Approved Recovery Plan

Wollemia nobilis
Wollemi Pine
Recovery Plan

January 2007

Australian Government

Department of Environment and Conservation (NSW)

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Wollemi Pine Recovery Plan

Executive Summary

This document constitutes the formal Commonwealth and New South Wales Recovery Plan for the Wollemi Pine, and as such considers the conservation requirements of the species across its known range. It identifies the future actions to be taken to ensure the long-term viability in nature of the Wollemi Pine and the parties who will carry out these actions.

Wollemi Pine is listed as endangered on Schedule 1 of the NSW *Threatened Species Conservation Act 1995* and as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. It is a tree which grows to 40 m and is currently known from only one population consisting of several stands of fewer than 100 adult plants and about 200-300 juveniles/seedlings from within Wollemi National Park. Stands within Wollemi National Park are threatened by dieback from the pathogen *Phytophthora cinnamomi* and potentially threatened by the further introduction of plant pathogens and weeds, soil compaction, seedling damage, collectors and catastrophic fire events. Stands may also be threatened by changes to the habitat through the effects of climate change.

This recovery plan for the Wollemi Pine was prepared by the Wollemi Pine Recovery Team in accordance with the requirements of the *Threatened Species Conservation Act* 1995 (TSC Act), and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999. The plan was prepared in consultation with a recovery team consisting of DEC land managers, researchers and specialists in the biology and ecology of the species.

To provide for the future recovery of the Wollemi Pine, this recovery plan advocates a program that:

- protects and maintains the known stands and their habitat from threatening processes in the long term;
- provides a greater understanding of the biology of the species and associated species;
- maintains and utilizes representative off-site populations in botanic gardens;
- continues the implementation of an education and awareness program; and
- supports the commercial release of Wollemi Pines.

It is intended that this recovery plan will be implemented over a five-year period. The cost to implement the plan over that period is estimated to be between $1,251,000 and $1,356,000 and will largely be provided for by a proportion of the royalties from the commercial release of Wollemi Pines in 2005 and recurrent funds. This figure includes significant contingency funds to implement the access policy and manage potential threats to the Wollemi Pine in the catchment such as wildfire and weed invasion.

Lisa Corbyn
Director-General

Bob Debus MP
Minister for the Environment

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The research into, and management of, Wollemi Pine has been a joint effort of the Department of Environment and Conservation's (DEC) Parks and Wildlife Division (PWD), Policy and Science Division (PSD), Botanic Gardens Trust (BGT) and Environment Protection and Regulation Division (EPRD). This Recovery Plan is a revision of the 1998 Plan and has been the combined effort of many people who have contributed to the survey and research on the species. The DEC would like to thank the following people:-

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1 Introduction

The Wollemi Pine is a tree that grows to 40 metres, frequently coppicing from the base. The species is endemic to the Wollemi National Park, where it is currently known from one population in several stands of fewer than 100 adult trees and about 200-300 juveniles/seedlings in total. There are a number of threats to the survival of the species, including the introduction of pathogens, illegal collection of plant material and catastrophic fire events.

This document constitutes the formal NSW and national recovery plan for *Wollemia nobilis* and as such considers the requirements of the species across its known range. The recovery plan describes the current conservation status and summarises current biological and ecological knowledge of the species, documents past and current management actions undertaken, and details a program for the next five years to promote the recovery of the species.

2 Legislative context

2.1 Legal status

Wollemi Pine (*Wollemia nobilis* W.G. Jones, K.D. Hill & J.M. Allen) of the family Araucariaceae is listed as an endangered species on Schedule 1 of the NSW *Threatened Species Conservation Act 1995* (TSC Act) and under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The consequences of listing a species under the TSC Act and the EPBC Act include that:

- consideration must be given to the species when assessing the impacts of developments and activities, with the aim of minimising adverse impacts; and
- other actions that are likely to result in the harming or picking of that species or damage to its habitat must be licensed.

2.2 Recovery plan preparation

The TSC Act provides a legislative framework to protect and promote the recovery of threatened species, endangered populations and threatened ecological communities in NSW. Under this legislation the Director-General of the NSW Department of Environment and Conservation (DEC) may prepare recovery plans for any species, populations or ecological communities listed as critically endangered, endangered or vulnerable on the TSC Act schedules. Similarly, the EPBC Act requires the Commonwealth Minister for the Environment and Water Resources to ensure that there is approved conservation advice in place for each nationally-listed species and community. The Commonwealth Minister may also require the preparation of a recovery plan for nationally listed species and communities or adopt plans prepared by others including those developed by State agencies. Both Acts include specific requirements for the matters to be addressed by recovery plans and the administrative process for preparing recovery plans.

This recovery plan has been prepared to satisfy the requirements of both the TSC Act and the EPBC Act and therefore will be the only recovery plan in operation for the species. It is the intention of the Director-General of DEC to forward this final version of the recovery plan to the Commonwealth Minister for the Environment and Water Resources for adoption, now it has been approved by the NSW Minister for the Environment.

The TSC Act requires that, when preparing a recovery plan, consideration must be given to any species knowledge or interests that indigenous people may have in the species and the measures to be contained in the plan. The EPBC Act requires that in the preparation of a recovery plan regard must be had to the role and interests of indigenous people in the conservation of Australia's biodiversity (see Section 5.1).

2.3 Recovery plan implementation

The TSC Act requires that a public authority must take appropriate measures to implement the actions in a recovery plan for which they have agreed to be responsible. Public authorities identified as responsible for the implementation of recovery plan actions are required by the TSC Act to report on measures taken to implement those actions. In addition, the Act specifies that public authorities must not make decisions that are inconsistent with the provisions of the plan. The only public authority responsible for actions in this plan is the DEC.

2.4 Relationship to other legislation and planning instruments

The TSC Act and the EPBC Act interact with other NSW and Commonwealth legislation and planning instruments in a number of ways. Legislation which is also relevant to threatened species protection, management and recovery in NSW includes the

- *Environmental Planning and Assessment Act 1979*
- *National Parks and Wildlife Act 1974*

- *Native Vegetation Act 2003*
- *Rural Fires Act 1997*
- *Rural Fires and Environment Assessment Legislation Amendment Act 2002* and
- *Local Government Act 1993*.

2.5 Key Threatening Processes

The EPBC Act and the TSC Act provide for the identification and listing of key threatening processes. A key threatening process (KTP) is a process that threatens, or has the capability to threaten, the survival or evolutionary development of species, populations or endangered ecological communities. Several key threatening processes, as well as a number of other factors or activities which are identified in Section 8.1, are recognised as threatening the survival of the Wollemi Pine.

Three key threatening processes currently listed under the TSC Act are likely to, or may potentially, threaten the Wollemi Pine, as discussed in Section 8.1. These KTPs are:

- *Anthropogenic climate change;*
- *Infection of native plants by* Phytophthora cinnamomi; *and*
- *High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.*

Two key threatening processes listed under the EPBC Act are likely to, or may potentially threaten Wollemi Pine. These KTPs, essentially the same as some of those listed under the TSC Act, are:

- *loss of climatic habitat caused by anthropogenic emissions of greenhouse gases*; and
- *dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)*.

2.6 Critical habitat

The TSC Act makes provision for the identification and declaration of critical habitat. Under the TSC Act, critical habitat may be identified for any endangered species, population or ecological community occurring on NSW lands. Once declared, it becomes an offence to damage critical habitat (unless the action is exempted under the provisions of the TSC Act) and a Species Impact Statement is mandatory for all developments and activities proposed within declared critical habitat.

A declaration for critical habitat for Wollemi Pine under the TSC Act has been finalised in conjunction with this recovery plan. The declaration identifies habitat considered to be critical to the survival of Wollemi Pine.

2.7 Environmental assessment

The New South Wales *Environmental Planning and Assessment Act 1979* (EP&A Act) requires that consent and determining authorities, and the Director-General of DEC, as a concurrence authority, consider relevant recovery plans when exercising a decision-making function under Parts 4 and 5 of the EP&A Act. Decision-makers must consider known and potential habitat, biological and ecological factors and the regional significance of individual stands. The DEC is the only public authority currently known to have a decision making function in relation to Wollemi Pine. Additional public authorities may have responsibilities if the species is located in other areas in the future.

The EPBC Act regulates actions that may result in a significant impact on nationally listed threatened species and ecological communities. It is an offence to undertake any such actions in areas under State or Territory jurisdiction, as well as on Commonwealth-owned areas, without obtaining prior approval from the Commonwealth Minister for the Environment and Water Resources. As the Wollemi Pine is listed nationally under the EPBC Act, any person proposing to undertake actions likely to have a significant impact on this species should refer the action to the Commonwealth Minister for the Environment and Water Resources for consideration. The Minister will then decide whether the action requires EPBC Act approval. Further information concerning the operation of the EPBC Act environmental assessment requirements can be obtained from the Department of the Environment and Water Resources.

Wollemi Pine is also one of the World Heritage values of the Greater Blue Mountains World Heritage Area (GBMWHA) and would need to be assessed under the EPBC World Heritage trigger as well as the Threatened Species and Ecological Communities trigger.

3 Conservation status

Wollemi Pine (*Wollemia nobilis* W.G. Jones, K.D. Hill and J.M. Allen) of the family Araucariaceae is currently known from one population of fewer than 100 adult trees in several stands and about 200-300 juveniles/seedlings in total from within the Wollemi National Park and the Greater Blue Mountains World Heritage Area.

Wollemi Pine is listed as endangered in NSW and under the EPBC Act.

4 Description and taxonomy

4.1 Description

Wollemi Pine is a monoecious conifer tree that grows to 40 metres (Figure 1). It has an unusual growth habit of reiteration, which results from frequent self-coppicing at the base (Figure 2) and primary branches are plagiotropic and short lived (Hill 1995; Hill 1997). Trunks range up to one metre in diameter. The crown is slender and columnar. The bark peels in thin, fragile, equidimensional dark red-brown scales on younger stems. On older trunks the bark becomes densely covered with soft and spongy nodules or tubercules to 10 mm diameter and 15 mm long (Figure 3a) which form a layer up to 20 mm deep (Jones *et al*. 1995). The wood has distinct and annual growth rings (Banks 2002) and like other members of Araucariaceae has alternate bordered pits in the walls of tracheids (Heady 2002).

There are three different kinds of shoots or branches produced according to the position of the branches. These are:

- adult vertically growing shoots (orthotropic) (Figure 3a), which have a helical arrangement of leaves. The leaves taper to an acute angle at the tip, have a sharp point, are narrowly triangular and 3-10 mm long and 2-4 mm wide at the base. Primary branches arise at the apex of these vertical shoots and are plagiotropic (lateral) and short-lived;
- short-lived adult lateral branches (plagiotropic), which are initially nearly vertical then become horizontal and later pendulous. Leaves are opposite or sub-opposite and present the upper surface to the sky (Figure 3b) (Jones *et al*. 1995). Male (pollen) and female (seed) cones are terminal on these branches from one to ten years of age with no particular pattern to position. After bearing cones, branches may continue to grow vegetatively and produce cones. Branches grow for up to twelve years before cleanly abscising (Meagher and Offord unpubl.); and
- juvenile and lower canopy lateral shoots, which are horizontal, with leaves arranged in two opposite ranks. The leaves are twisted with the upper surface towards the sky and are linear to narrow triangular (Figure 2) (Jones *et al*. 1995). Branches occurring in higher light have a leaf arrangement similar to adult shoots and may bear pollen cones (Meagher & Offord, unpubl.).

