WEEDS OF NATIONAL SIGNIFICANCE

WILLOW

(*Salix taxa,* excluding *S. babylonica, S.* x *calodendron* and *S.* x *reichardtii*)

Strategic Plan

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Supporting information about the National Weeds Strategy, Weeds of National Significance and progress to date may be found at www.weeds.org.au where links and downloads provide contact details for all species, their management committees and copies of the strategy.

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EXECUTIVE SUMMARY

Willows (*Salix* – with some 32 naturalised taxa, including primary hybrids) are amongst the worst riparian and wetland weeds in temperate Australia. All taxa (except *S. babylonica, S.* x *calodendron* and *S.* x *reichardtii*) are Weeds of National Significance. These trees and shrubs were deliberately introduced in the 1800s and 1900s for a range of purposes, notably basket-making materials, cricket bat production, stream stabilisation, ornament and shelter. Willows continue to be predominantly used for a range of purposes, including stream stabilisation. Over 45 taxa are available in the nursery trade. Willows now occupy thousands of kilometres of streams, and numerous off-stream wetlands, from sea level to alpine locations. Victoria, Tasmania, New South Wales and the Australian Capital Territory have the largest current infestations, but only a fraction of potential habitat has been occupied in Australia. Dispersal is by vegetative means (fragmented stems) and by seed; production of wind-borne seed enables willows to be dispersed great distances and these species threaten most temperate, non-saline wetlands. Willows threaten to destroy biodiversity and the amenity values of invaded sites, and have already caused massive alterations to streams with blockages, increased flooding, erosion and channel realignments as well as destruction of infrastructure. They also have high water use. Millions of dollars are annually spent on willow control using chemical and/or mechanical techniques in south-eastern Australia. Mechanical and chemical control techniques are well understood and willows are relatively easy to kill. However, continuing follow-up control for at least three years is essential. Biological control offers considerable potential and a review of potential agents (invertebrates and pathogens) recently commenced in Victoria.

Major challenges for effective management of willows include: preventing entry of additional willows into Australia, and trade within Australia; regulating industries utilising willows with appropriate management protocols; replacing willows used for stream stabilisation with indigenous species; on-ground management of willow infestations; prevention of spread of key taxa; and development of biological control. This strategy was developed in consultation with representatives from government, catchment and conservation management agencies, industry groups, private consultants and community groups.

The vision of the strategy is:

To stop willows destroying our waterways and wetlands.

The strategy aims to deliver four primary outcomes:

1 Stop further spread of willows

- Set priorities for management of vulnerable areas currently uninfested by willows
- Ensure early detection of ‘dangerous’ situations and new willow outbreaks and develop rapid response mechanisms to deal with these
- Identify and address legislative barriers to effective control
- Evaluate the weed potential of non-naturalised cultivated willows
- Stop further planting of invasive willows
- Identify plant species, and ‘safe’ willows with similar beneficial functions, to replace willows
- Develop and implement sound on-ground management strategies at local level to prevent further spread
- Change attitudes and behaviour of public to prevent buying and planting of willows
- Stop importation of Salix taxa at national level

2 Manage the existing areas of willows

- Map infestations of the most serious willows
- Develop regional plans based on generic willow management model
- Assess and improve methods of control
- Establish and apply best-practice guidelines for willow management
- Develop and implement protocols for managing commercial willow plantations
- Control invasive willow species

3 Gain community support in managing the willow problem

- Highlight the nature and national significance of the willow problem
- Report on the outcomes and progress of the Willow Strategic Plan
- Present and implement solutions to the willow problem
- Attract sponsors/partners to promote and help fund management actions
- Coordinate and facilitate the dissemination of information relating to willows and their management

THE CHALLENGE

Willows (*Salix* spp.) are among the worst weeds of temperate Australian streams and wetlands. There are 32 willow taxa (species, varieties, subspecies and primary hybrids) naturalised in Australia, mostly in Victoria, Tasmania and New South Wales, with relatively minor occurrences in Queensland, South Australia and Western Australia. They have received national attention because of their impacts on stream and wetland hydrology, as well as biodiversity. In streams, willows cause channel diversion, soil or bank erosion, loss of stream capacity, stream obstruction, increased flooding and loss of infrastructure (eg bridges). Willows can degrade water quality and stream health. Losses to biodiversity have been very significant and are potentially catastrophic. Willows also seriously reduce amenity values of streams for canoeists, the fishing community, and other stream users.

Willows are either male or female and most taxa in Australia are single-sex clones. However, they are highly promiscuous and readily hybridise when opposite sexes come together. While most willow reproduction has been vegetative – by fragmentation or breaking of twigs and branches which rapidly root in water – reproduction by seed is increasingly common, and is the predominant means of proliferation for several species (particularly *S. cinerea* and *S. nigra*). For species that reproduce vegetatively, invasions are confined to riparian zones; willow fragments can be transported many kilometres. Taxa that reproduce by seed are capable of transport by wind over many kilometres. These species show a great ability to invade off-stream wetlands, from sea level to alpine locations.

The extent of willow infestation in Australia has not been fully documented. They have invaded thousands of kilometres of riparian environments and perhaps only 5% of their potential range has been invaded. Invasion of off-stream wetlands is relatively minor to date, but all non-saline wetlands in temperate Australia are vulnerable. Of the naturalised willows, some are of little significance, some are relatively benign, while others are highly invasive. The most seriously invasive willow (*S. cinerea*) is expanding its range exponentially in Victoria and New South Wales, and perhaps in Tasmania.

Annual costs of willow management to reduce flooding and related hydrological impacts by river management authorities has been calculated at $2,000,000 per annum in Victoria; while in Tasmania, a large proportion of the current $2,000,000 Rivercare grants are for willow removal. The environmental costs – to biodiversity and other natural values – are immense but poorly quantified or documented. Willow invasion is currently known to threaten plant and animal species and vegetation communities on public (local, regional, state and national) and private lands.

Unless effective management is mobilised, willows will continue to have highly adverse environmental impacts, and these will rapidly increase in scope and intensity. Once degraded, many ecosystems will not be recoverable; in many cases degradation and biodiversity loss is effectively irreversible. The tasks of management, however, are compounded by the economic and social significance of willows, as well as the potentially adverse impacts of wholesale willow removal on stream stability and other utilitarian values. A balance must be struck between the desirability of broad-scale willow removal, and retention for other values conferred by willows in defined situations. Certain willow taxa (eg weeping willows) must be tolerated in particular contexts and managed accordingly. In other situations (eg conservation areas) no level of willow invasion can be tolerated and it is desirable to aim for broad-scale elimination.

Prevention of spread of vegetatively reproducing willows is relatively easy as they are confined to streams and are dispersed downstream. For seeding willows, prevention of spread is extremely difficult because seed can be dispersed for tens or even hundreds of kilometres. Recruitment and growth can be very rapid and seed production is immense. Early detection and control is essential to prevent the development of new infestations. Co-

operation is also essential at a national level between the States and interest groups, eg. the horticultural and cricket bat industries. Prevention of willow importations, a responsibility of the Australian Quarantine Inspection Service, needs to be maintained, except for defined sterile or, in some cases, male clones.

Willow control generally embraces a combination of chemical and mechanical control methods. Biological control of willows using insects and pathogens has enormous scope, as no members of the willow family (Salicaceae) are native to Australia. Potential impacts on non-target willows (eg. cricket bat and ornamental willows) need evaluation. Depending on the specific site issues, willow control could be a combination of biological control with other traditional methods, mechanical or chemical controls.

Integrated management of willows needs to be approached with the recognition of limited resources, the varied impacts of differing willow taxa, the benefits of some willows, and potential alternatives for utilitarian purposes. Considerably more information on the extent, rate of spread and impacts of certain willows is essential, notably the seeding willows (*S. cinerea, S. nigra* and *S. purpurea)*.

Implementation of the *Willow Strategic Plan* will result in containing the spread of key willow taxa and minimising the environmental, economic and social impacts of infestations in Australia.

1 BACKGROUND

Willows (*Salix* taxa, family Salicaceae) are Weeds of National Significance because they have major negative impacts on stream flow and hydrology, on infrastructure resulting from obstructed waterways, amenities, and biodiversity. Invading willows eliminate indigenous riparian, wetland and associated dryland vegetation as well as faunal habitats by the formation of dense, continuous, light-intercepting canopies; and negatively impact stream health and water quality by producing pulses of deciduous leaves in the waterway. However, three willows have been exempted, *S. babylonica, S.* x *calodendron* and *S*. x *reichardtii*[+].

Figures 1 and 2 show the current and potential distribution of willow in Australia as used in the determination of weeds of national significance by Thorp and Lynch (2000)

Willows have so far occupied a fraction of their potential geographic range in temperate Australia at all altitudes. Victoria has the largest number of naturalised willow taxa and the most extensive invasions. New South Wales, the ACT, and Tasmania also have extensive infestations, whilst South Australia, Queensland and Western Australia have relatively minor infestations. Most of temperate Australia is vulnerable to willow invasions, where hundreds of thousands of hectares of suitable habitat exist from sea level to high alpine environments.

As already mentioned in "The Challenge", the annual costs of willow management to reduce flooding and related hydrological impacts by river management authorities has been calculated at $2,000,000 p.a. in Victoria; while in Tasmania, a large proportion of the current $2,000,000 Rivercare grants are for willow removal. The environmental costs – to biodiversity and other natural values – are immense but poorly quantified or documented.

[+] exempt by State agreement under the National Weeds Strategy

1.1 The biology of willows

Willows are deciduous trees or shrubs naturally occurring in permanently or seasonally wet, inundated or waterlogged sites. Plants are usually either male or female; sometimes rarely both sexes are present in a single plant. Bee-pollinated flowers are borne in axillary catkins in spring. Some willows (*S. nigra*) can evidently change sex, first producing flowers of one sex then later flowers of the other sex. Many willows reproduce commonly or exclusively by vegetative means because suitable sex-clones are absent from the area.

