-C2-C3
L3.16
B1-C2-C3
2.8 ha
3.5 ha
1.1 ha
L3.15
B1-3, C3
R3.16
A3, B1-3
1 ha
R3.15
B1-3-C2
L3.14
B1-3-C2
2 ha
2 ha
0.7 ha
R3.14
B3-C2
2 ha
8 ha
L3.13 B3-C2
1 ha
L3.12
B3
R3.13
C2
1 ha
R3.12
B3-C1-C2
L3.11
B3-C1
R3.11
B3
R3.10
A2-A3
L3.10
A2
N
0
500 m
Large
sediment
deposit
L3.9
B1-C3
1.5 ha
Palmdale Rd

Map 7

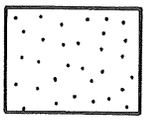

Chester Pass Rd
R4.9
B1-2-B3
R4.8
B1-B3-C2
L4.10
B2-3-C3 3.7 ha
R4.7
A3-B1-C3
Huge washout
3 ha
Washout
L4.9
B1-B3-C3 3 ha
R4.6
B1-B3-C2-C3
5 ha
L4.8
B1-B3-C2-C3
3.5 ha
Washout
3.5 ha
L4.7
B1-B2-C2-C3
Takalarup Rd
1 ha
0.5 ha
2 ha
R4.5
B1-B2-C2-C3
R4.4
B1-B2-C1-C2
R4.3
B1-B2-3-C1
L4.6
B1-B2-C1-C2
0.5 ha
L4.5 B1-B2-3
1.8 ha
1 ha
R4.2
B3-C1-C3
L4.4 C2
1 ha
L4.3 B3-C1,C2
R4.1
B2-3
L4.2 C2-3
0.8 ha
L4.1
B2-3
N
0
500m
Takalarup Rd
Map 8


2.5 ha
R5.5 Pool embankments: C2
Embankment: C1-C2-C3
Floodway: B1-3
5 ha
L5.7
Floodway: B1-3
Pool embankments: C2
Embankment: C1-C2-C3
Bostock Rd
Woogenellup Rd
4 ha
1.5 ha
R5.4 Floodway: B1-3 Embankment: C1
1.5 ha
0.8 ha
R5.3
Floodway: A3-B2
Embankment: B3-C1
L5.6
Floodway: A3-B2
Embankment: C1-2-C3
3 ha
Kalgan
L5.5
Floodway: A3-B2
Embankment: B1-2
Reserve
L.5.4
Floodway: A3-B2
Embankment: B2-3
R5.2
B1-2
2 ha
River
L5.3 B3
L5.2 B1-3
0.8 ha
R5.1
B1-B2-C3
4 ha
L5.1 B1-3
Reserve
Chester Pass Rd
N
0
500 m
Map 9

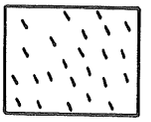

R5.9
B2-3
Large sediment deposit
Washouts
Washout
L5.13
B2-3,C3
L5.14
B1-2
Boonawarrup Ck
4.5 ha
R5.8
B3-C1,C2-3
2 ha
Yaralla Rd
4 ha
L5.12
B3-C1,C3
Woogenellup Rd
R5.6
Floodway: B1-3
Embankment: A3
R5.7
A2-3
Washout
0.8 ha
2.5 ha
Livestock damage
L5.11
A2-B1
1 ha
Washout
L5.10
B3-C1-C3
4 ha
L5.9
Floodway: A2-3
Embankment: B3-C1-C3
L5.8
B3-C3
N
0
500m
Map 10


R6.4 Floodway: B1-2
Embankment: B2-3
R6.3
B1-3
Young River
R6.2
Floodway: B1-2
Embankment: B1-3
L6.4
B1-2
2 ha
Washout
L6.3
B1-3-C3
Washout
4 ha
L6.2
Floodway: B1-2
Embankment: B1-3
1.5 ha
Washout
R6.1
Floodway: B1-2
Embankment: B3-C2,C3
Hillside Rd
Washout
6.5 ha
Washout
N
0
500 m
L6.1
Floodway: B3-C2
Embankment: B3-C3
Burnside Rd
Woogenellup Rd
3 ha
North
Woogenellup Rd
R5.10
B2-3-C2
1.5 ha
4.3 ha
Woogenellup Rd
L5.15
B2-3-C2
Map 11

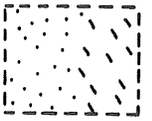
LEGEND



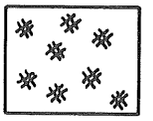
Fringing vegetation



Adjoining remnant bush



Vegetation with open tree canopy



Granite outcropping

Point of severe erosion or subsidence

River pool

Fencing at time of survey

Known new fencing since survey

Subsection delineation marker

Paddock boundary at river

0.6 ha

Area needing vegetation rehabilitation (eg 0.6 ha)

A1-A2-3,B1

Foreshore condition (eg Mainly A2-3, extending to A1 and with some B1)

River crossing point