Subsidiary orthotropic (upright) branches grow from epicormic shoots that develop from the trunk in a scale leaf axil (Burrows *et al*. 2003) or from adventitious shoots arising from just below the cotyledons (Burrows, Meagher and Offord unpubl.).

The xylem structure at the base of lateral branches is unusual in this species which may account for the clean abscising and dropping of branches (Burrows *et al*. unpubl.).

Male cones are cylindrical with sporophylls spirally arranged (Figure 4). Female cones are spiny with a fully fused bract-scale complex (Figure 5). The scales are spirally arranged and are shed on maturity. The seeds are flat, brown and papery with a single circumferential wing, free from bract-scale complex. Seeds are 7-11 mm long and 5-7 mm wide, and 5-9 mm wide including wing (Jones *et al*. 1995) (Figure 6).

4.2 Taxonomic significance

Wollemia is a monotypic genus with only a single extant species known. Wollemi Pine is of considerable significance in the study of the evolutionary relationships of early Gondwanan flora. It has contributed to understanding of structures in fossil Araucariaceae (Macphail *et al*. 1995; Chambers *et al*. 1998; Dettmann and Jarzen 2000). Its survival has informed our understanding of long-term regional floristic change (Briggs 2000).

Wollemia is a relatively newly described genus in the gymnosperm family Araucariaceae, and although it possesses morphological characteristics from the related genera *Agathis* and *Araucaria*, it also possesses unique features (Hill 1995) (Table 1 from Meagher and Offord in press). The evolutionary relationships within the Araucariaceae are poorly known. *Wollemia* was confirmed to be distinct by Gilmore and Hill (1997) through DNA sequencing of the plastid gene *rbc*L. This sequence data combined with different ranges of other conifer taxa suggests that *Wollemia* derived prior to *Agathis* and *Araucaria* and may be the earliest derived genus in Araucariaceae (Setoguchi *et al*. 1998) or *Wollemia* is a sister group to *Agathis* with these two forming a clade that is sister to *Araucaria* (Gilmore and Hill 1997, Stefanović *et al*. 1998).

Figure 1. Self-coppicing habit of Wollemi Pine emerging above the rainforest canopy, showing adult phase foliage.
(Photo: Jaime Plaza © Botanic Gardens Trust Sydney)

Figure 2. Self-coppicing habit of Wollemi Pine below the rainforest canopy, showing steep slope with dense litter layer and juvenile phase foliage.
(Photo: Patricia Meagher © Botanic Gardens Trust Sydney)

Figure 3a. Wollemi Pine stems, showing bark detail and axillary buds developing.
(Photo: Jaime Plaza © Botanic Gardens Trust Sydney)

Figure 3b. Wollemi Pine adult plagiotropic foliage, with pollen and seed cones developing on branch tips. (Photo: Jaime Plaza © Botanic Gardens Trust Sydney)

Figure 4. Male strobili of Wollemi Pine develop terminally on 1st order juvenile or adult plagiotropic branches.
(Photo: Jaime Plaza © Botanic Gardens Trust Sydney)

Figure 5. Female strobili of Wollemi Pine occurring terminally on 1st order adult phase plagiotropic branches .
(Photo: Jaime Plaza © Botanic Gardens Trust Sydney)

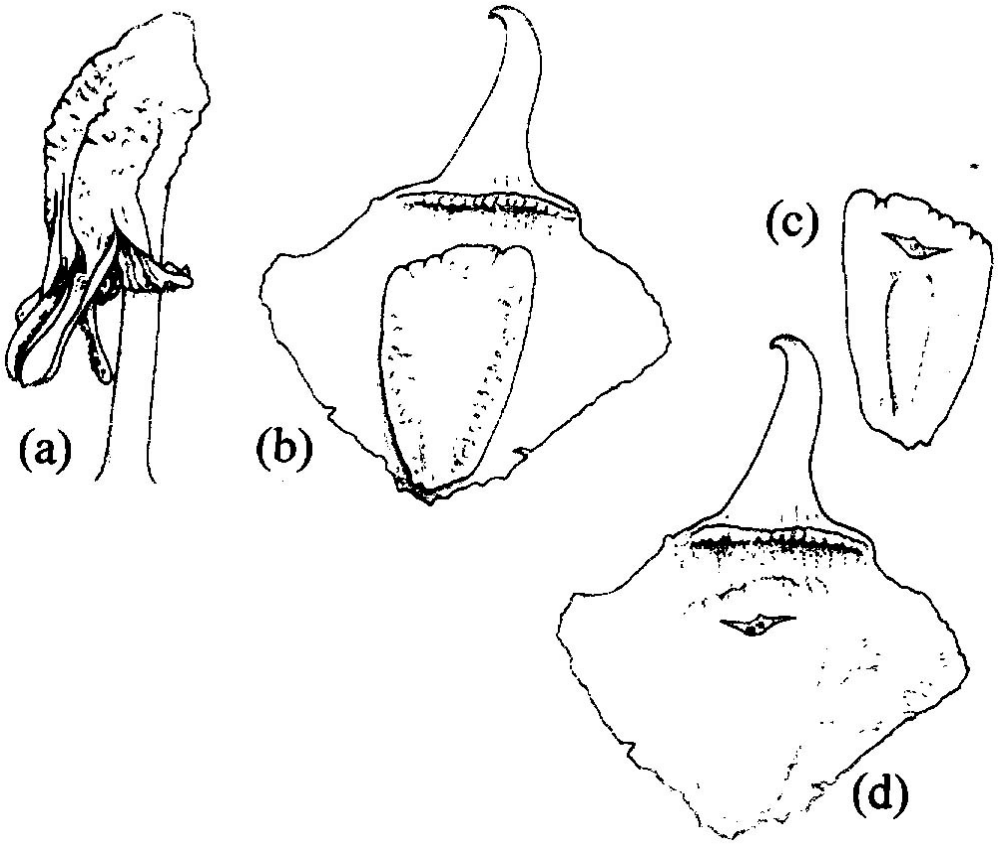

Figure 6. Reproductive parts of Wollemi Pine (a) microsporophyll, (b) female bract-scale complex with attached seed, (c) seed, (d) female bract-scale complex with seed detached.
(Drawing by D. Mackay)

Table 1: Comparison of some *Wollemia nobilis* characters with extant Araucariaceae, adapted from Meagher and Offord 2002, and in press.

Character	Closest Araucariaceae or unique to *Wollemia*	Source
rbcL gene from chloroplast DNA	*Agathis*	Gilmore and Hill 1997, Setoguchi *et al*. 1998
28s rRNA gene	*Agathis*	Stefanovic *et al*. 1998
Leaf anatomy	*Araucaria*	Burrows and Bullock 1999
Leaf axil anatomy	*Agathis* & *Araucaria*	Burrows 1999
Cuticle morphology	*Araucaria* (mostly Eutacta)	Chambers *et al*. 1998, Hill 2003
Cone scale shape and size	*Araucaria* (mostly Eutacta)	Chambers *et al*. 1998
Seed wing and attachment to scale	*Agathis*	Chambers *et al*. 1998
Pollen	*Agathis* & *Araucaria*	Dettmann and Jarzen 2000, Labreau-Callen and Meagher (in press)
Mycorrhizae: 1.Paris-type arbuscular mycorrhizae 2.ectendomycorrhizae	 *Agathis* & *Araucaria* Unique to *Wollemia*	McGee *et al*. 1999
Steam volatile oils	*Agathis australis*[1]	Brophy *et al*. 2000
Architecture Architectural model (modified Cook model) Adaptive reiteration, both branching and coppicing	 Unique to *Wollemia* Unique to *Wollemia*	Hill 1997
Seed storage	Orthodox – similar to small seeded Araucariaceae	Offord *et al*. 2005

[1]The major diterpene in *W. nobilis* is (+)-16 kaurene, which it is reported to be (-)-16 kaurene in *Agathis australis* (Brophy *et al*. 2000).

5 Distribution and habitat

5.1 Current and historical distribution

Wollemi Pine is a relict species currently known to occur in several stands in Wollemi National Park on the Central Tablelands of New South Wales in south eastern Australia (see Figure 7). The known stands are located in a deep sandstone gorge. The gorge walls are composed of Triassic sandstones from the Narrabeen Group.

Evidence suggests that major gymnospermous forests or woodland strata were once widespread in Australia, and Araucariaceae fossils have been found in every Australian state from the Tertiary period (Lange 1982). A decline in the distribution of Araucariaceae species appears to have taken place over millions of years through major climate changes, the evolution and dominance of the environment by angiosperms, and a probable severe reduction in numbers as a result of increasing fire frequency and intensity. The distribution of Wollemi Pine may have undergone a decline similar to that of other species of Araucariaceae.

In the fossil record the Araucariaceae first appeared in the late Triassic period (c. 210 million years before present (BP)) and had a world-wide spread (both hemispheres) in the Jurassic (205-145 million years BP) and Cretaceous (145-65 million years BP) periods. The distribution of the Araucariaceae contracted at the end of the Cretaceous (c. 65 million years BP) when the family became extinct in the northern hemisphere. The genera in the southern hemisphere have slowly declined in distribution and diversity since that time (Hill and Scriven 1998) and prior to the discovery of *Wollemia*, was known from South America, New Zealand, north-eastern Australia, New Guinea, Vanuatu (New Hebrides), Malesia, the Philippines and New Caledonia by only two extant genera, *Araucaria* and *Agathis*. Palaeobotanical analysis indicates that the pollen of Wollemi Pine is similar to the fossil pollen of a species of *Dillwynites* (Macphail *et al*. 1995; Chambers *et al*. 1998; Dettmann and Jarzen 2000), which is known from the late Cretaceous (c. 91

million years BP) (Macphail *et al*. 1995) to about 2 million years BP (Chambers *et al*. 1998). There is no conclusive fossil evidence to indicate when the Wollemi Pine evolved but its pollen is very similar to that of more ancient species (Dettmann and Jarzen 2000). *Wollemia* pollen peaked in abundance 65-34 million years ago then steadily declined in response to cooling and drying during the northward movement of Australia (McLaughlin and Vajda 2006).

The discovery of *Wollemia* has made it possible to reassess and compare a range of araucarian fossils going back about 116 million years to the early Cretaceous. From the study by Chambers *et al*. (1998) it seems likely that *Wollemia* was possibly present over an extensive area of eastern Australia and perhaps over a very much wider geographic range including India, Antarctica, New Zealand and southern South America. For example, *Araucarioides* fossil leaves from Tasmanian deposits dated to the early Tertiary (about 50 million years BP) closely match juvenile leaves of Wollemi Pine and cone scale fossils from the same bed compare to Wollemi Pine cone scales (Hill 1996).