Salix taxonomy is complicated but now reasonably understood in Australia. The genus contains 300-400 species and some 32 naturalised taxa (species, subspecies, varieties, primary hybrids and cultivars) are now recognised in Australia (Appendix 1). Some hybrids have been imported into Australia, while some have arisen *in situ* between cultivated and/or naturalised taxa. Additional hybrid combinations and hybrid swarms will likely be recorded with further fieldwork.

Willows flower in spring with variations of several weeks according to natural flowering-time differences, and local climatic variables. Flowering occurs briefly (two or three weeks), and seed ripens about 3-4 weeks later in late spring or early summer. The seed is small with long silky hairs attached to one end to aid in dispersal. Seed crops may be massive and dispersal is by wind or water, sometimes over scores or perhaps hundreds of kilometres.

Seed viability is extremely brief (about two weeks) and seeds need to lodge on suitable bare and wet soils or other substrates. Germination is extremely rapid, occurring within 24 hours. Seedling growth may be rapid where conditions are favourable. Willow recruitment by seed is not common because of the very short window of opportunity available for germination. The presence of viable seed and generally bare, wet soils are required for germination and subsequent establishment. Several species reproduce almost exclusively by seed (notably *S. cinerea* and *S. nigra*) or commonly as part

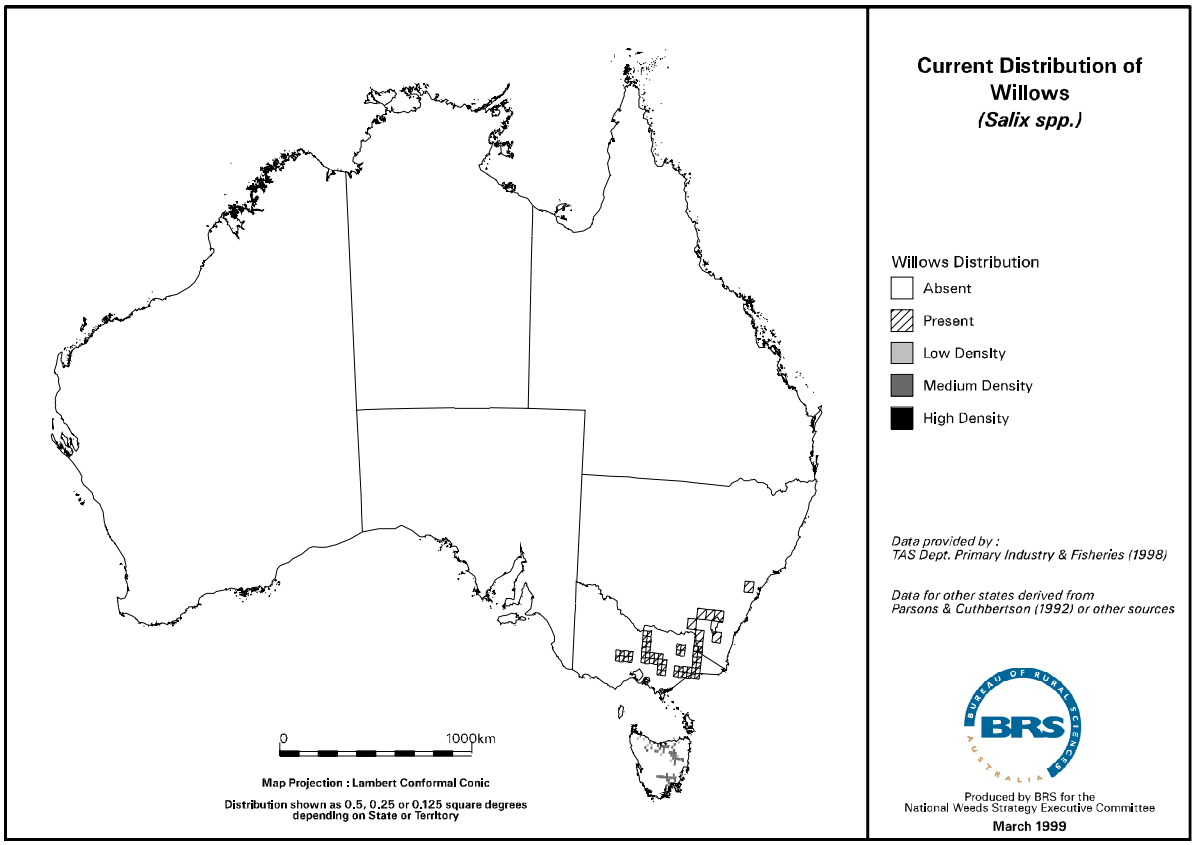

Figure 1 *The current distribution of willows (Thorp and Lynch* 2000)

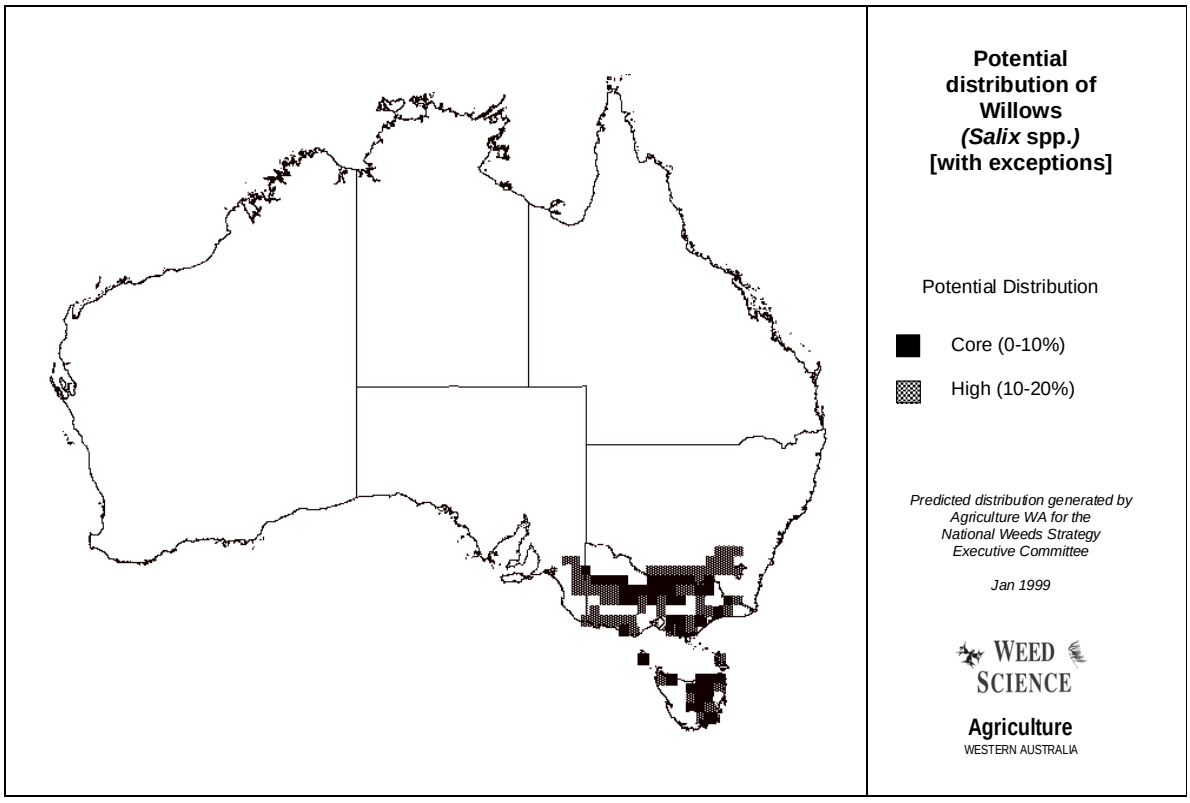

Figure 2 *The potential distribution of willows based on climate prediction (Thorp and Lynch 2000) showing the parts of Australia where the weed has the potential to become a major problem. Willows could grow outside the area indicated, but would be restricted to favourable microclimates.*

of a sexual and vegetative reproductive strategy.

Massed recruitment of willows by seed typically occurs on exposed wet sand, gravel or mud. In the Australian Alps *S. cinerea* probably recruits from wind-blown seed on sites following disturbance by cattle in alpine and subalpine bogs but disturbance is not a prerequisite for establishment.

Many taxa are present as one sex only or the populations throughout their range are predominantly of one sex (Appendix 2). Thus, many willow species reproduce solely, or predominantly by vegetative means, (i) by branches or twigs breaking off in winds, floods, etc., and rooting where they lodge in water, or on wet ground; and (ii) by trunks of willows collapsing whilst retaining their root system and rooting where they touch the soil (layering). New trunks then develop along the collapsed stems. In the former case dispersal in streams can occur progressively over very long distances, while in the latter, progression is very slow and these willows tend to form small stands only.

Willows characteristically form large, dense, thick root-mats on the surface of the substrate (soil, gravel, etc) either in shallow water or on wet sites.

The 'fragility' or brittleness of willows varies greatly and this is the single most important attribute conferring invasibility in species that reproduce predominantly by vegetative means. There is a direct correlation between 'fragility' and abundance: the most abundant willow in Victoria on streams, *S. fragilis* var. *fragilis*, is the most fragile, and reproduction in this taxon is largely vegetative.

Hybridisation is very common in *Salix* within the *Vetrix* and *Salix* subgenera, which are naturalised and widely planted. It seems that hybrids can occur between any *Salix* of the same subgenus provided flowering is simultaneous, they are within bee pollinating distance (generally 300 m but sometimes over much greater distances) and they have the same ploidy level. Many taxa in Australia are hybrids, some of which have arisen in Europe (and material then imported) and some of which have arisen in Australia (eg *Salix fragilis* var. *fragilis* x *S. nigra* and *S. nigra* x *S. matsudana* 'Tortuosa'). Some hybrids known in Europe have arisen independently in Australia between the same taxa. In very rare instances hybrids occur between the subgenera eg *S.* x *mollissima* (*S. triandra* x *S. viminalis*) naturalised in Victoria.