There is anecdotal evidence that European settlers may have had some knowledge of the existence of the species. However, there is as yet no evidence of prior indigenous knowledge (C. Pavich pers. comm.) and so no indigenous interests would be affected by this plan.

5.2 Tenure

The known stands of Wollemi Pine occur within Wollemi National Park, which is managed by the PWD of DEC. Wollemi National Park is within the Greater Blue Mountains World Heritage Area and is protected by the *Environment Protection and Biodiversity Conservation Act 1999*.

6 Habitat

6.1 Vegetation

Wollemi Pine occurs in the warm temperate rainforest and rainforest margins in a *Eucalyptus* spp. forest/woodland complex within the Sydney Sandstone Biome of the eastern coast and tablelands of New South Wales. The rainforest is included in sub-alliances 36 or 37 in Floyd (1990).

Most individuals of Wollemi Pine occur on large ledges or grow from crevices in the cliffs. Canopy species growing with Wollemi Pine include Coachwood (*Ceratopetalum apetalum*), Sassafras (*Doryphora sassafras*), Lilly Pilly (*Acmena smithii)* and Grey Myrtle (*Backhousea myrtifolia*). Understorey species include the Soft Tree Fern (*Dicksonia antarctica*)*,* Rough Tree Fern (*Cyathea australis*)*,* Bolwarra (*Eupomatia laurina*), Umbrella Fern (*Sticherus flabellatus*)*,* Bristle Fern (*Blechnum cartilagineum*)*,* King Fern (*Todea barbara*)*,* Sword Sedge (*Lepidosperma urophorum*)*,* Wonga Vine (*Pandorea pandorana*), Native Jasmine (*Morinda jasminoides*) and Silkpod (*Parsonsia straminea*). Dry sclerophyll species such as the trees Sydney Peppermint (*Eucalyptus piperita*) and Grey Gum (*E. punctata*) and shrubs such as the Tea Tree (*Leptospermum trinervum*) and the Geebung (*Persoonia linearis*) occur on the upper slopes of Wollemi Pine groves (Benson and Allen unpubl.).

6.2 Soil characteristics

Soils are sandstone-derived boulder alluvium, with high organic matter and some shale component (Jones *et al*. 1995). The soil is very shallow. In some areas there is little or no soil layer. Roots of Wollemi Pine plants grow into rock fissures or extend for tens of metres away from the main groups of trunks. Nutrient levels are low and the soil is extremely acidic, often in the range pH 3-4, with low levels of most elements although high in aluminium, sulphate and iron. There are patches of highly saline soil (Offord *et al*. 1996; C. Offord unpubl.).

Senescent branches fall and contribute substantially to the litter layer (Hill 1995). Decomposition of these fallen branches may contribute to the low pH of the soil. Acidity has not been found to inhibit growth of potted seedlings. On the other hand, the lack of nutrients may contribute to the slow growth of mature trees and seedlings (Offord *et al*. 1996; Meagher and Offord unpubl.).

6.3 Climate summary

Climate is typical of low altitude Blue Mountains. Air temperature data recorded in Stand 1 for one year is presented in Figure 8, showing highest air temperatures recorded at the site in the months November-February, maximum 30°C. In winter the recorded maximum temperatures were ≤15°C and minimum near freezing from June to August.

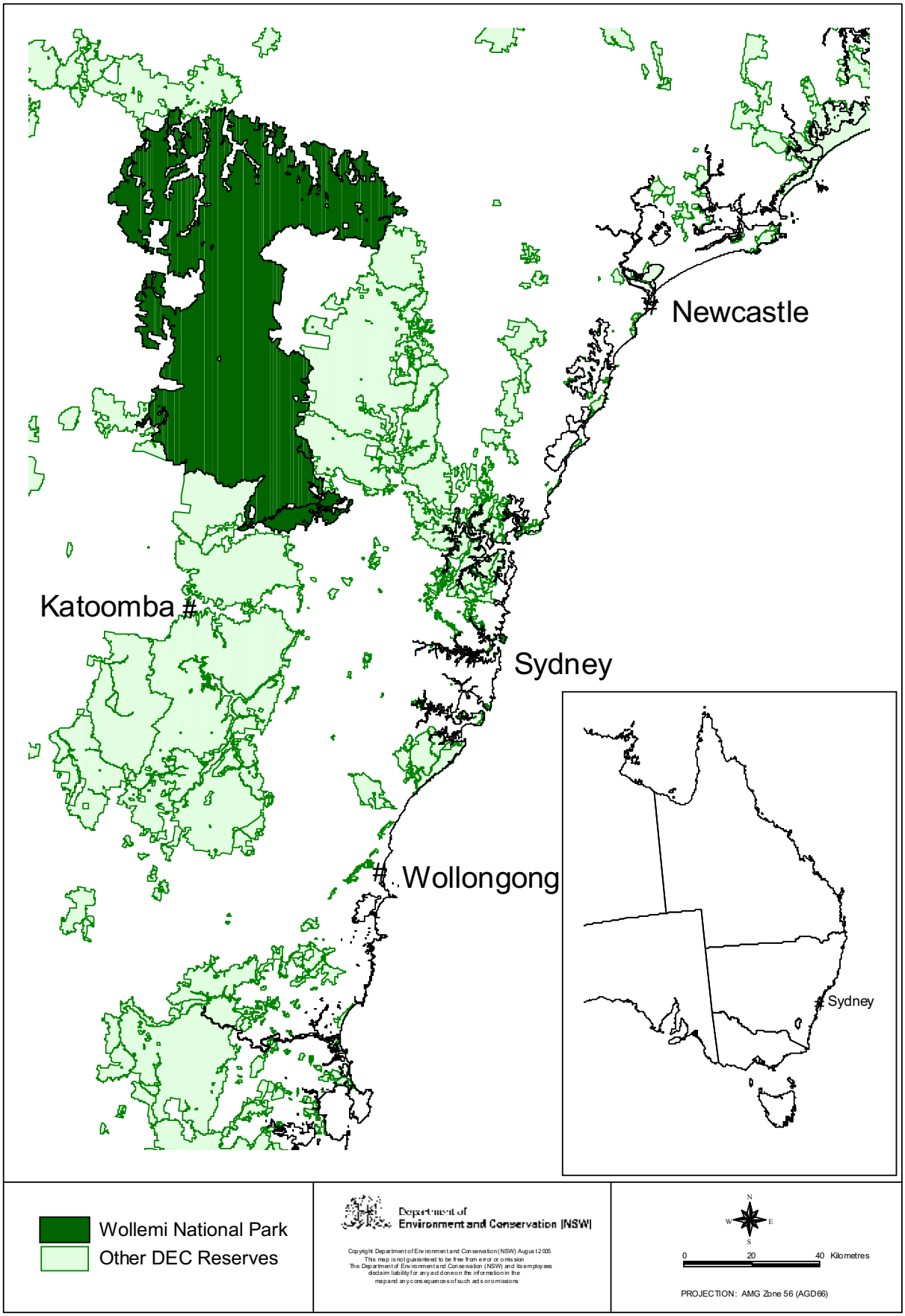

Figure 7. Location of Wollemi National Park, New South Wales

7 Biology and ecology

7.1 Habit, growth rate and longevity

The typical form of Wollemi Pine in the wild is a tall long-lived tree which has a self-coppicing habit (see Figure 2) (Hill 1997). Mature trees are usually multi-trunked with up to 22 stems of greater than 2 cm diameter (Benson unpubl.). The habit of coppicing makes it difficult to identify which trunks represent an individual tree. The height of the largest tree is 38.5 metres (Benson unpubl.) with most trees being between 10 and 30 metres (see Figure 9). The primary branches are only produced at the apical meristem and are short-lived and cleanly abscising. New primary branches are produced on epicormic shoots from the trunk which creates a branched crown.

Light controls the growth of seedlings in glasshouse conditions, with good growth rates in cultivation at between 25 and 75% ambient light. However, growth rates in the wild are very slow (see 7.3.5). High light causes 'sunburn' (photoinhibition) in seedlings in cultivation (Meagher, Offord and Martyn unpubl.). Growth is also affected by soil pH, with greater growth at low pH (pH 4.5) when compared to higher pH (~pH 6) in a potting mix trial (Meagher and Offord unpubl.).

The wood of Wollemi Pine produces distinct and annual growth rings which makes it possible to estimate the age of an individual trunk. At Stand 1, ring counts from wood of a fallen 40 m tall trunk suggest an estimated age of the trunk at around 400 years. Living trunks from five trees have also been cored to estimate the age and growth of the trunks. The data revealed a mean annual diameter increment of 2 mm but this varied across the sampled trunks and may be affected by competition and access to resources such as soil, light and water. There were three age cohorts for the sampled trunks: the youngest was around 50 years, three trees were around 145 years and the oldest was around 180 years (Banks 2002). However, there may also be several decades of slow growth when the trunks were small, that could extend the actual estimate of ages for each trunk. As there is no way of knowing how old the tree was before it produced a trunk it is impossible to age an individual tree. The current cohort of mature trees may have occupied its current site for well over 1,000 years.

7.2 Phenology

Wollemi Pine is a monoecious species with the reproductive organs borne on specialised leaves called sporophylls. These are arranged in cones or cone-like structures called strobili (Harden 1990). The male strobili (Figure 4) are located at the end of lateral growing juvenile and adult phase branches and are up to 153 mm long and 25 mm wide (Meagher and Offord unpubl.). At maturity the scales are numerous (more than 500), are helically arranged and turn from green to dark red-brown. Each has 4-9 elongated, drooping microsporangia in which the oval-shaped, granular, unwinged pollen is formed (Figure 6) (Jones *et al*. 1995). Male strobili appear in early to mid summer and mature in spring when pollen is shed (Meagher and Offord unpubl.). The species is wind pollinated.

Female strobili (Figure 5) are located at the end of leafy adult lateral growing (plagiotropic) branches. They are globular to broadly egg-shaped, measuring up to 125 mm long and 100 mm in diameter. Each strobilus has numerous bract-scales (between 250-300) flattened with a lateral wing. The female strobili are mid-green at first and then become brown and shed their individual bract-scales at maturity (Jones *et al.* 1995, Offord *et al*. 1999). Female cones can first be observed in mid to late summer, and they are pollinated in the following spring. Fertilisation occurs approximately one year after pollination, several months prior to seed cone maturation in late summer and early autumn when seed and bract-scale are shed (Prakash, Clarke, Meagher and Offord unpubl.).

7.3 Reproductive biology

7.3.1 Vegetative reproduction

The majority of adult trees appear to have a multi-trunked habit in the wild (Benson, Auld and Allen unpubl.). Vegetative reproduction (resprouting) occurs through meristems which are carried in the axils of vertical shoots, slowly developing into bud primordia within the thickening bark, an unusual characteristic in conifers which are usually devoid of bud-forming potential (Burrows 1999). These buds can replace the leading shoot if it is damaged but may also spontaneously develop into orthotropic shoots. Shoots may also arise from the basal region possibly through adventitious bud formation, which is poorly understood at the moment (Burrows *et al*. 2003). It appears that this unusual long-lived meristematic potential exists in most, if not all, leaf axils and many will develop into bud primordia. This slow but continued development provides a ready source of additional or replacement leaders and thus new branches and leaves. Coppicing, through either adventitious or epicormic buds, leads to a number of trunks of various ages in a mature

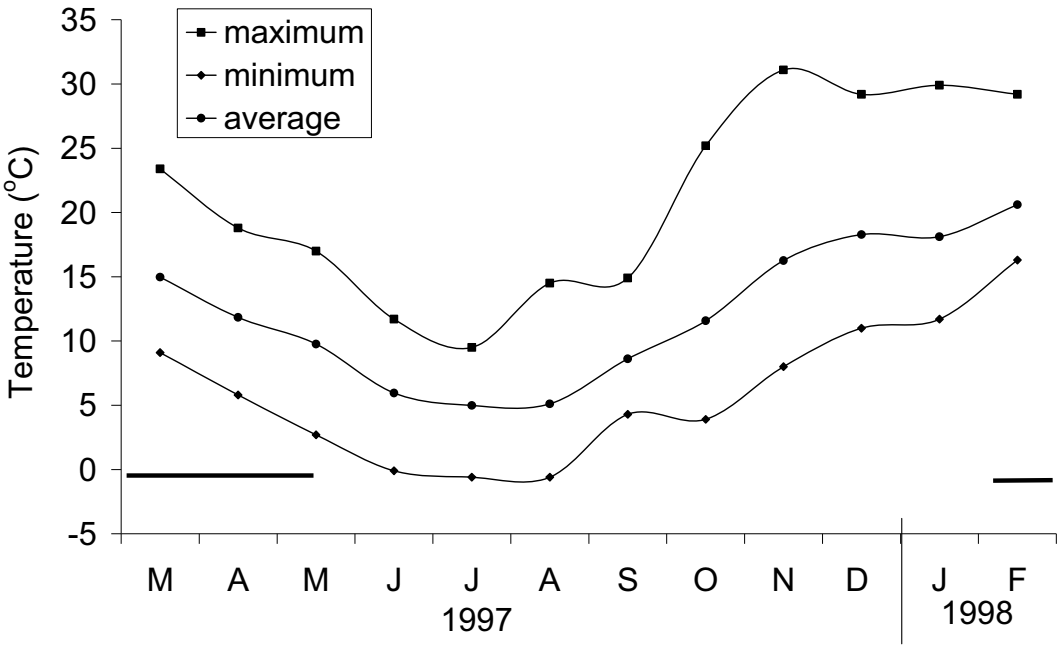

Figure 8. Monthly means of daily maximum, minimum and average air temperatures recorded in a Wollemi Pine stand (March 1997-February 1998). The dark line horizontal indicates the period of seed shed, from Offord *et al*. (1999).

tree. In the wild, most trunks arise from a common base. It is possible that trunks may also develop from the epicormic shoots of fallen branches that have taken root although there is no current evidence of this in the field. Root buds, which are uncommon for conifers, are known from several species in Araucariaceae, although there is also no current evidence of this occurring in the field.

7.3.2 Sexual reproduction

7.3.2.1 Breeding system

Because of a lack of reproductive material available, it has been difficult to study the breeding system of Wollemi Pine. Recent female cone production in cultivated plants has enabled some manipulations and easier access for repeated preliminary observations. The long time to seed cone maturity, around two years, means that no trends have yet been established although selfing has been observed (Meagher and Offord unpubl.).

Embryo development follows a similar pattern to *Agathis australis* (Owens *et al*. 1997). Interestingly in *Wollemia* many ovules are destroyed by active pollen tubes (Prakash and Clarke unpubl.).

7.3.2.2 Cone and seed production

Field observation indicates that female cones are only produced on adult phase leaf branches which occur above the rainforest canopy layer, whereas the male cones are produced on both adult and juvenile phase leaf branches, the latter only when in high light conditions. Both male and female cones develop from branches aged from one to ten years. After cones mature branches continue to grow vegetatively. No observations of further cone development on these branches have been made. In cultivation, male cones have developed on plants as young as five years of age with some branches producing cones again. Female cones have developed on two seedlings, one at eight years and the other at ten years (Meagher and Offord unpubl.).

Female cones and seeds mature from late summer to early winter. Generally, less than 10% of the approx. 250 ovules in female cones develop into viable seeds. In Stand 1, approximately 300 cones matured and dropped seed in the 1996 season, producing an estimated 4000 seeds (Offord *et al.* 1999). Cones have been observed with up to 22% viable seeds (Grace, Hargreaves and Meagher, unpubl.).

Birds, mainly parrots such as Crimson Rosellas (*Platycercus elegans*), have a significant impact on seed fall. Crimson rosellas have been observed in the wild grazing along the leafy branches and disturbing the shattered strobili. The coats of many seeds falling into the seed traps (erected 1996 and 1997) had been neatly split and the seed contents removed. Rodent or marsupial toothmarks have also been found on apparently viable seed. Predation from these

sources appears to destroy at least 37% of putative viable seed (Offord *et al.* 1999).

7.3.3 Seed viability and germination factors

Laboratory trials suggest that seeds of Wollemi Pine germinate in the temperature range 24-30ºC. However, the rate of germination is somewhat protracted unless the seeds are subjected to a period of cold moist stratification, at < 10ºC, followed by incubation in the optimal range. This period of stratification is analogous to the temperature regime experienced after seed fall (eg. see Figure 8), with seeds that survive after winter germinating quickly and taking advantage of moisture conditions in spring and early summer (Offord and Meagher 2001). Some seed germination also occurs in the field in late summer/autumn (Auld unpubl.).

Seeds are orthodox in regards to their storage capability i.e. they can be dried down to less than 10% moisture content and stored at low temperature (-18ºC) for up to five years, and possibly longer. Wollemi Pine seeds contain around 40% oil, including a short chain omega 3 fatty acid not commonly found in plants. Seeds stored at sub-optimal temperatures (> 0ºC) show decreased germinability and viability, which correlates with an increase in lipid degradation (Offord *et al.* 2005).

7.3.4 Seed dispersal and seedling establishment

Seeds of Wollemi Pine are light (ranging from 10-44 mg (Meagher & Offord unpubl.) and winged and it is most probable that they are dispersed within existing stands by wind. Aerial dispersal appears to be in a down-canyon direction as the seedlings occur up to 30 metres downslope of the nearest tree but are more limited upslope. It is possible that there may be very rare movement of seeds by birds if they feed on cones and move the cones to a feeding tree. This could account for the current distribution of *W. nobilis*. There may also be movement of seeds by water if floods coincide with seed fall (Offord *et al.* 1996).

Seedlings have been identified in the wild population by the presence on the plants of cotyledons and cotyledon scars. They occur in the wild on a variety of substrates including rocks, logs, tree ferns and in the soil litter layer (W. Jones, J. Allen, field obs.). Seedling recruitment in the wild may be influenced by moisture and light availability, competition from angiosperms and heavy litter cover from fallen lateral branches. Future changes in temperature and rainfall patterns due to climate change may also influence germination and seedling survival.

7.3.5 Seedling growth

Growth of seedlings in the wild is very slow. Current observations indicate growth rates of < 1cm and one new branch per year in seedlings and juveniles (Auld unpubl.). In cultivation, growth is much faster, with seedling growth rates of around 0.5 m per year after an initial lag period (*Offord et al*. 1999). Although mycorrhizal associations have been identified (McGee *et al*. 1999), as yet no mycorrhizal association appears necessary for seedling growth and survival in cultivation (Offord *et al*. 1999). Seedlings prefer soil pH in the range 4-6 (Offord and Meagher unpubl.).

7.4 Population structure

In all, there are fewer than 100 adult plants in the wild, distributed between several stands. All non-reproductive plants in the population, which are not identified as seedlings by the presence of cotyledons or cotyledon scars, have been classified as juveniles. Seedlings and juveniles are present at all stands indicating that successful sexual reproduction and the establishment of new plants can occur at all stands (Auld and Benson unpubl.).

Across all stands, some 300 juveniles and seedlings have been observed (Auld and Benson unpubl.). The survivorship and growth rates of those at Stand 1 are currently being monitored. Figure 9 shows the size distribution of the trees and juveniles within the population in the main gorge at Stand 1.

Most trees coppice from buds low down on trunks (see Section 7.3.1). Only one tree contains a single stem. Adult trees may have up to 22 stems greater than 20 mm in diameter and all trees have numerous smaller suckers (Benson unpubl.). The diameters of trunks show a skewed distribution with very few trunks between 25 mm and 200 mm.

The key remaining research and management issues are to establish what proportion of juvenile plants ever reach maturity and what factors control the transition from juvenile to adult plants.

7.5 Disturbance

7.5.1 Fire

The response of Wollemi Pine to fire is unknown. It is likely that intense fires that kill all foliage will kill individuals of Wollemi Pine and hence, catastrophic fire is a threat to the known stands. However, all stands show evidence of previous fires as indicated by fire scars on the trees or burnt out remains of

Eucalyptus piperita (Sydney Peppermint). Small scale spot fires may occasionally occur at or in the vicinity of known stands. The role of such small scale fires on the competitive interaction between Wollemi Pines and angiosperms and in creating gaps for recruitment of new plants is currently under investigation (Auld and Hughes unpubl.). An appropriate disturbance regime may be required to ensure the long-term viability of stands in the wild. Further monitoring is required to provide information on the role of fire in the survival of Wollemi Pine.

7.5.2 Canopy Gap Formation

Wollemi Pine is restricted to specialised habitats in rainforest communities in deep sandstone gorges. These wet micro-habitats act as refugia for species which are not tolerant to drought or to high fire frequencies or intensities because they are sheltered from the hot, dry, fire-prone conditions of the surrounding forest and woodland. Conditions within these microhabitats have enabled Wollemi Pine to survive and to share the habitat with other canopy species, particularly coachwood and eucalypt species. A regime of disturbance is operating within this habitat. It appears to consist of major events over a long time frame such as catastrophic events (fire events, rock falls and tree falls) and individual tree deaths, which produce the canopy gaps that may be necessary for successful regeneration.