Salix are rarely sterile, but sterility is known to occur in *S. purpurea* 'Booth', a form of *S. purpurea* originating in New Zealand, and *S.* x *calodendron* a sterile female tri-hybrid (*S. caprea* x *S. cinerea* x *S. viminalis*).

Most hybrids are classically intermediate between both parents, but amongst the most common willows in Australia is a suite of hybrids involving *S. alba* and *S. fragilis*. The primary hybrid *S. alba* x *S. fragilis* is called *S.* x *rubens* but a complex suite of material is difficult to identify with precision. It is likely that hybrids have been introduced as well as arisen in Australia between these species.

Given the facility with which hybridisation occurs, additional hybrids within subgenera will appear in Australia, and the chances of this are increasing as *Salix* are more widely planted or become naturalised.

Of the naturalised willow taxa in Australia, several are outstandingly invasive because of their reproductive ability. This includes species that reproduce vegetatively and/or by seed. The following are currently the most seriously invasive species; other taxa clearly show potential to be as invasive but are presently restricted in distribution and/or population size.

Salix cinerea (Grey sallow or pussy willow)

This large and spreading shrub or small tree from Europe to Siberia is one of the most widespread of the willow taxa and it has been naturalised for a very long time. Both sexes are present. In common with most shrub willows (sallows) *S. cinerea* is not very fragile, and twigs or branches are rather hard to break. Reproduction is almost exclusively by seed that is capable of very wide dispersal. *S. cinerea* is one of the few taxa so far recorded outside stream environments and it is highly invasive in swamps, drainage lines and other moist sites.

Large and rapidly expanding populations occur in Victoria (where it is most abundant) eg in the Ballarat – Daylesford area, around Mt Macedon, in South Gippsland, the Eastern

Highlands of north-east Victoria. The structure of the populations indicates that this species is expanding its range and that it will become a major wetland and riparian weed species (as it is in New Zealand). *Salix cinerea* is unquestionably the most seriously invasive of willows currently in Australia.

Salix cinerea forms hybrids with other shrub willows, eg *S. cinerea* x *S. caprea* (*S.* x *reichardtii*), *S. cinerea* x *S. viminalis* x *S. purpurea* (*S.* x *calodendron*).

Salix fragilis var. ***fragilis*** (crack willow) and ***S.*** x ***rubens*** (basket willow)

These single or multi-stemmed trees from Europe are by far the most widespread and abundant willows, occupying thousands of kilometres of streams and stream sides in south-eastern Australia. They have been naturalised since last century and widely planted for stream stabilisation, ornament and shade. Almost all plants of both taxa present in Victoria are males, although females occur in some locations.

Salix fragilis is very brittle and twigs break off with slight pressure, at least in winter. Almost all reproduction is vegetative, thus *S. fragilis* is only found associated with streams, where vegetative dispersal occurs downstream.

Salix fragilis is one of the parents of numerous hybrids in Australia. These have been imported or have arisen *in situ*. Hybrid combinations have been recorded in Australia with the following: *S. alba* var. *alba* (*S.* x *rubens*), *S. alba* var. *vitellina* (*S.* x *rubens* forma *basforthiana*), *S. matsudana* 'Tortuosa' and *S. nigra.* Hybridisation between any *Salix* subgenus *Salix* is likely if flowering is contemporaneous.

Salix x *rubens* and a range of backcrosses generally behave in the same way as *S. fragilis*, *i.e.* they are fragile, form large trees and propagate vegetatively. Basket willow has spread through the Mitta Mitta Heritage River.

S. fragilis in Australia is male, and where it occurs by itself it spreads vegitatively, often over many kilometres. In NSW (e.g. Bega River) it also occurs with female *S. alba* var *vitellina* and female *S.* x *rubens,* fertilising these and producing many seeds and resultant seedlings.

S. x rubens occurs as male and female

Salix nigra (Black Willow)

Salix nigra, a tree willow from North America, was introduced in 1962 from Missouri to Canberra. It has been widely planted in north-east Victoria and at several sites in NSW. Both sexes are present and seed is freely produced; it is now very abundant in some streams where large recruitment events have occurred. For example, large populations of seedlings were first noted in 1993 on gravel bars of the Ovens River, Victoria, but they have since increased spectacularly and now occupy almost all available recruitment sites. *Salix nigra* has the potential to behave in the same invasive manner as *S. cinerea* in wetlands.

Hybrids between *S. nigra* and *S. fragilis* var. *fragilis* have been recorded in the ACT and NSW and such hybrids are likely to increase the potential of further willow recruitment by making both sexes more freely available to reproduce amongst themselves, or form hybrids with other *Salix.* Hybrids between *S. nigra* and *S. matsudana* 'Tortuosa' have been recorded from NSW.

1.2 History of spread

Willows have had a wide range of uses for utility and ornament in Australia since early European settlement.

Willows on waterways

Weeping, basket and crack willows have been widely planted along the rural waterways of south-eastern Australia for erosion control. Most river catchments in the higher rainfall drainage systems of Victoria, New South Wales and Tasmania have well-established populations of willows. The populations are concentrated in the middle and lower agricultural reaches, especially those subject to clearing and channelisation works.

Although planting began soon after settlement, it was extensive from the 1950s to the 1970s. Former River Management Trusts and boards and the Snowy Mountain Authority frequently led the planting program, introducing new taxa and distributing cutting

material; land managers followed with enthusiasm. By the late 1980s, with alternatives such as rock lining of streams to control erosion and a growing sophistication in the river management industry, the willow as an erosion control tool had lost favour, even among the keenest advocates.

In rural areas where waterway management was given a low priority, willows are a low-cost, accessible means of arresting the waterway erosion caused by the effects of land clearing and cattle grazing of stream banks. It was favoured for its ability to establish rapidly and withstand stock grazing pressure without fencing. As indigenous riparian vegetation declined under the unrestricted grazing regime, willows were seen as the ideal replacement.

The deliberate planting of willows along waterways has now all but halted and extensive removal operations, often by the same trusts and boards that advocated their use, are the norm. In the agricultural landscape, willows, as the frequent dominants of highly degraded vegetation communities and river systems, are receding.

In the largely forested upper reaches of waterways where willows are a relatively minor component of the riparian vegetation, removal operations have commenced. Willow control programs are underway, for example, in the National Parks along the Genoa River in Victoria and NSW, the Snowy River in Victoria and the Colo River in NSW. Extensive willow removal operations are also carried out on urban waterways. These programs are dependent on reliable funding.

The legacy of willow planting and years of unrestricted reproduction is being addressed. The kilometres of often large, over-mature trees that have altered the ecology and hydraulics of the waterway are being removed by management agencies concerned by altered flooding regimes and degraded ecology. However, the management strategies and techniques required to establish a complement of indigenous species in place of willows are being developed and adopted more slowly and the two strategies are often not integrated.

Willows of off-stream wetlands

Grey sallow (or pussy willow) (*S. cinerea)* has only recently been recognised as an aggressive invader of streams and off-stream wetlands. Unlike most other willow species its spread is not restricted to waterways.

As this species is spread by seed, it is only limited by the opportunities for successful germination and subsequent establishment. Ornamental catkins made grey sallow a popular cut flower. The readily grown cuttings, and the fact that it is a tough, long lived tree, made it a frequent component of early country gardens. The seed, equipped for long distance dispersal, originated from these ornamental plantings.

The extent of the grey sallow invasion is yet to be fully investigated and documented but an indication of the capacity of grey sallow to invade can be deduced from the diverse environments it occupies in the following Victorian locations:

- the upper King River below Lake William Hovel;
- sphagnum bogs and the alpine meadows of the Baw Baw National Park and Bogong Unit of the Alpine National Park;
- roadside drains and wet grassy paddocks of a former pine plantation, Creswick;
- forestry roadside drains, Strezlecki Ranges;
- tributaries, mainstream and floodplain of Olinda Creek, Lilydale.

Black willow (*S. nigra)* is also emerging as a major weed of off-stream wetlands while purple osier (*S. purpurea*) clearly has potential as an important weed.

Other cultural and economic factors in willow spread

Willows have many uses apart from stream stabilisation and these have been important factors in their dispersal and naturalisation in Australia. Several taxa provide the materials for diverse basket-making uses in Europe, historically of great significance but now somewhat superseded. A basket-making industry using willows (especially the highly invasive crack willow) was established in the

1800s and early 1900s (eg at Loch, Victoria). Basket-making and other craft applications using willows in Australia are now confined to a small, mostly amateur craft-making community; at least one plantation was established in Victoria (in 1992) to provide materials for basket-making. Otherwise, sources of material are wild (naturalised) populations of several taxa.

A cricket bat industry using the cricket bat willow (*S. alba* var. *caerulea*) operated in Victoria in the 1800s until the mid 1900s but was discontinued. It has recently been revived with plantations established in several locations in Victoria (eg Yarra Valley, Daylesford) and Tasmania. The cricket bat willow, though not naturalised, hybridises with other taxa (eg *S. fragilis*), to produce viable seed.

Willows provide an early source of pollen and nectar for honey bees, but they are not held in high esteem by most apiarists because the pollen is of poor nutritional quality. A small-scale floricultural industry utilises pussy willows for cut flowers and other willows for winter-bare branches (viz. *S. matsudana* 'Tortuosa', *S. myrsinifolia*, *S. alba* var. *vitellina, S. purpurea*).

Willows are widely used in horticulture for ornament and in farming for windbreaks; the latter application utilises nine selections of New Zealand hybrid willows (*S. alba* x *S. matsudana* (syn. *S. babylonica* var. *pekinensis*)). Currently 47 willow taxa are sold in the nursery trade in Australia (Appendix 3) including weedy taxa. There is high potential for additional willow taxa to become naturalised from existing cultivated stocks and future imports if importation is not closely regulated. Many have the potential to become naturalised or produce hybrid combinations with existing willows. Several living collections of willows are known, notably the National Willow Collection at Dunkeld, south-west Victoria.