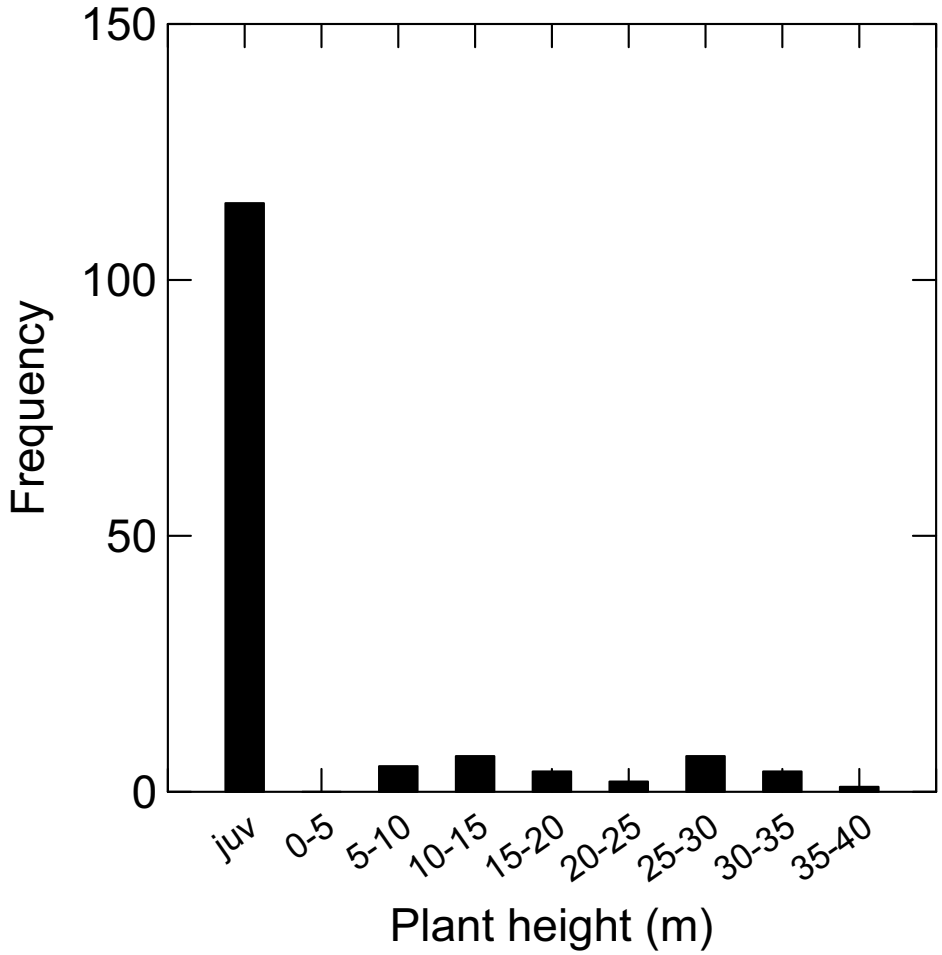

Figure 9. Size distribution of trees and seedlings/juveniles (juv) across Stand 1 (Auld and Benson unpubl.).
Juv: refers to non-reproducing individuals that are seedlings or small juvenile plants.

8 Management issues

8.1 Threats

Wollemi Pine is considered to be an endangered species due to its extremely restricted distribution, the possibility of a very restricted number of genetic individuals, its seemingly slow rate of recruitment of new genetic individuals, and the long time before sexual maturity. The species is considered to be threatened by unauthorised collection (this may impede the long-term replacement of

reproductive plants and cause a loss of genetic diversity), catastrophic fire events, the introduction of pathogens, especially fungal species such as *Phytophthora cinnamomi* (this pathogen has recently been found causing dieback of foliage in some trees at Stand 1), and other impacts from unauthorised site visits such as trampling of seedlings, compaction of soil and the introduction of weeds. The species may also be threatened by changes to its known habitat by the effects of climate change.

8.2 Ability to recover from threats

Wollemi Pine is considered to have become rare through natural factors, but is also at risk of additional threats from the activities of humans. The ability of the species to maintain a wild population is currently unknown, but management activities will attempt to reduce the likelihood of declines in the wild.

8.3 Social and economic factors

8.3.1 Scientific and taxonomic value

To the scientific community, Wollemi Pine is of very high scientific value as it is the sole living representative of an ancient genus. Study of this species will enable scientists to gain knowledge about the evolutionary relationships between extant species in the Araucariaceae and to get an insight into an ancient taxon which until now was known only from fossils.

8.3.2 Biodiversity value

As a monotypic species, the genetic diversity within this species constitutes the full genetic range of the genus. Therefore each genetic individual plays a key role in the future evolution of the genus. The microflora and other species associated with the microhabitats provided by the species are important and unique components of the biodiversity of Wollemi National Park and New South Wales and, indeed, the Australian continent. The presence of Wollemi Pines was used as the flagship species to highlight the number of endemic species in the nomination of the area for World Heritage.

8.3.3 Bioprospecting value

Several studies have investigated the chemical qualities of Wollemi Pine. None appear likely at this stage to be of harvestable quantity.

A fungus found to be associated with the stems and leaves of Wollemi Pine (*Pestalotiopsis guepinii*) yields low levels of taxol, a drug used to treat cancer (Strobel *et al.* 1997).

The steam volatile oils in the leaves of this species have been profiled (Brophy *et al.* 2000) and a unique terpene (Wollemia lactone) has been extracted but the properties not yet fully explored (Fookes pers. comm.).

An Omega 3 fatty acid in the seeds has been characterised and this group is of interest because of its role in human and other animal nutrition. Due to the low amount (8%) it is merely a curiosity in this species, compared with high yielding seeds such as flax which has commercially useful amounts of around 60% (Offord *et al.* 2005; Duke, Duke, Meagher, Offord unpubl.).

Allelopathy of leaves is currently being investigated for use as herbicide (T. Haig pers.com.).

8.3.4 Social benefits

In situ management costs are borne by the whole community through the DEC. The BGT has provided opportunities for the public to view the species by establishing plants in its gardens and with a commercial partner, Wollemi Australia, sales of the plants have made Wollemi Pine available for horticulture. All people will, therefore, benefit from the research and management of this species and future generations will continue to enjoy these benefits. Through awareness of Wollemi Pine the profile of all threatened species is raised in the general community. This in turn leads to greater opportunities for the conservation of threatened species and their habitats, and increased protection of biodiversity.

8.3.5 Commercial value

Commercial release of the Wollemi Pine has been undertaken with the specific objective of reducing the threat to the population in the wild from illegal collectors. The Wollemi Pine is keenly sought after as a horticultural plant and the plant has been commercially available from early 2006 via the Wollemi Pine Agreement, collaboration with DEC and the commercial partners, Wollemi Australia. It has been estimated that the worldwide demand for this plant is in the millions (B. McGeoch, pers. comm.). Royalties from sales through this partnership will also be directed to the conservation of this and other endangered plant species in NSW.

Since the discovery of Wollemi Pine, DEC has received thousands of requests for plants of this species. The popularity of the plant has been increased by its profile as one of the world's rarest plants and its status as a conifer species (a much collected and grown group

worldwide). The biggest risks identified by the Recovery Team were over-collecting and the possibility of fire, disease or weeds entering the site. Therefore, collection and distribution of plant material requires careful planning and control to minimise these risks.

Initial assessment indicates that the wood quality of Wollemi Pine is high, but further research is required to see if it is as useful as other members of the Araucariaceae and amenable to growing in plantations.

Ecotourism opportunities have been created in NSW through planting groves in botanic gardens and by focusing on the special flora in the recently listed Greater Blue Mountains World Heritage Area. Wollemi Pine has contributed to the perception that NSW has unique biodiversity and high conservation values and is a destination for tourists wanting to experience the Australian natural environment.

8.4 Biodiversity benefits

The discovery of Wollemi Pine highlights the importance of habitat conservation and the integral role that national parks play in the conservation of biodiversity. It also shows the importance of conserving areas of diverse vegetation types and the crucial role that rainforests play in the environment by providing a relatively stable habitat through periods of great changes in other habitats. The rainforest habitat of the Wollemi Pine has provided a refuge for the species during the great climatic changes experienced in Australia (Hill 1995).

The conservation and study of Wollemi Pine will also benefit the other species which share the same habitat. This includes invertebrates and fungi and micro-organisms. Further research on the associations of other species with Wollemi Pine and its habitat is continuing.

9 Previous actions undertaken

The newly discovered *Wollemia* created a sensation. It is linked with fossils that are connected to ancient groups back to the Jurassic and the age of the dinosaurs, giving it great appeal to both scientists of many disciplines and the general public of all ages (Briggs 2000). This has resulted in many requests from researchers for access to material and from the general public for information, as well as the added pressure for increased protection of the fragile site.

9.1 Wollemi Pine Recovery Team

The Wollemi Pine Conservation Team was convened by the then NPWS and the RBG in 1994 to oversee the interim research and management of Wollemi Pine. With the introduction of the TSC Act and the legislative need for a recovery plan, the Wollemi Pine Recovery Team was formed to oversee the initial investigations (see below) and guide the NPWS preparation of the recovery plan that was approved in 1998. The Recovery Team has undertaken assessment of the many requests for access to the site, material for research and information from scientists, the general media, educational institutions, students and the general public, as well as involvement in the commercial release of Wollemi Pine. The Actions in Section 12 of the 1998 Recovery Plan are reported here, and summarised in Table 2. Additional information that has been found on this high profile species and work performed for the species is also presented.

9.2 Wollemi Pine Access Strategy

The DEC has adhered to a policy of highly restricted access to the site for both staff and the public in an effort to minimise the risk to the in situ population (Action 12.1.1 in 1998 Plan). The Wollemi Pine Access Strategy outlines the protocols for site access and restricts access only to people authorised by the DEC. These measures have been further codified in the Wollemi National Park Plan of Management and the Draft Wollemi National Park Fire Management Plan. Authorised visits to the sites for research purposes have also been monitored by the Wollemi Pine Recovery Team. Only essential on-site work has been authorised and all visits must be approved. Where ever possible plant material from the off-site population at Mount Annan Botanic Garden is used for research and collaboration is encouraged. A registry of all approved site visits is maintained by Blue Mountains Regional Office of the PWD. Site surveillance has been increased after it was found that unauthorised visits had occurred.

Table 2: Implementation schedule from 1998 Recovery Plan

Section (from 1998)	Description	Responsibility for implementation	Priority	Status
12.1	**Management**			
12.1.1	Wollemi Pine Access Strategy	NPWS	Essential	Ongoing [1] see 9.2
12.1.2	Wollemi Pine Community Relations Strategy	NPWS	Essential	Ongoing, see 9.5
12.1.3	Wollemi National Park Reserve Fire Plan	NPWS	Essential	Ongoing, see 9.4
12.1.4	Catchment management	NPWS	Essential	Ongoing, see 9.3, 9.4 & 9.5
12.1.5	Site Hygiene Protocol	NPWS/RBG	Essential	Ongoing, see 9.3
12.2	**Ecological research**			
12.2.1	Ecological monitoring	NPWS / RBG	Highly desirable	Ongoing, see 9.6
12.2.2	Age structure studies	RBG	Highly desirable	Ongoing, see 9.6.4
12.2.3	Mycological studies	RBG	Highly desirable	Complete, see 9.6.7
12.3	**Genetic studies**			
12.3.1	DNA extraction	RBG	Highly desirable	Complete, see 9.12
12.3.2	Genetic variability analysis	ANU/RBG	Highly desirable	Complete, see 9.12
12.4	**Ex situ collection**			
12.4.1	Collection of material for propagation	RBG	Highly desirable	Complete, see 9.8
12.4.2	Create and maintain a register of propagules	RBG	Highly desirable	Complete, see 9.9
12.4.3	Seed storage studies	RBG	Highly desirable	Ongoing, see 9.9.1
12.4.4	Vegetative propagation research	RBG	Highly desirable	Ongoing, see 9.9.2
12.4.5	Investigation of aspects of cultivation	RBG	Highly desirable	Ongoing, see 9.10
12.4.6	Commercialisation strategy	NPWS/RBG	Highly desirable	Complete, see 9.11
12.4.7	Reintroduction	NPWS/RBG	Highly desirable	Under consideration, see 10.1.6
12. 5	**Survey of potential habitat**	NPWS	Highly desirable	Complete, see 9.7

[1] Ongoing refers to actions that have strategies/plans completed but their implementation is ongoing.