In many south-east Australian locations, naturalised and planted willows, especially along streams, are valued as elements in cultural landscapes. Several classified landscapes on the register of the National Estate feature willows as major landscape components (eg Port Arthur, Tasmania; parts of Lake Burley Griffin, ACT) and willows feature in some National Trust classified landscapes and the gardens of classified properties.

1.3 Weeds of National Significance

The impacts of willows are summarised as follows:

Willows as invaders of waterways

Willows colonise river and stream beds by vegetative or sexual reproduction, with potentially severe environmental and biological effects through formation of dense stands of structurally unstable trees or shrubs with extensive, dense, root mats. Impacts include:

- modification of stream morphology, hydrology and stability, causing blockage/obstruction, avulsion, increased erosion and sedimentation and increased flooding.
- increased water-use in streams resulting from higher transpiration rates than indigenous vegetation.
- severe damage to infrastructure where willow debris obstructs stream channels during floods (eg loss of bridges and roads).
- alterations to ecological processes in streams, including energy fluxes and nutrient cycling (timing, quality and consistency of organic matter inputs), water temperature modifications (through intense shading) and water quality via anoxic conditions produced (biological oxygen demand) during breakdown of the massed autumn leaf fall.
- dense shading by willow canopies alter (or decrease) primary production, impacting on higher order consumers such as invertebrates and fish.
- destruction of instream and streambank indigenous vegetation communities and dependent faunal communities by intense shading.
- destruction of significant flora and fauna species and populations of streams and streambeds.
- visual degradation by the introduction of discordant exotic elements in high-quality landscapes dominated by indigenous

vegetation eg Snowy River National Park, Victoria, and Kosciuszko National Park, NSW.

- reduction in amenity values associated with streams, for example reduced access for fishing, canoeing and rafting on streams densely vegetated with willows.

Willows as invaders of off-stream wetlands

Willows which reproduce by seed (which is wind dispersed over long distances), most significantly grey sallow (*S. cinerea*) and black willow (*S. nigra*), are able to invade all non-saline wetlands including streams from sea level to alpine bogs. Impacts are similar to those on streams outlined above, but generally without the adverse impacts on stream morphology and hydrology, except excess water use.

Willows seriously threaten biodiversity of wetlands communities. These threats include:

- Nationally endangered Helmeted Honeyeater habitat at Yellingbo, Victoria. (*S. cinerea*).
- Nationally significant Sedge-rich Mountain Swamp Gum Community at Yellingbo, Victoria (*S. cinerea*).
- Nationally endangered plant species and communities in Wingecarribee Swamp, NSW (*Gentiana wingecarribiensis, Prasophyllum uroglossum, Lepyrodia anarthria* rushland) (*S. cinerea*).
- Nationally significant alpine bogs and fens in Victoria (eg Bogong High Plains) (*S. cinerea*).
- Nationally significant Red Gum floodplain vegetation, Lower Ovens Heritage River, Victoria.

1.4 Legislative controls

Willows (*Salix* taxa) are Weeds of National Significance (though *S. babylonica, S.* x *calodendron* and *S.* x *reichardtii* are excluded). Currently only a few nominated species with perceived high weed potential are excluded by the Australian Quarantine Inspection Service (AQIS). AQIS prohibits the importation of plants or seeds of *Salix bebbiana* and *S. exigua* under Condition 7172, and applications to import nursery stock or seeds of all other *Salix* species must be referred to the Animal and Plant Programs Branch, Canberra, for approval. At the State and Territory level, legislative barriers to willow management exist with only a few taxa specifically listed as weeds in two States. Uniform legislation applying across Australian States and Territories is mandatory for effective control.

- Willows are not declared in Victoria, Queensland, Tasmania or Western Australia but are declared in the following states:
- New South Wales (Regional Declaration as Category W4 noxious weed): The provisions prohibit sale or cultivation of all *Salix* species excluding *S. babylonica, S.* x *calodrendron, S.* x *reichardtii* and require control of *S. nigra* in Maclean Shire only. Landholders are not legally obliged to remove willows but it is illegal to plant or propagate them, and for nurseries to sell willows. (This has effectively stopped further planting in NSW).
- South Australia: *Salix* species (excluding *S. apoda, S. arctica. S. babylonica* var. *babylonica, S. boydii, S.* x *calodendron, S. chilensis, S. myrtilloides, S.* x *reichardtii, S. serpyllifolia* and *S.* x *sepulcralis* var. *sepulcralis*) are proclaimed but no control is required. The sale of willows in South Australia had been banned and the Animal and Plant Control Commission (SA) is currently working on enforced control of hybrids in certain areas, particularly the Riverina.
- Western Australia: All species of *Salix* are permitted except *Salix bebbiana* and *S. exigua* although these are not declared.

1.5 Control methods and strategies

History of willow control

Willow management actions in Australia have largely been implemented on rivers and streams to deal with willows as riparian weeds causing waterway management problems.
In the last decade control has also been driven by the recognition of willows as serious environmental weeds. Therefore willow management has advanced from the riparian situation to become a priority in natural resource management at the broader scale. The shift in priority has been

driven by a number of factors, which include:

- Senescence, leading to structural instability (breakage and collapse) of willow trees planted on streams in the 1960s and 1970s for river stabilisation;
- sexual reproduction in some willow taxa and the recognition of the role of seed production in advancing spread;
- establishment and growth of willows, particularly in natural areas, from unchecked dispersal from plantings;
- increased funding for river management and utilisation of relatively more expensive forms of erosion control such as rock lining of streams;
- a levelling off of stream erosion in agricultural areas;
- improved knowledge of willow taxonomy so that grey sallow (*S. cinerea*) for example, is now recognised as an invasive willow;
- changes in natural resource management organisations and structures (*i.e*. the formation in Victoria of the Catchment Management Authorities with their responsibility for waterway management, flood mitigation and broader control programs are funded for whole-river health projects;
- appreciation of the detrimental impacts of willows on the natural values of the stream;
- the ability to restore the riparian environment, albeit in a modified form.

Historically, willow management has been undertaken by government agencies (eg the former Victorian Soil Conservation Authority), semi-government authorities (eg River management trusts and boards) and by private land managers, mainly farmers. Willow control has gone through a number of phases:

1950 – 1980: Extensive plantings by soil conservation and river management agencies and land managers, often to control erosion on unstable, newly channelised streams due to increased flow velocity. Control was limited to the prevention of flooding or damage to infrastructure (eg removal of instream willows on islands or at bridges).

1980s: As the decade progressed there was a reduction in the agency plantings as alternative erosion prevention techniques were adopted; there was growing recognition of the problems associated with willows exacerbating flooding and erosion.

1990s – 2000: Willow planting by agencies virtually ceased (although land managers were slower to forsake willows). Extensive stands of willows were directly implicated in major flooding, avulsions and erosion of streams eg in north-east Victoria and East Gippsland where extreme flood events occurred in 1993 and 1998 respectively. The role of willows as very serious invasive environmental weeds was accepted, concomitant with recognition of the environmental values of waterways. New river management agencies were created in Victoria, South Australia and New South Wales and the attention focused on increasing the efficiency of mechanical and chemical control techniques. Towards the end of the decade, acceptance of willows as serious weeds is almost universal. Willow control along remote and wild rivers commenced (eg Snowy River and Genoa River in East Gippsland and the Southern Tablelands of NSW).

Control techniques and strategies

There is a need to establish clearly defined priorities for control of willow populations which focus on (i) geographic areas (eg catchments) and (ii) willow taxa. Areas of higher significance for defined biological and other values such as National Parks and other biological reserves, and heritage rivers with current willow populations requiring control (eg Snowy River National Park, Victoria) need to be managed for willows, while areas of higher significance that are threatened by willow invasion need to be kept free of willows.

The following willow control methods (Table 1) are available, with use depending upon taxa involved, size of populations, the situation or 'setting', and many other factors:

Table 1. Willow control methods

Chemical	Susceptible at all life stages to many commonly used agricultural herbicides formulated for the control of woody plants. Some formulations of glyphosate are registered for willow control (under several trade names) by stem injection, or foliar application in all states. Willows are susceptible to herbicide applied via foliar, bark (chemical girdling), stem injection and cut-and-paint methods of application.
Manual	Seedlings are readily hand pulled.
Mechanical	The soft timber is easily cut and is relatively light to handle.
Burning	Green foliage and timber will burn in a hot fire; the cambium is readily killed by fire. However, burning can be indiscriminate and should be avoided.
Grazing	Favoured by domestic stock – cattle, sheep and goats will eat leaves, twigs and smaller stems. They will also strip bark off branches. Possums heavily graze and defoliate isolated trees.

Willow control methods are evolving with experience and as the scope of control programs broadens. The main locations for control activities are:

- agricultural and urban waterways
- natural areas (National Parks and other reserves) and
- defined waterways.

The objectives for control dictate the timing and speed required. Where willows are a physical impediment to stream flows, especially when they occupy the stream bed and compromise hydraulic efficiency, mechanical removal of root mats and stems is required. Where willows are being removed because they threaten biological and other natural values (eg National Parks) and the risk to downstream infrastructure (eg bridges) is low, plants can be treated with herbicide and the stems left standing to break down over time. Where infrastructure, farming operations, or public safety demand removal, herbicide treatment, felling and disposal by chipping or burning is practised.

The most common method of control on agricultural waterways is to cut and paint with concentrated herbicide, and poisoning prior to removal of stems; trees are felled and the stump treated with herbicide. Heavy machinery is frequently used to handle debris, which is either burnt or chipped. Machinery (used in forest industries) is being utilised to cut and handle timber; machines may also be equipped for herbicide application. In all willow control programs there is a strong need for follow-up control of regrowth (from stumps, fragmented stems or seeds). This may require a period of 3-5 years' monitoring after the initial control measures.

The effect of grazing pressure in restricting willow colonisation is frequently overlooked. Because of stock grazing pressure, willows often grow midstream, on snags or against steep banks but not along accessible banks.

Biological control is potentially the most cost-effective control method for willows and has considerable potential, as numerous insects and other invertebrates and pathogens eat or parasitise willows in their countries of origin. Australia has no naturally occurring members of the family Salicaceae (willows, poplars) thus there is little or no potential to adversely impact the indigenous flora and fauna. No exotic invertebrates specific to willows are currently known in Australia, but in New Zealand the Willow Sawfly is proving to be very damaging. The only pathogens reported in Australia are the fungi, European Willow Rust (*Melampsora epitea*) - a leaf parasite of weeping willows (*S. babylonica* and some of its hybrid combinations); Oriental Willow Rust (*M. coleosporoides*) (*S. babylonica*); and Willow Anthracose (*Marssonina salicola*) - causing lesions on stems and leaves (eg *S. babylonica*, *S. alba* var. *caerulea*, *S. purpurea*). They have little impact. Low-level impacts of grazing and browsing by wallabies, possums,

deer and domestic stock are observed but these animals overall have minimal effects on reproductivity or recruitment.

An evaluation of biological control for *Salix*, consisting initially of bibliographic research on pests and pathogens, (commissioned by the Victorian Catchment Management Authorities) has been carried out by the Keith Turnbull Research Institute.

As objectives and access for control change with the move into natural areas, new combinations of control methods are employed. In locations where access is difficult because of vegetation or terrain, a number of different methods have been employed eg

- spraying from boats, stem injection and burning on the root pad (eg Yarra River, Victoria);
- spraying of seedlings from all-terrain vehicles (eg Cann River, Victoria);
- cut-and-paint of trees with helicopter access (eg Genoa River, Victoria).

Seedlings of different species are frequently sprayed and larger trees stem injected as part of the one control operation; large mid-stream trees are also removed (including the rootmass) (eg on gravel beds in the King River, Victoria).

Strategic approach

A more strategic approach is evolving where willow control is managed over years as part of a broader program of riparian vegetation rehabilitation. The control area is broadened to encompass adjoining townships that are contributing propagation material and control is effected progressively over years. Maintenance to control sexual and asexual propagation is an accepted annual practice (eg Genoa River willow control 1994-2000). Early detection of willows and rapid management responses are indicated.

The recognition of the need for total riparian vegetation management rather than a single-species approach has seen the emergence of strategic, staged control programs providing efficient willow control and resulting in improved regeneration of indigenous vegetation (eg Yarra River, Warrandyte, Victoria). Chemical control, which results in low levels of physical disturbance, has been observed to promote abundant regeneration (indigenous species) on the formerly heavily shaded banks and willow root mats. Manipulation of the control process has yet to be exploited to its full potential to promote riparian vegetation regeneration. However, the removal of the willow canopy often promotes weed invasion and there is the potential for other serious weeds to take their place, eg. *Glyceria maxima* (Tarago River, Victoria). This demonstrates the need to be holistic about riparian rehabilitation and ensure an integrated approach.

At the willow species (or taxon) level, local or regional populations of the most seriously invasive willows (*S. cinerea* and *S. nigra*) need to be targeted for control because of their highly effective wind dispersal. While such populations may not threaten values where they occur (eg in degraded agricultural landscapes) seed dispersal will ensure that they pose major threats to values in sometimes distant locations, especially those downwind during the relatively brief seed-dispersal period in late spring/early summer.

1.6 Principles underlying the plan

This plan is based on the recognition and acceptance of four principles outlined by the National Weeds Strategy:

1 Weed management is an essential and integral part of the sustainable management of natural resources and the environment, and requires an integrated, multidisciplinary approach.

2 Prevention and early intervention are the most cost-effective techniques that can be employed against weeds.

3 Successful weed management requires a coordinated national approach, which involves all levels of government in establishing appropriate legislative, educational and coordination frameworks in partnership with industry, land managers and the community.

4 The primary responsibility for weed management rests with land managers, but collective action is necessary where the problem transcends the capacity of the individual land manager to address it adequately.

1.7 Socio-economic factors affecting management decisions

The cost of control on public and private lands with current methods (herbicides and machinery) is an impediment to control; follow up work will be required, adding to costs. The need to implement revegetation and fencing in some situations where willows are removed *en masse* – to confer stability on stream banks – may add considerably to costs of control.

Commercial and non-commercial uses of willows, viz. cricket bat industry, floriculture, ornamental horticulture, farm plantings for shelter and the crafts (baskets, furniture) may in some cases conflict with needs to control willows. This may also apply to the use of willows to stabilise stream banks – the major traditional use of willows. In some locations there has been considerable resistance to willow control from community and farming groups. These people object to willow removal because they value willows for their aesthetic attributes (eg weeping willows) or for utilitarian functions such as shade for stock, while believing that willows do not cause many problems.

For the most part, protocols can be formulated to govern commercial activities (eg cricket bat willow production), or alternative non-invasive willow taxa or male plants, rather than female plants with seed production potential, can be used. Some willow taxa cannot be tolerated in any context and there is a need to prohibit importation of all except sterile taxa.

1.8 Relevance to other strategies

The *Willow Strategic Plan* has been established to provide a framework for coordinated management of willows across Australia. This strategy is linked to many National and State management laws and strategies for maintenance of biodiversity and sustainable development and management of a range of natural resources. It is also linked at regional and local levels to biological and physical resource management and the maintenance of amenity values e.g. stream-related recreational activities. The strategy also links with and accords with the broad range of community and government willow management activities at the catchment level, particularly those current in Victoria and New South Wales. Significantly, the strategy also links with international conventions and agreements for the maintenance of biodiversity of wetlands. The relevance of these laws, agreements, policies and covenants is summarised in Table 2, below.

Table 2. Policy and Strategy Linkages

Jurisdiction	Weed strategies	Related initiatives
Worldwide		Agreements or conventions negotiated in United Nations or OECD forums World Conservation Union
National	National Weeds Strategy Weeds of National Significance	CRC for Weed Management Systems
Commonwealth	Policies, strategies, plans and controls applied to Commonwealth lands (eg. Conservation and Military)	World Heritage Areas RAMSA Sites Decade of Landcare Natural Heritage Trust
Multi-state Regions		Strategies under Murray-Darling Basin Initiative
State / Territory	State weed strategies / plans State strategies for Weeds of National Significance species Listed community and species recovery plans State biodiversity strategies,	All State/Territory noxious weed and related legislation Conservation strategies State biodiversity strategies Forest management plans River, estuary and wetland policies
Regional and Local	Regional and/or local weed plans and species strategies Catchment / vegetation management plans	*State of the Environment* reports Regional environmental plans and other regional initiatives Regional forest agreements Development control plans Landcare groups and plans
Utilities	Rail, road, and utility corridor management plans	Environmental impact assessments
Local Governments	Local government pest management plans	Local laws Local conservation strategies Local Agenda 21 programs Integrated local area planning
Neighbourhood	Community action strategies	Landcare groups and plans, roadside conservation and other greening projects
Land / Property	Management plans for land managers Control schedules Property / farm management plans	Incentive schemes Land for wildlife

2 STRATEGIC PLAN

To ensure that all Weeds of National Significance are effectively managed, the *National Weeds Strategy* outlines the need for the development, implementation and evaluation of a management program for each species, or, in the case of willows, a number of taxa.

VISION

To stop willows destroying our waterways and wetlands.

2.1 Stop the spread of willows

Desired Outcome

The spread of willows is halted.

Strategy	Actions	Responsibility	Priority[1]
2.1.1 **Set priorities for management of vulnerable areas currently uninfested by willows (eg National Parks and heritage rivers)**	Identify areas potentially at risk from willow invasion (refine Weed Risk Assessment) Identify and map areas susceptible to invasion by the most serious willows Develop and implement a rating system to identify priorities and develop response protocols	State and Territory Catchment and Waterway Management Bodies	1
2.1.2 **Ensure early detection of 'dangerous' situations and new willow outbreaks and develop rapid response mechanisms to eradicate populations**	Train 2-3 staff per state/territory to recognise these situations Develop and implement eradication and monitoring protocols	State and Territory Governments	1
2.1.3 **Identify and address legislative barriers regarding trade and distribution of willows**	Declare all *Salix* taxa except *S. bablyonica*. *S* x *calodendron* and *S* x *reichardtii* in all States and Territories to prevent trade and distribution	State and Territory Governments	1
2.1.4 **Evaluate the weed potential of non-naturalised cultivated willows**	Assess the potential of willows in key cultivated sections to become naturalised Devise protocols in consultation with owners or managers of collections to deal with those willows found to be potentially weedy	State and Territory Governments	1
2.1.5 **Stop further planting of invasive willows**	Raise awareness amongst public, Landcare groups, and management authorities, not to plant invasive willows Develop extension and eradication programs targeting S. *cinerea*, S. *fragilis*, S *rigra* (and other species to be determined by the National Willows Taskforce) to prevent planting and invasion where populations threaten previously uninfested areas.	State and Territory Governments Regional Bodies Local Government	2
2.1.6 **Identify plant species, and 'safe' willows with similar beneficial functions, to replace willows**	Encourage research into safe willow alternatives (both indigenous plants and *Salix* taxa) in various local contexts Develop appropriate educational resources	State and Territory Governments	2
2.1.7 **Develop and implement sound on-ground management strategies at local level to prevent further spread**	Develop "best management" practices Train staff in appropriate management responses	State and Territory Government agencies	2

[1] The National Weeds Strategy Executive Committee defines priorities as follows: Priority 1 – "what must be done"; Priority 2 – "what should be done"; Priority 3 – "what could be done".