9.3 Site Hygiene Protocol

A threat to the known stands of the Wollemi Pine is the introduction to the site of pathogenic fungi, particularly *Phytophthora cinnamomi*. This pathogen has recently been found at Stand 1. A Site Hygiene Protocol has been developed by the BGT (See Appendix 1). Strict quarantine measures have been enforced during all authorised site visits (Action 12.1.5 in 1998 Plan, see Table 2). This protocol has been reviewed and procedures revised where required ensuring it is current and fully adhered to. This protocol includes the use of clean clothes and sterilised footwear at all times on site. All equipment used for sampling is also sterilised before it is introduced into the site and if used within the site. Since the introduction of *Phytophthora cinnamomi* into the site, within site hygiene has been strengthened.

9.4 Fire Management Protocol

As part of the Wollemi National Park Fire Management Plan, the DEC has developed a protocol for fighting a fire which threatens the population of Wollemi Pine (Action 12.1.3 in the 1998 Plan). In addition, the fuel management plan for Wollemi National Park will include a risk assessment strategy to protect the known habitat of the species in Wollemi National Park. These interim measures will provide a response specifically for the protection of the Wollemi Pine stands from fire and are designed to reduce the fire hazard, the intensity of any fire which is deemed to be a potential threat, the response time in the event of a direct threat, and to suppress any fire at the stands with all due caution for the safety of the fire fighters.

9.5 Wollemi Pine Community Relations Strategy

A community relations strategy has been developed by the DEC (Action 12.1.2 in the 1998 Plan). All community relations initiatives are linked to key management objectives. The major objectives of the strategy are to:

- discourage the general public and special interest groups from trying to find and visit the site within Wollemi National Park;
- increase community awareness of the Wollemi Pine in an effort to encourage community support for the protection of the site and for research into the species;
- emphasise the importance of biodiversity and habitat protection; and
- use the Wollemi Pine as a flagship species to convey messages for conservation and protection of endangered species and their habitats, and conserving protected areas in general.

A number of actions in the community relations strategy have been undertaken and are ongoing, such as contact with key park neighbours and regular media updates, the production of two posters and four brochures for display at key target areas, delivery of Wollemi Pine presentations to regional schools, conservation and bushwalking groups, community presentations at field days and community events, development of interpretation and displays at Botanic Gardens Trust Sydney properties, publication of articles in the general media (Da Silva 1997, Entwisle 2003; Hill 1995, Hill 1996, Kuisma 2003, Lake 2000, Meagher and Offord 2000, Meagher and Offord 2002, Meagher and Offord 2006, Offord 1995, Offord 1996a, Offord 1996b, Ravallion 2000, The Gardens 2001), publication of a book (Woodford 2000) and numerous newspaper, radio and television interviews, both local and international. Footage taken at Stand 1 in March 2005 has been made freely available through the ABC for education, scientific and general news use and for a fee for commercial uses.

9.6 In situ biological research and monitoring

An in situ ecological research program was initiated in mid-1995 under the guidance of the Recovery Team. This program of ecological research has provided the baseline information required for the formulation of the Recovery Plan. This program is continuing. Initial description of the growth habit and habitat of the Wollemi Pine was undertaken on site and material has been collected for analysis of embryology, phenology, cuticle morphology, wood anatomy, tree aging, flammability, invertebrate associations, seed germination, seedling vigour, leaf oil analysis, genetic variability and branching pattern studies. Activities carried out to date are described below.

9.6.1 Description of the habit and habitat of Wollemi Pine

The main species associated with the Wollemi Pine were identified and a description of the general character of the habitat was recorded. This is discussed in Section 6. A complete survey of all stands has since been carried out (Benson & Allen unpubl.).

Readings of light intensity were taken using a Licor Instrument at Stand 1, and these light levels were used to devise ex situ experiments on seedling light responses.

9.6.2 Preliminary description of the population structure at known stands

The coppicing habit of the Wollemi Pine makes identification of individual trees somewhat difficult in the field. In order to undertake a preliminary description of the population structure, putative individuals have been identified and tagged at all stands. Subsequently, the number of trunks of each putative individual was counted, the basal diameter of each trunk was measured and plant height was measured or estimated (Benson, Auld, Allen unpubl.). This gives data on the existing adult stand structure at each stand. The position of individuals in Stand 1 has been mapped.

9.6.3 Tagging and measurement of seedlings and juveniles

A survey of all known stands has confirmed the presence of seedlings and juvenile plants. Seedlings were identified in situ by the presence of cotyledons or cotyledon scars. Measurements of plants size have allowed the juvenile stand structure at each stand to be recorded (Auld and Benson unpubl.). At Stand 1, a number of juveniles have been tagged with permanent numbered metal stakes and tags. In addition, several seedling cohorts have been tagged over a number of years. Plant height and the number of leafy branches have been recorded on a series of site visits over several years to estimate plant survival and growth.

9.6.4 Estimation of the age and growth rates of individual trunks

Ring counts of fallen trunks were undertaken to give a preliminary assessment of the age of standing trunks. In addition trunks from a number of trees in Stand 1 were cored to obtain estimates of the age and enable estimates of growth rates of these trees (Banks 2002). Results are discussed in Section 7.1.

9.6.5 Wood anatomy

Wood anatomy of Wollemi Pine has been described (Heady 2002, Heady *et al.* 2002) and can be clearly identified as a member of the Araucariaceae by three identifying characteristics that it shares with *Agathis* and *Araucaria* i.e. 'alternate' pitting, 'araucaroid' cross-field pitting and absence of crassulae. This study includes a comparison of mature wood, collected from the site, and juvenile wood, collected from the off-site population.

9.6.6 Edaphic and climatic factors

At Stand 1, small soil samples were collected from the base of selected trees for physical and chemical analysis (Offord unpubl.). Results are discussed in Section 6.2.

Humidity, air and soil temperature in Stand 1 are being recorded and data stored at Mount Annan Botanic Garden. In 1997 maximum air temperature exceeding 30°C in November and minimum of 0°C was recorded in June, July and August (see Figure 8) (Offord and Meagher 2001).

9.6.7 Mycological research

Mycological research has been undertaken by the BGT to:

- determine the presence or absence of the pathological fungus *Phytophthora cinnamomi* in soils associated with the Wollemi Pine;
- determine the fungal flora associated with the Wollemi Pine and associated soils; and
- determine the susceptibility of Wollemi Pine to pathogens.

In order to gain baseline data on the levels and types of fungal organisms present on site, samples of soil, litter, leaves, sterile seed and cone material were collected from Stand 1 in 1995 by the BGT. Additional sampling for *Phytophthora cinnamomi* has been conducted in 2005 and 2006 and an ongoing monitoring program established.

Approximately 50 species of fungi were recovered from the samples. The identification of many of these species is still in progress (Strobel *et al.* 1997). *P. cinnamomi* was not isolated from any of the soil samples taken in 1995. This indicates that there is a high likelihood that the soil was free of this fungus at that time (B. Summerell pers. comm.). More recent samples (2005, 2006) have positively identified the presence of the pathogen at Stand 1.

In a controlled glasshouse experiment, plagiotropic cutting-grown plants were subjected to a range of common fungal pathogens. *Phytophthora cinnamomi* and *Botryosphaeria* sp. were found to cause significant disease, reinforcing the need for site hygiene in the wild minimising stresses such as soil compaction and good horticultural practice in cultivation (Bullock *et al.* 2000).

Two distinct mycorrhizal associations have been found in Wollemi Pine in the wild. These occur in different parts of the roots. A Paris-type arbuscular mycorrhiza has been found in the nodules and less commonly in the elongated roots. This type of association has been previously found in Araucariaceae. An ensheathing ectendomycorrhizal association was also found; such a relationship has not previously been recorded in Araucariaceae (McGee *et al.* 1999).

9.6.8 Cone counts, monitoring of pollen release and seed crop estimation

The production of female and male cones has been observed over a number of years and the timing of the development the cones is now known but not the production cycle over time (see Section 7.3.2). A long-term study of cone production in Stand 1 began in 2001. This involves using photography to record the male and female cone production in spring and

autumn. The photographs will be used to estimate the seed production for these trees and the population over time, the length of the greatest female and male cone production cycles, the relative placement of female and male cones within a tree and the fate of branches after producing a cone (P. Meagher unpubl.).

A number of male and female cones have been produced on cultivated plants and they are being more closely monitored to better understand the details of the breeding system (see Section 7.3.2).

9.6.9 Litter flammability and invertebrates

Litter samples have been collected to assess the relative flammability of Wollemi Pine litter compared to litter from associated rainforest species. In addition, the invertebrates associated with the litter have been collected for identification and assessment of invertebrates associated with Wollemi Pine and its habitat. This work is continuing (Auld and Hughes unpubl.).

9.6.10 Branch attachment

A study of the attachment of the short-lived branches of Wollemi Pine, is being conducted using both adult leaf-phase branches from in situ trees and juvenile leaf-phase branches from the ex situ grown plants. This study has revealed a most unusual branch connection with a pronounced constriction of the xylem which may facilitate branch abscission (Burrows *et al.* unpubl.).

9.7 Survey

In order to ascertain the distribution of Wollemi Pine, a strategic survey of similar habitats within Wollemi National Park was undertaken during 1995, 1996 and 2000. Areas of potential habitat, with similar topographic and floristic characteristics were identified using aerial photo interpretation and GIS modelling (D. Crust pers. comm.).

The surveys were undertaken using low fly-overs in helicopters combined with ground searches. Ground searching is necessary for the detection of sub-canopy and juvenile plants. The area within 15 km of Stand 1 was extensively ground searched and 300 km of gorge and canyons have been exhaustively searched by helicopter. Aerial searches have also been carried out in other parts of the Wollemi National Park. Several areas remote from the stands were ground searched after they were assessed as suitable habitat. Further stands have been found since the release of the initial recovery plan increasing the number of adult trees from 40 but still fewer than 100.

9.8 Seed and vegetative material collection

Wollemi Pine produces numerous fruiting cones, but the position of these cones on the crown of the tree makes collection of seed difficult (Offord 1995). Low impact seed traps were constructed by the BGT and the NPWS. These traps were located at strategic points within Stand 1 to capture fallen seed during 1996 and 1997 (Offord *et al*. 1999). Some seed has been collected from the ground at Stand 2. Other cone and seed collections have been made by helicopter. Each seed collected is assigned a number and its progress is monitored at every stage of experimentation and subsequent growth (Offord *et al*. 1999).

Cutting material was collected from the majority of putative trees from all stands from small accessible orthotropic (upright) stems over a number of years. Some adult plagiotropic material has also been collected during cone collections by helicopter.