Strategy	Actions	Responsibility	Priority[1]
2.1.8 **Change attitudes and behaviour of public to prevent buying and planting of willows**	Implement pre-emptive education in "clean" (willow-free) areas Focus on particular situations where willows may be invasive, as well as taxa that are not invasive	State and Territory Governments Regional Bodies Nursery Industry	2
2.1.9 **Stop importation of *Salix* taxa at national level**	Determine *Salix* taxa to be prohibited from entry into Australia Implement quarantine prohibition at the barrier	Australian Quarantine Inspection Service	1

2.2 Manage the existing areas of willows

Strategy	Actions	Responsibility	Priority
2.2.1 Map infestations of the most serious willows	Identify or confirm the most seriously invasive willow taxa their mode of spread and behaviour Approve and apply a methodology for mapping Assess willow threats and impacts	State and Territory Governments Regional Bodies	1
2.2.2 Develop regional plans based on generic willow management model	Establish generic model with costings and possible funding sources Recognise legislative obligations to protect natural resources and assets (e.g. heritage rivers, listed waterways, threatened species) Develop and implement catchment-based action plans	State and Territory Governments Regional Bodies	1
2.2.3 Assess and improve methods of control	Undertake and apply research to introduce biocontrol agents for willows Collate existing control data, including survey of CMAs and land managers in Australia and New Zealand Develop additional control methods/techniques as needed Develop data for chemical usage permits and recommendations to extend the use pattern of herbicides	State and Territory Governments Regional Bodies	1 2
2.2.4 Establish and apply best-practice guidelines for willow management	Develop guidelines for eradication and control to meet legislative obligations (after implementation actions in strategy 2.1.3) Review, assess, develop and adopt current willow management practices when controlling willows. Review and assess and develop rehabilitation practices and refine ongoing management requirements of sites following willow removal	State and Territory Governments State Catchment Bodies Regional Bodies	2
2.2.5 Develop and implement protocols for managing commercial willow plantations	Develop detailed prescriptions to prevent willows spreading (per taxon) Develop codes of practice for plantation managers	State and Territory Governments Regional Bodies Industry Groups	3
2.2.6 Control invasive willow species	Eradicate willows from key locations identified above and in 2.1. Enforce eradication and control of S. *cinerea*, S. *fragilis*, S *ruger* and other priority species to be determined by the National Willows Taskforce (after implementation actions in strategy 2.1.3) to require land managers to implement control.	Land holders, Land Managers, Regional Bodies, Industry Groups, State and Territory Governments	1

2.3 Gain community support in managing the willow problem

Strategy	Actions	Responsibility	Priority
2.3.1 Highlight the nature and national significance of the willow problem	Develop and implement a broad public communication strategy Review current extension material, and develop appropriate additional educational resources	State and Territory Governments Regional Bodies	1
2.3.2 Report on the outcomes and progress of the *Willow Strategic Plan*	Report annually to the National Weeds Strategy Executive Committee and to interest groups	State and Territory Governments Regional Bodies	1
2.3.3 Present and implement solutions to the willow problem	Identify and encourage management options Promote alternative species that fulfil existing functions of willows in various local contexts Develop land manager partnerships	State and Territory Governments Regional Bodies	2
2.3.4 Attract sponsors/partners to promote and help fund management actions	Develop appropriate proposals for sponsorship	Regional Bodies	3
2.3.5 Coordinate and facilitate the dissemination of information relating to willows and their management	Establish a willow network and develop willows expert information web site	State and Territory Governments Regional Bodies Industry Groups National Weeds Strategy Taskforce	2

3 MONITORING AND EVALUATION

This strategic plan is subject to a five–year review. The National Willow Taskforce will monitor the implementation of the strategy. The Taskforce will report to the NWSEC and NWP on funded projects.

Monitoring and evaluation are essential to the development of the strategy to gain efficiencies and to obtain best results. It may require up to 3% of the control budget. Evaluation would include assessing changes to distribution and size of willow populations (current versus potential), determining effectiveness of control techniques and their integration, determining changes in rate of spread, frequency of locating new infestations, and assessments of the costs and benefits of the strategies.

Performance indicators for the plan include:

- No additional importation of weedy willows into Australia.
- Declaration of 'problem' willows and uniform regulations governing 'harbouring' or cultivation, trade and uses of weedy willows in Australia.
- Increased awareness at all levels, including the general community and industry groups, about the environmental, economic and social impacts of willow invasions.
- Formulation and operation of guidelines and protocols for managing plantation willows.
- A clear understanding of the biology, ecology, distribution and abundance (and factors affecting these) of key willow taxa, notably the seeding *S. cinerea* and *S. nigra.*
- Substantial progress in the elimination or containment of key willow taxa (particularly the seeding *S. cinerea* and *S. nigra*).
- Publication of comprehensive 'best practice' guidelines on willow management objectives, strategies and control methods.
- A biological control, research and evaluation program in operation for key willow taxa (notably *S. cinerea*).
- Establishment and implementation of an effective communication and extension plan for specific community sectors with an interest in willows and willow management.
- Establishment of an expert willow group as a "clearing house" for information and to disseminate advice on willow management.
- Demonstration that stakeholders and funders are receiving value for money through the national *Willow Strategic Plan*.

4 STAKEHOLDER ROLES AND RESPONSIBILITIES

All land managers, both public and private, shall achieve the highest level of willow control.

Private land managers

To ensure that key willow taxa are not planted on their properties, to control problem willows and prevent spread to neighbouring lands.

- To control problem willows on their own properties and prevent spread to neighbouring lands.
- Avoid planting 'problem' willows.
- Involvement in Landcare and other management groups.
- Develop and implement management plans that address 'best practice' willow control on properties and prevention of spread from properties (downstream or by wind-dispersed seed).
- Be able to identify willow taxa.

Local Governments

To ensure key willow taxa are not planted, and are contained or eradicated as appropriate throughout all areas managed directly.

- Ensure that management plans for lands managed include and effect willows management and control as appropriate to the taxa/taxon involved.
- Ensure private land~~holder~~ managers are aware of willow management issues and effect control as appropriate.

Utility companies/Regional catchment and waterway management agencies

To ensure key willow taxa are not planted, and are contained or eradicated as appropriate throughout the area being managed.

- Develop and implement willow management plans appropriate to the situations and types of willows present, address 'best practice' control and prevent spread (downstream or by wind-dispersed seed).
- Develop and implement protocols for statewide management recommendations for commercial willow plantations, potential new outbreaks and legislative barriers.
- In conjunction with Regional Bodies develop management tools to prioritise activities and list proactive management guidelines.

State Government Departments
(responsible for conservation and resource management)

To ensure that the biological, economic and social impacts of willow invasions are understood by the general community and interest groups, and that willow invasions are minimised and appropriately managed on public and private lands.

- In consultation with State Agents, develop and implement a sound public communication strategy.

Federal Government Agencies

- Maintain quarantine barrier controls to minimise introduction of problem *Salix* taxa (Australian Quarantine Inspection Service).
- Ensure willow control is undertaken on all lands under management in the States and Territories (essentially Defence lands).
- Oversee and manage federal funds including NHT and NWP (Environment Australia; Agriculture Forestry and Fisheries Australia).

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6 ABBREVIATIONS AND GLOSSARY

ABBREVIATIONS

CMAs – Catchment Management Authorities
NWP – National Weeds Program
NWSEC – National Weeds Strategy Executive Committee

GLOSSARY

asexual (propagation) – reproduction which does not involve production of seeds (following pollination and fertilisation of flowers)
avulsion – a change in the course of a stream where it breaks its bank(s) during a flood
axillary – borne at the base of a leaf stalk
boreal – pertaining to the north; in this context, northern hemisphere locations with severe winter climates
naturalised – plants which have become 'wild', naturally producing outside the context of gardens, plantations, etc. without human intervention
ploidy – the degree of repetition of the base number of chromosomes of a species (or taxon)
pussy willow – used commonly for *S. calodendron*, but also for *S. cinerea* and *S. reichardtii*
recruitment – acquisition of new individuals to the population by seed or vegetative propagation (it is not equivalent to the term regeneration)
sexual (propagation or reproduction) – reproduction involving seed production following pollination and fertilisation
sterile – without reproductive structures (flowers or fruits)
subgenus (plural: **subgenera**) – formal classification immediately below the level of genus
substrate – material (usually soil) in which a plant is rooted or on which it establishes
taxon (plural: **taxa**) – formal or informal unit of taxonomic classification – in this context a **species, subspecies, variety, hybrid** or **horticultural selection** (garden form)
taxonomy – formal classification and nomenclature of plants (or animals)
tri-hybrid – a hybrid with three taxa in its parentage
vegetative (reproduction) – reproduction of plants from cuttings, layering, etc. but not involving flowers and fruits/seeds (equivalent to asexual reproduction)
weeping willow – the name generally applies to *Salix babylonica* (a species excluded from the list of Weeds of National Significance) but *S. babylonica* is one of four weeping willows naturalised in Australia (the others are *S.* x *pendulina, S.* x *sepulcralis* var. *sepulcralis* and *S.* x *sepulcralis* var. *chrysocoma*)

Appendix 1. Salix taxa and hybrids naturalised in Australia

Includes **species**, **sub-species**, **varieties**, **cultivars** and **primary hybrids** (between established taxa). Some of the following taxa form backcrosses to an original parent or a different taxon. A query (?) preceding an entry indicates that the information is unconfirmed.

Taxa in **bold** are excluded from the National Weeds Strategy.

Sources of data: Carr (1996, unpubl. data), Cremer (1999a, pers. comm.).