9.9 Off-site propagation

Research into the off-site propagation of Wollemi Pine has been carried out by the BGT since February 1995. Cutting material was collected from the majority of putative trees from all stands and a register of propagules established and maintained. Tree numbering has been revised in the latest survey of the stands and so the population maintained by the BGT at Mount Annan Botanic Garden is no longer a full representation of all putative individuals. Nevertheless more than 95% of accessible individuals are represented. This off-site representative population is maintained by the BGT at Mount Annan Botanic Garden and a duplicate full representative population will gradually build-up for Mount Tomah Botanic Garden for risk management.

These ex situ populations are monitored for growth and development and these plants are used for a number of research projects and educational displays relieving pressure on the in situ population.

9.9.1 Propagation from seed

Viable seed has been successfully germinated and seedling growth is faster off-site than in the wild (Refer Section 7.3.5). Experiments in seed germination and storage have been conducted (Offord *et al*. 1999, Offord and

Meagher 2001, Offord *et al*. 2005). However, the low percentage of viable seed produced (10%) in the field and the high predation rate means that large scale propagation from seed is not a viable option for off-site propagation at the present time and commercial propagation is based on vegetative production (cuttings and tissue culture), see Section 9.11 (Offord *et al*. 1999).

9.9.2 Vegetative propagation

Vegetative propagation has proved to be a successful technique for propagating Wollemi Pine and is the basis for the development of the off-site population and the commercialisation program (Fensom and Offord 1998). Wollemi Pine can be propagated from both juvenile and adult shoots, with best growth from juvenile orthotropic cuttings. The natural coppicing habit of the Wollemi Pine has allowed for a propagation system similar to that used for the commercial production of the related species *Araucaria cunninghamii* or Hoop Pine (Offord 1995).

For vegetative propagation, orthotropic shoots are the preferred material as they establish a seedling-like habit. There are a limited number of these shoots available on the trunks of trees in the wild. Cuttings from the more numerous plagiotropic shoots (sideways growing shoots) produce prostate plants of horticultural interest (Meagher and Offord 2002; Meagher and Offord in press).

9.10 Horticultural experimentation

Horticultural experiments using the seedlings from germination experiments have been conducted to investigate effects of soil pH, light, fertiliser and potting mix (Offord and Meagher unpubl.).

9.11 Commercial propagation

A commercialisation strategy has been developed to manage the release of the plants into cultivation. This strategy was launched in October 2005 by an international auction conducted by Sotherby's at the Royal Botanic Gardens Sydney. The process has been managed by BGT and overseen by the Recovery Team. It has involved the development of a tender, selection of preferred proponent (Wollemi Australia (WA) - a partnership between the Queensland Department of Primary Industry and Birkdale Nursery), and on-going communication between DEC and WA to deliver the project.

The strategy involves the development of a commercial release scheme that is sensitive to the conservation concerns of this and other Australian species, by ensuring that minimal material is collected from the wild, that illegal collection is discouraged and that supporting communication material gives strong positive messages about conservation. On release of plants, messages regarding plant conservation are provided with packaging, printed, and web-based documentation, and other publicity efforts, in concert with the community relations strategy (see Section 9.5 and www.wollemipine.com).

WA has a strong background in Araucariaceae development for the international market as well as marketing connections worldwide. The development process has involved a significant research phase, at the BGT and by WA, often jointly. A strong conservation and environmental branding message has been developed which adds benefit to the sales of the product. Royalties from sales will go directly to the conservation and management of Wollemi Pine, and other rare or threatened NSW plant species.

Material obtained from the off-site population was multiplied by propagation at Mount Annan Botanic Garden for WA to produce stock plants for mass propagation. The BGT has also contributed expertise and support to ensure the success of this project. The first plants were released to the public in October 2005, and plants are now available through nurseries worldwide.

9.12 Genetic variability

Genetic variability of the Wollemi Pine has been intensively studied; using 13 allozyme loci, more than 800 amplified fragment length polymorphism (AFLP) loci and 20 simple sequence repeat (SSR) loci. Despite this extensive search to date, no DNA variation has been detected between seedlings, putative trees or stands. This is considered to be an extreme case but it has been found that other members of the Araucariaceae family are also low in DNA variation. In *Araucaria cunninghamii* (Hoop Pine) variation was found in only 10 of > 800 AFLP and five of 20 SSR loci, and in *Agathis robusta* (Queensland Kauri Pine) variation was found in only one of 12 allozyme, five of 800 AFLP and none of the 15 SSR loci. Low or no detectable DNA variation in Wollemi Pine reinforces the need to protect the wild populations from introduced pathogens (Peakall *et al.* 2003).

Differences in the growth characteristics of clonal lines have been detected, indicating that

there is measurable genetic variability. This needs to be further explored.

9.13 Research using off-site representative population

Numerous studies have been conducted by local and international researchers in a range of disciplines which have added to the understanding of this species and the Araucariaceae. These include molecular classification by Gilmore & Hill (1997), Stefanovic *et al*. (1998) and Setoguchi *et al*. (1998); reanalysis of fossils by Chambers *et al.* (1998) and Dettmann and Jarzen (2000); and studies of the wood anatomy by Heady *et al.* (2002), cytology (Hanson 2001), steam volatile oils in leaves (Brophy *et al*. 2000), leaf anatomy (Burrows & Bullock 1999), leaf axil anatomy (Burrows 1999), bud development (Burrows *et al*. 2003), branch attachment (Burrows *et al*. unpubl.) and pathogenicity (Bullock *et al.* 2000).

10 Recovery objectives and performance criteria

10.1 Recovery objective 1: Protect and maintain wild stands and their habitat from threatening processes in the long term

Action 10.1.1 *Continue implementation of access strategy and protecting the stands from unauthorised visits.*

The location of Wollemi Pine will remain confidential, with only essential staff being made aware of the location of the natural population. All visits to the site by DEC employees, or by other approved persons, will be conducted in accordance with the Wollemi Pine Access Strategy (see Appendix 2). This strategy will be part of the Wollemi National Park Plan of Management. A register of all people visiting the stands will be maintained by the Blue Mountains Regional Office of PWD.

Statutory overflight controls will be sought to minimise the potential use of light aircraft by aspiring unauthorised visitors to identify the location of Wollemi Pine stands. This is consistent with a commitment in the draft Commonwealth-State Strategic Plan for GBMWHA.

On ground site surveillance will be conducted to discourage and detect unauthorised visitation to the stands. The *National Parks and Wildlife Act* may be used to restrict access to the area under the Land Management Regulations and declaration of Critical Habitat and associated regulations further restrict/prohibit access to provide additional protection to the stands.

Performance criterion 10.1.1 The known stands of the Wollemi Pine are protected from damage by visitation to the stands. Enforcement of area closures, under the NPW Act Land Management Regulations and regulations in accordance with critical habitat occur.

Action 10.1.2 *Continue implementation of site hygiene protocol and monitoring plant health, including the effects of* Phytophthora cinnamomi

This task involves the protection of the wild population of Wollemi Pine and control of the introduced pathogen *Phytophthora cinnamomi* by the implementation of strict hygiene measures during all approved site visits and the monitoring of soil for introduced pathogens. To protect the stands during approved site visits, a protocol developed by the BGT has been adopted.

- All authorised personnel visiting the Wollemi Pine site will be required to sterilise all footwear and equipment in accordance with the approved protocol.
- Any further outbreaks of fungal pathogens at the site will be treated as an emergency and dealt with promptly and effectively using expert advice available through the BGT and NSW Department of Primary Industries.
- Soil sterilants and systemic fungicides may be used in emergency situations on wild stands of Wollemi Pine to contain active fungal pathogen outbreaks (see 10.1.3).
- The BGT, in consultation with the Recovery Team, will review approved procedures for minimising the risk of introducing fungal pathogens to the Wollemi Pine stands and to off-site populations where appropriate.
- DEC, in consultation with the Recovery Team, will develop an emergency management plan for dealing with fungal pathogen outbreaks and will list appropriate contacts within DEC and DPI who may be available to assist.
- Annual monitoring of plants and habitat health of the wild population will be conducted in order to detect any deleterious changes that may be occurring, including sampling for soil-borne pathogens.

Performance criterion 10.1.2 The known stands of the Wollemi Pine are protected from the detrimental impacts of pathogens or other threats to plant health.

Action 10.1.3 *Manage introduction of* Phytophthora cinnamomi *in the wild population by controlling infection and preventing spread within the site.*

DEC will manage trees infected with disease caused by *Phytophthora cinnamomi* and will control the pathogen in the wild population. This involves a number of steps:

- Trees showing symptoms will be treated in the short term with Phosphate by injection, and soil where *Phytophthora cinnamomi* has been identified in sampling will be drenched with Ridomil;
- Experiments on cultivated plants will be conducted to investigate the optimum control treatment for *Phytophthora cinnamomi* and these results will be used to inform future treatments of diseased trees in the wild; and
- A monitoring program, including the use of photography and soil sampling will be designed and implemented. This will include gathering all images taken on site since the discovery in 1994, building an image catalogue, defining the photo-points for future images and assessing the changes to plants over time.

Performance criterion 10.1.3 A monitoring program is designed and implemented and treatments are investigated and used, leading to control of *P. cinnamomi* in the site, further infections being halted and infected trees being effectively treated.

Action 10.1.4 *Manage threats to Wollemi Pines in the catchment.*

DEC will ensure that the risk of pollution, flooding, weed infestation, sedimentation and other adverse changes to the integrity of the catchment of the Wollemi Pine stands is minimised by implementing the following practices.

- DEC will seek the co-operation of all relevant authorities and owners of properties adjoining the park, if appropriate, to minimise the risk of chemical, oil or fuel spills.
- Annual monitoring of blackberry and other weed incursions in the catchment of the Wollemi Pine sites will be carried out and treatment of infestations will occur when the PWD, in consultation with the Recovery Team, concludes that the infestation could adversely affect the population of the Wollemi Pine.
- Weed control for the Wollemi Pine sites will be carried out using best practice and low-impact methods.

Refer to Action 10.1.2 and 10.1.3 for protection from plant disease and Action 10.1.5 for protection from fire.

Performance criterion 10.1.4 The stands of the Wollemi Pines are protected from the detrimental impacts of pollution, flooding, weed infestation, sedimentation and other adverse changes to the hydrology of the catchment of the wild population.

Action 10.1.5 *Implement Wollemi National Park Fire Plan.*

The Draft Wollemi National Park Fire Management Plan will outline fire management policies and procedures for the area surrounding the Wollemi Pine stands. These management strategies will assist in the long-term protection of the species from potentially devastating fires. Fire management procedures will be tailored to provide conservation of the habitat of the Wollemi Pine. It is currently assumed that intense fire events will lead to individual tree deaths and a reduction in the population.

Performance criterion 10.1.5 The risk of damage to Wollemi Pine stands from wildfire and bushfire management activities is minimised.

Action 10.1.6 *Prepare guidelines for translocations of Wollemi Pine.*

Translocations of the Wollemi Pine may be needed to re-establish wild populations if there is significant adult plant death due to pathogens or intense wildfires. Changes to climate may increase the risk of high intensity fires or change rainfall patterns which impact on plant vigour or survival. Translocations may also be advantageous in order to successfully maintain a range of ex situ living collections. DEC in consultation with the Recovery Team will prepare guidelines for the translocation (including reintroduction) of the Wollemi Pine. This will include triggers for translocation or reintroduction and possible locations for translocation (for risk management reasons) within the Greater Blue Mountains region which have been identified by a targeted survey (see 10.2.7).