	Taxon	Sub-genus	Common name	Country of origin	Distribution							Means of propagation	
					V	N	Q	S	T	W	A		
1	*Salix aegyptiaca*	*Vetrix*	Asian Sallow	Iran, Armenia, Asia.							✔	?S	?V
2	*Salix alba* var. *alba*	*Salix*	White Willow	Europe	✔	✔							V
3	*Salix alba* var. *vitellina*	*Salix*	Golden Upright Willow	Europe	✔	✔	✔	✔	✔		✔	S	V
4	*Salix alba* var. *alba* x *S. matsudana* (syn. *S. babylonica* var. *pekinensis)*	*Salix*	New Zealand Hybrid Willow	hort. (NZ)	✔	✔					✔	S	V
5	*Salix alba* var. *vitellina* x *S. matsudana* 'Tortuosa'	*Salix*	Golden Tortured Willow	*In situ* hybrids	✔								?V
6	*Salix alba* var. *vitellina* x *S.* x *sepulcralis* var. *chrysocoma*	*Salix*	Willow	*In situ* hybrids		✔						?S	?V
7	***Salix babylonica***	*Salix*	Weeping Willow	China	✔	✔	✔	✔	✔	✔	✔	S	V
8	***Salix* x *calodendron*** (*S. caprea* x *S. purpurea* x *S. viminalis*)	*Vetrix*	Pussy Willow	Europe	✔	✔					✔		V
9	*Salix chilensis* 'Fastigata'	*Salix*	Chilean Pencil Willow	Chile	✔	✔						?S	V
10	*Salix cinerea* ssp. *cinerea*	*Salix*	Grey Sallow, Pussy Willow	Europe - Siberia	✔	✔		✔				S	V
11	*Salix cinerea* ssp. *oleifolia*	*Vetrix*	Rusty Willow	Europe, N. Africa	✔				✔			S	?V
12	*Salix cinerea* ssp. *cinerea* x *S.* x *reichardtii*	*Vetrix*	Pussy Willow	*In situ* hybrids	✔							S	?V
13	*Salix fragilis* var. *fragilis*	*Salix*	Crack Willow	W. Europe	✔	✔		✔	✔		✔		V
14	*Salix fragilis* var. *furcata*	*Salix*	Forked-Catkin Crack Willow	W. Europe	✔								V
15	*Salix fragilis* var. *fragilis* x *S. matsudana* 'Tortuosa'	*Salix*	Willow	*In situ* hybrids, Vic,								S	?V
16	*Salix fragilis* var. *fragilis* x *S. nigra*	*Salix*	Willow	*In situ* hybrids		✔					✔	S	?V
17	*Salix glaucophylloides*	*Vetrix*	Dune Willow	N. America		?✔					✔	S	?V
18	*Salix glaucophylloides* x *S. ?* x *reichardtii*	*Vetrix*	Willow	*In situ* hybrid							✔	S	?V
19	*Salix matsudana (*syn*. Salix babylonica* var. *pekinensis)*	*Salix*	Peking Willow	China, Mongolia, Korea			✔						V

	Taxon	Sub-genus	Common name	Country of origin	Distribution							Means of propagation	
					V	N	Q	S	T	W	A		
20	*Salix matsudana* 'Tortuosa'	*Salix*	Tortured Willow	hort. (?location)	✔	✔					✔	S	V
21	*Salix* x *mollissima* (*S. triandra* x *S. viminalis*)	*Salix /Vetrix*	Willow	Europe	✔								V
22	*Salix nigra*	*Salix*	Black Willow	N. America	✔	✔					✔	S	V
23	*Salix nigra* x *S. matsudana* 'Tortuosa'	*Salix*	Willow	*in situ* hybrids		✔						?S	
24	*Salix* x *pendulina* (*S. babylonica* x *S. fragilis* var. *fragilis*)	*Salix*	Weeping Willow	hort. (Europe)		✔				✔			V
25	*Salix* x *pendulina* var. *elegantissima* (*S. babylonica* x *S. fragilis* var. *fragilis*)	*Salix*	Weeping Willow	hort. (Europe)		✔							V
26	*Salix purpurea* (and several cultivars)	*Vetrix*	Purple Osier	Europe, Asia	✔	✔					✔	S	V
27	***Salix* x *reichardtii*** (*S. caprea* x *S. cinerea*)	*Vetrix*	Pussy Willow	Europe	✔	✔			✔		✔		V
28	*Salix* x *rubens* (*S. alba* x *S. fragilis*)	*Salix*	Basket Willow	Europe/ *In situ* hybrids	✔	✔			✔		✔	S	V
29	*Salix* x *rubra* (*S. purpurea* x *S. viminalis*)	*Vetrix*	Osier	Europe	✔	✔						S	V
30	*Salix* x *sepulcralis* var. *chrysocoma* (*S. alba* var. *vitellina* x *S. babylonica*)	*Salix*	Golden Weeping Willow	hort. (Europe)	✔	✔			✔		✔	S rarely	V
31	*Salix* x *sepulcralis* var. *sepulcralis* (*S. alba* var. *alba* x *S. babylonica*)	*Salix*	Weeping Willow	hort. (Europe)	✔	✔	✔				✔		V
32	*Salix viminalis*	*Vetrix*	Osier	Europe – Russia	✔	✔					✔	S	V

hort. – horticultural hybrid or sport.

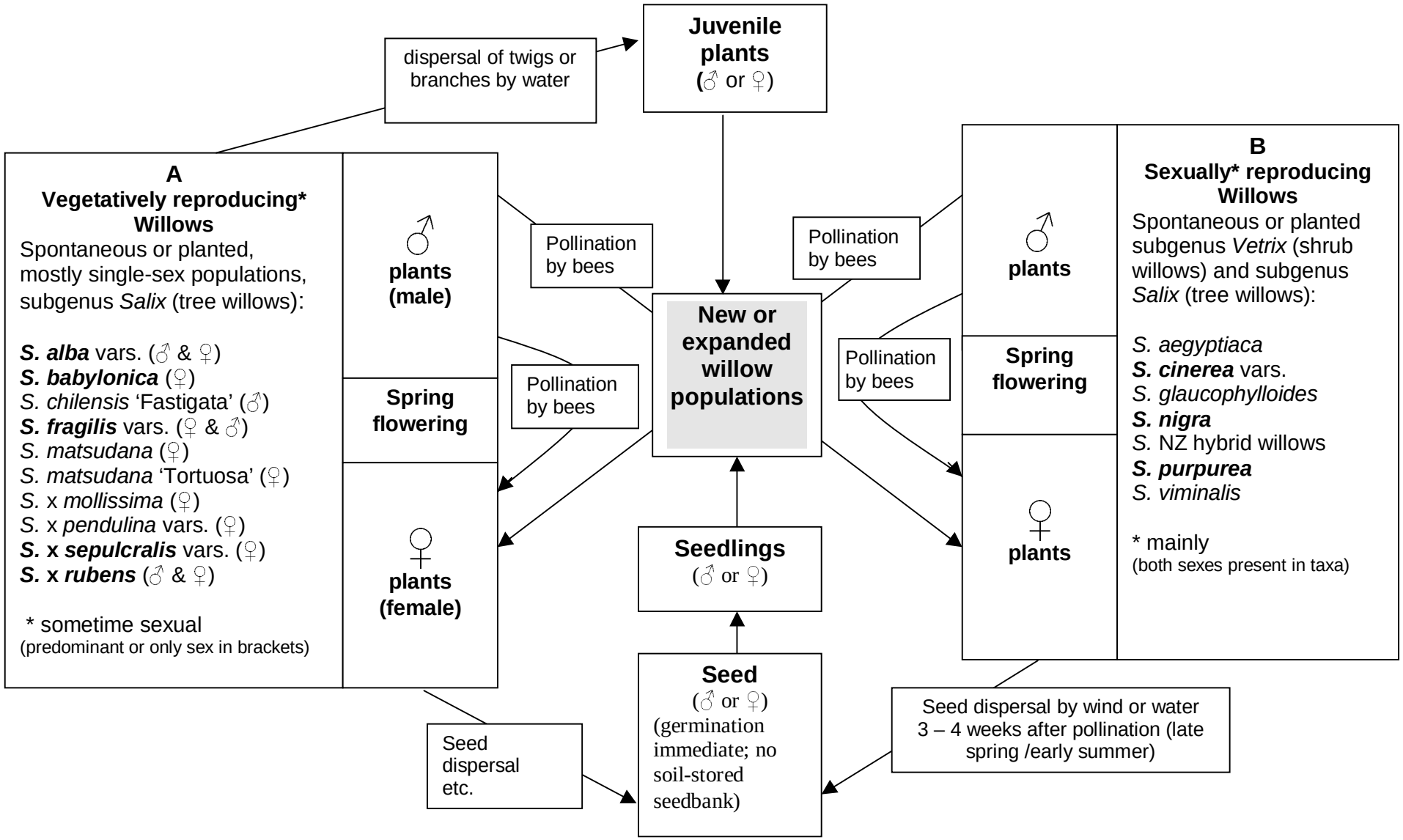
Distribution:

V Vic; **N** NSW; **Q** Qld; **S** SA; **T** Tas; **W** WA; **A** ACT

Means of Propagation: **S** – seed; **V** – vegetative (rooting of detached twigs or branches, or layering).

Appendix 2: Life cycles of naturalised *Salix* (willows)

Taxa in **bold** are the most widespread and abundant naturalised willows in Australia; numerous hybrid combinations are not shown. Note that hybridisation is within (not between) subgenera.



Appendix 3: Commercially available *Salix* in the Australian nursery trade

Source of list of taxa: Hibbert (1999) (except for *S. alba* var. *caerulea*).

	Taxon	Common name	Subgenus	Origin	Sexuality of stock	State(s) in which available
1	*Salix acutifolia* 'Blue Streak'	-	*Vetrix*	Poland – E. Asia	♂	V
2	*S. alba* var. *alba*†	White willow	*Salix*	Eur.	?	N, Q
3	*S. alba* 'Britzensis'	-	*Salix*	hort.	♂	N, T, V
4	*S. alba* var. *caerulea*	Cricket bat willow	*Salix*	Eur.	♀	T, V
5	*S. alba* 'Chermesina'	-	*Salix*	hort.	? ♂	N, T, V
6	*S. alba* var. *argentea* (*S. alba* var. *sericea*)	Silver willow	*Salix*	Eur.	?	T, V
7	*S. alba* var. *vitellina*†	Golden willow	*Salix*	Eur.	♀	N, V
8	*S. alpina*	-	*Chamaetia*	Eur.	?	N
9	*S. apoda*	-	*Chamaetia*	E. Eur.	?	N, T
10	*S. arbuscula*	Mountain willow	*Chamaetia*	Eur. – Siberia	?	N
11	*S. babylonica* †	Weeping willow	*Salix*	China	♀	N, Q, V, W
12	*S. bockii*	-	*Vetrix*	China	♀	N
13	*S.* x *boydii* (*S. lapponum* x *S. reticulata*)	-	*Chamaetia*	Britain	♀	N, T, V
14	*S. caprea* 'Pendula'	Kilmarnock willow	*Vetrix*	hort.	♀	N, Q, V, W
15	*S. chilensis*†	Chilean willow	*Salix*	Chile	?	N, V
16	*S. cinerea* 'Tricolor'	Variegated grey sallow	*Vetrix*	hort.	?	V
17	*S. daphnoides*	Violet willow	*Vetrix*	Scandinavia	?	Q, V
18	*S. elaeagnos*	Hoary willow	*Vetrix*	Eur., W. Asia	?	V
19	*S.*'Erythroflexuosa' (*S. matsudana* 'Tortuosa' x *S sepulcralis* var. *chrysocoma*)	Golden tortured willow	*Salix*	hort.	?	N, V
20	*S. fargesii*	-	*Salix*	China	?	N, T, V
21	*S.* x *finnmarchica* (*S. myrtilloides* x *S. repens*)	-	*Chamaetia*	Norway, Sweden	? ♂	N
22	*S. gracilistyla* var. *melanostachys*	-	*Vetrix*	Japan	♂	N, Q, T, V
23	*S.* x *grahamii* (*S. aurita* x *S. herbacea* x *S. repens*)	-	*Chamaetia*	Britain	♀	N
24	*S.* x *moorei* (*S. aurita* x *S. herbacea* x *S. repens*)	-	*Chamaetia*	Ireland	♀	V
25	*S. hastata* 'Wehrhahnii'	-		N. Amer.	♂	T, V
26	*S. helvetica*	Swiss willow	*Vetrix*	Eur.	?	T, V
27	*S. integra* 'Hakuro-nishiki'	-	*Vetrix*	Japan, Korea	?	Q, V
28	*S. irrorata*	-	*Vetrix*	N. Amer.	?	V
29	*S. lanata* 'Mark Postill'	Woolly willow	*Chamaetia*	Eur., Russia	♀	N, T
30	*S. lapponum*	Lapland willow	*Chamaetia*	Eur., Russia	?	N
31	*S. magnifica*	-	*Salix*	China	?	V

32	*S. matsudana (*syn. *S. babylonica* var. *pekinensis)*†	Peking willow	*Salix*	China, Mongolia, Korea	?	N
33	*S. matsudana* 'Tortuosa'†	Tortured willow	*Salix*	hort.	♀	N, Q, V, W
34	*S. myrsinifolia* (*S. nigricans*)	Dark-leaved willow	*Vetrix*	Eur., Russia	?	T, V
35	*S. myrtilloides* 'Pink Tassels'	Swamp willow	*Chamaetia*	Eur., Asia	♂	T, V
36	*S. purpurea* f. *gracilis* (*S. purpurea* 'Nana')	Dwarf purple willow	*Vetrix*	? hort.	?	V
37	*S. purpurea* 'Pendula'	Weeping purple willow	*Vetrix*	hort.	♀	V
38	*S. repens* var. *argentea*	Silver creeping willow	*Chamaetia*	Eur.	?	N, V
39	*S. repens* 'Iona'	Creeping willow	*Chamaetia*	hort.	♂	V
40	*S. repens* 'Voorthuizen'	Creeping willow	*Chamaetia*	hort.	♀	N
41	*S. retusa*	-	*Chamaetia*	Eur.	?	V
42	*S. sachalinensis* (*S. udensis*)	-	*Vetrix*	Japan	?	V
43	*S.* x *sepulcralis* var. *chrysocoma*†	Golden weeping willow	*Salix*	hort.	?	N, Q
44	*S. serpyllifolia*	Thyme-leaved willow	*Chamaetia*	Eur.	?	N, V
45	*S. subopposita*	-	*Chamaetia*	Japan, Korea	?	N
46	*S. udensis* 'Aurea'	-	*Chamaetia*	Japan	?	V
47	*S. yezoalpina*	-	*Chamaetia*	Japan	?	N, T

† - Taxa currently known to be naturalised in Australia

State(s) in which available

N	New South Wales
Q	Queensland
T	Tasmania
V	Victoria
W	Western Australia

Appendix 4: Legislation relating to maintenance of biodiversity and riparian management relevant to willow control.
Source: Cripps (1999)

	Legislation
NSW	*Native Vegetation Conservation Act 1997* *Threatened Species Conservation Act 1995* *Local Government Act 1993* *Murray-Darling Basin Act 1992* *Catchment Management Act 1989* *Protection of the Environment Operations Act 1988* *Wilderness Act 1987* *Water Administration Act 1986* *Environmental Planning and Assessment Act 1979* *National Parks and Wildlife Act 1974* *Rivers and Foreshore Improvement Act 1948* *New South Wales – Queensland Border Rivers Act 1947* *Soil Conservation Act 1938* *Forestry Act 1916* *Irrigation Act 1912* *Western Lands Act 1901* *Crown Lands Act 1898*
Victoria	*Coastal Management Act 1995* *Catchment and Land Protection Act 1994* *Murray-Darling Basin Act 1993* *Heritage Rivers Act 1992* *Water Act 1989* *Flora and Fauna Guarantee Act 1988* *Conservation, Forests and Lands Act 1987* *Planning and Environment Act 1987* *Land Conservation Act 1970* *Land Conservation Act 1970* *Forests Act 1958* *Land Act 1958*
Queensland	*Integrated Planning Act 1997* *Murray-Darling Basin Act 1996* *Coastal Protection and Management Act 1995* *Environment Protection Act 1994* *Fisheries Act 1994* *Land Act 1994* *Local Government Act 1993* *Nature Conservation Act 1992* *Water Resources Act 1989* *Soil Conservation Act 1986* *Rural Lands Protection Act 1985* *The South-East Queensland Waters Act 1979* *River and Improvement Trust Act 1940*
Western Australia	*Seeds Act 1981* *Agriculture and Related Resources Protection Act 1976* *Plant Diseases Act 1914*

South Australia	*Water Resources Act 1997* *Development Act 1993* *Environment Protection Act 1993* *Murray-Darling Basin Act 1993* *South Eastern Water Conservation and Drainage Act 1992* *Wilderness Protection Act 1992* *Native Vegetation Act 1991* *Pastoral Land Management and Conservation Act 1989* *Soil Conservation and Land Care Act 1989* *Forestry Act 1983* *National Parks and Wildlife Act 1972* *Water Conservation Act 1936*

Tasmania	*Weed Management Act 1999* *Land Use Planning and Approvals Act 1993* *Local Government Act 1993* *State Policies and Projects Act 1993* *Forest Practices Act 1985* *Crown Lands Act 1978* *Water Act 1957*

ACT	*Water Resources Act 1998* *Environment Protection Act 1997* *Commissioner for the Environment Act 1993* *Land (Planning and Environment) Act 1991* *National Land Ordinance 1989* *Australian Capital Territory (Planning and Land Management)Act 1988* *Nature Conservation Act 1980* *Lakes Act 1976* *Cotter River Act 1914*

Appendix 5: Process used to develop the national *Willow Strategic Plan*

The national *Willow Strategic Plan* is the product of several months of planning. A national workshop was held at Attwood (Melbourne) on 22nd March, 2000, which led to the development of a Taskforce and the national strategy – a draft of which was released in June 2000.

Individuals and Organisations that contributed to the national *Willow Strategic Plan*:

The lead agency for the formation of the national *Willow Strategic Plan* was the Department of Natural Resources and Environment (Victoria).

Technical Editor – Geoff Carr of Ecology Australia provided unpublished technical information, reviewed and edited the strategic plan.

Collators –Sarah Keel BSc (Hons), and Patrick Pigott, MSc.

The delegates at the March national workshop, who developed the outline for the strategy and commented on the resultant draft were;

- CSIRO Forestry & Forest Products (Hon.) (Kurt Cremer)
- Ecology Australia (Geoff Carr)
- Greening Australia (Simon Lang - Cooma, NSW)
- NRE (Vic) KTRI (Sarah Keel, Patrick Pigott)
- Land Management Council Victoria + Farmer (Alex Arbuthnott)
- Melbourne Water (Vic) (Roger Lord)
- Monash University (Vic) (Dennis O'Dowd)
- North East Catchment Management Authority (Vic) (John Riddiford - Chair)
- North Central Catchment Management Authority (Vic) (Greg Peters)
- Parks Flora and Fauna (NRE, Vic) (Hugh Bramwells)
- Primary Industry, Water & Environment (Tas) (Mark Boersma)
- Catchment & Water Division (NRE, Vic) (Kishor Melvani)
- Weed Science Society of Victoria (Kelly Raymond)

Facilitator:

- John Thorp (Project Manager, National Weeds Strategy)

Members of the National Willows Taskforce are:

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- Department of Land and Water Conservation (NSW) (Allan Raine)
- Environment Victoria (Geoff Carr)
- Greening Australia (Simon Lang - Cooma, NSW)
- NRE (Vic) KTRI (Sarah Keel)
  PFF Division (Hugh Bramwells, Julia Reed)
  CAW Division (Kishor Melvani, John Oates)
- Melbourne Water (Vic) (Roger Lord)
- North Central Catchment Management Authority (Vic) (Greg Peters)
- North East Catchment Management Authority (Vic) (John Riddiford - Chair)
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Cover photograph: Flowering male Crack Willow (*Salix fragilis* var. *fragilis*).
Photo: GW Carr

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- Environment Planning & Legislation (ACT) (Geoff King)
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- Latrobe Landcare Group (Ron Hedditch)
- Mallee Catchment Management Authority (Scott Glyde)
- Nursery Industry Association of Victoria (David Gordon)
- Royal Botanic Gardens, Sydney (Surrey Jacobs)
- Swan River Trust (Darryl Miller)
- Tasmanian Farmers and Graziers Association (Meredith Roodenrys)
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Primary Industry, Water & Environment (Tas)
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