Any such translocation will be undertaken in accordance with the Australian Network for Plant Conservation Guidelines for the Translocation of Threatened Plants (Vallee *et al*. 2004).

Material for translocation or re-introduction will be sourced from a representative sample from the off-site collection held by BGT.

Performance criterion 10.1.6 Guidelines for translocation of Wollemi Pine are prepared.

Action 10.1.7 *Declaration and enforcement of Critical Habitat and associated regulations.*

There is potential for increased incidence of unauthorised visits to the wild Wollemi Pine site and the possible damage to plants and further introduction of pathogens that may affect the health and viability of the Wollemi Pine population. In order to give increased legislative power to protect the habitat of the Wollemi Pine population, DEC in consultation with the Recovery Team has prepared recommendations for declaring known stands of Wollemi Pine as Critical Habitat. The declaration also identifies habitat considered to be critical to the survival of the Wollemi Pine. Regulations concerning the application of Critical Habitat have been prepared.

Performance criterion 10.1.7 Critical Habitat and associated regulations are declared and enforced as required.

10.2 Recovery objective 2: Understand the biology of Wollemi Pine and associated species in its natural habitat to inform conservation of the species and its habitat

This action is to promote research that will assist with the management and conservation of the species and its associated habitat. All in situ research programs will be reviewed/approved by the Wollemi Pine Recovery Team.

Action 10.2.1 *Continue investigation of stand dynamics.*

The ecology of the Wollemi Pine is not well understood. A number of years of low impact in situ monitoring of the known stands are required to gather ecological data. Investigation of stand dynamics is being conducted to study:

- Population dynamics;
- Age structure;
- Growth rates of individual stems;
- Seedling recruitment; and
- Seedling and juvenile growth and survivorship.

Dead fallen material and a method of incremental coring which does not endanger living trees, will be used to relate the size of standing trunks to their age and determine the growth rates of individual trees. Temperature data will be gathered to relate to seed germination. Information gained will be used to inform Action 10.2.2.

Performance criterion 10.2.1 Aspects of the stand dynamics of the Wollemi Pine are documented and the age structures of the standing trunks in known stands are estimated. Ecological data is used to modify the management program outlined in Section 10.1 and assists in the tasks outlined in Section 10.3 and 10.4.

Action 10.2.2 *Investigate gap dynamics (including impacts of fire, wind and rock and tree fall).*

A study of the impacts of scarring from fire, wind-shake and rock or tree fall of the Wollemi Pine will be designed and implemented by DEC, in consultation with the Recovery Team, in order to:

- estimate the fire history and impact on the stands;
- estimate the extent of damage from fire, wind-shake and rock/tree fall;
- assess how the creation of canopy gaps has influenced the present population structure to inform future management; and
- estimate impact of fire on juvenile and seedling survival.

The study will include photographic records of the fire scarring to assist with long-term management of the population.

Performance criterion 10.2.2 The fire history of the sites and impact of fire, rock-fall and wind-shake on Wollemi Pines is examined. Key gap forming processes are identified. This information is used to modify existing management practices outlined under Section 10.1.

Action 10.2.3 *Initiate studies to increase understanding of evolutionary history.*

An understanding of the long term history of the known habitat for Wollemi Pine and other relevant areas will inform about the future possible responses of the species to climate change (and its corresponding impacts on fire regimes, water availability and plant growth rates) and changes to disturbances that are

important in maintaining the existing population (eg gap formation).

Techniques including dendrochronology, pollen and fossil analysis will be used to determine changes to Wollemi Pine and its habitat over time.

Performance criterion 10.2.3 Qualified individual/s are found to initiate a study/studies to increase understanding of evolutionary history of Wollemi Pine.

Action 10.2.4 *Determine the range of genetic variability of the known population.*

Extensive DNA analysis has not identified any variation between putative individuals in the wild (Peakall *et al*. 2003). This may partly reflect the limitation of the techniques applied. As new methods are introduced further detailed genetic study will attempt to determine how many individuals occur in each stand and therefore how much genetic variation is present in the known population of the Wollemi Pine. There is some evidence of morphological and other character variability in ex situ populations.

A representation of most putative individuals of the population is maintained by the BGT (see Section 9.9) to provide material for genetic analyses when required. Application of the selected techniques will address the following issues:

- Genetic variation within Wollemi Pine stands;
- Gene flow between Wollemi Pine stands;
- Clonality of the larger stem groups;
- Extent of cross-pollination;
- Representative sample for off-site collection; and
- Assess morphology, and other character variations.

Knowledge gained will provide guidelines for propagation to ensure that the off-site collection represents the full range of the species' genetic diversity.

Performance criterion 10.2.4 New techniques for the analysis of population genetics are investigated and, where appropriate, applied.

Action 10.2.5 *Initiate studies to increase understanding of reproductive biology.*

The reproductive organs and their developmental cycles are evolutionarily conservative and therefore are used as an indication of the relationships of related species. Understanding the embryology of the Wollemi Pine will lead to a greater understanding of the species' relationship to other extinct and extant genera in the Araucariaceae family.

The production of pollen and seed cones of conifers tends to be cyclical. This is a long term study as cycles are affected by temperatures and rainfall, so variations in weather patterns will influence the length of the cycles. Data, including developing seed cones and high resolution images, will be collected in order to understand the embryology and cone production cycles of the species. Pollen growth and fertilisation will be studied on the off-site collections of sexually reproducing individuals.

Performance criterion 10.2.5 Embryology and cone production cycles are better understood providing information for establishing evolutionary relationships within Araucariaceae and enabling estimation of seed production in different years. Knowledge gained is used to modify the management program outlined in Section 10.1.

Action 10.2.6 *Increase our understanding of the species associated with the Wollemi Pine and its habitat.*

The Wollemi Pine does not exist in isolation in the wild. It has numerous interactions with other species and may have some dependence on those other species for maintenance of components of its life history or habitat. Similarly, there may be other species that are dependant upon the Wollemi Pine for their continued existence. These dependencies will also be used to inform effects of climate change on survival of Wollemi Pine in the wild.

Investigations of these interactions or species associations will be continued. Targeted taxa will include litter and foliage invertebrates, flora and fungi. Disease interactions will also be investigated. The ability to conduct these studies may depend on the success of the control of *Phytophthora cinnamomi*.

Performance criterion 10.2.6 Knowledge of species associated with the Wollemi Pine and its habitat is gained and this information is used in the management of the wild population (Actions10.1).

Action 10.2.7 *Undertake further systematic survey.*

Modelling of physical and ecological attributes will be used to inform new surveys for potential suitable habitat for *W. nobilis*. This will allow additional targeted searches for new

populations as well as providing information to guide any proposals for future translocations deemed necessary as a risk minimisation strategy for conservation of the pine in the wild. As future climate projections for NSW are for continuation of the current drying trend, together with ongoing warming, the use of bioclimatic/GIS modelling will be used to locate sites that may serve as climate refugia in the future. Information gained would be used to inform Action 10.1.6.

Performance criterion 10.2.7 Potential habitat is identified and surveyed.

10.3 Recovery objective 3: Establish, maintain and utilize representative off- site populations

The production of a representative off-site population is considered necessary for the long-term survival of the Wollemi Pine, in case of severe decline of the wild population, to provide material for translocation, for various research projects, for horticultural development and educational display. Information gained in cultivation will be used to assist with protecting and maintaining the wild population and production of plants for commercial release. The off-site populations will be maintained and replicated.

Maintenance of the off-site populations will be assisted by knowledge of the genetic variation of the material available in the wild, from Action 10.2.4. The wild population is small enough to obtain, grow and analyse material from nearly every mature plant.

There are three main tasks as discussed below.

Action 10.3.1 *Maintain an off-site representative collection of the wild population.*

Representatives of all trees identified in the wild will be collected as they are identified, then propagated and maintained as an off-site population (see Section 9.9). Suitable locations will be investigated for the planting of the population on the Botanic Gardens Trust land. There should be at least two plants of each individual at two sites for risk management. Some seedlings from germination experiments will be included in the population to obtain maximum genetic potential. A register will be maintained by the BGT of plants and their genetic makeup.

Establishment of a representative off-site collection will allow:

- commercial propagation;
- dispersal to other conservation agencies, principally botanic gardens;
- replication to minimise risk of loss of the collection;
- any potential future translocation; and
- scientific research.

Dispersal of plant material will take place in accordance with BGT Licence and in consultation with the Recovery Team.

Performance criterion 10.3.3 A representative off-site collection is maintained and replicated at a second off-site location.

Action 10.3.2 *Research seed biology and store seed.*

Recent studies indicate that seeds are orthodox but long term viability in storage needs to be investigated.

The study will investigate the optimum conditions for seed germination and storage. The studies will examine the effect of storage at low temperature and reduced moisture content over time on the germination of the Wollemi Pine seed.

Performance criterion 10.3.2 Determination of the optimum conditions for seed germination and storage is achieved, providing a means of low cost off-site conservation. This knowledge is used to inform management of the wild population.

Action 10.3.3 *Continue with horticultural research.*

A series of studies designed to determine the optimum growing conditions for the Wollemi Pine have begun (Offord and Meagher unpubl.). They include studies of nutrition, potting mix, soil requirements, light intensity and photoperiod in combination with temperature on propagated stock held in pots. Studies to identify climate range will also be undertaken to provide information for the maintenance of the wild population coping with the effects of climate change. Monitoring of plant growth will occur for all propagated stock currently held as pot plants at Mount Annan Botanic Garden, as well as for any Wollemi Pines planted in the Botanic Gardens.

Performance criterion 10.3.3 The optimum conditions for the cultivation of the Wollemi Pine are determined and knowledge gained is used to inform management of the wild population.

10.4 Recovery objective 4: Implement a community relations strategy

Action 10.4.1 *Continue implementation of the education and awareness program.*

The strategy of protecting the wild stands by continuing to restrict the knowledge of their location relies on the general community's understanding and continued support. A well developed education and awareness program is critical for its success.

A number of actions in the education and awareness program have already been undertaken and found to be successful. These will be continued and other actions will be undertaken as funds become available. Further community education on the risk of *Phytophthora cinnamomi* is needed.

To date, the education and awareness program has included developing and maintaining a web presence on the BGT website, providing information and displays where possible including local field days and community events, preparing material including posters and leaflets on potential of spread of disease and weeds, liaison with neighbours and recreational groups, and presenting talks to bushwalking, conservation and gardening groups, maintaining syllabus relevant Wollemi Pine lesson packages, providing information for the NSW Schools curriculum, delivering targeted lessons out to regional schools, development and maintenance of relevant and up to date interpretative information, including exhibitions, for Botanic Gardens Trust properties, within Wollemi National Park and travelling to regional areas. This program will be continued, as appropriate.

Off site collections have been planted in the Botanic Gardens and interpreted to increase awareness and strengthen the community relations strategy.

Performance criterion 10.4.1 Community appreciation of and support for the conservation and protection of the Wollemi Pine is enhanced. This has been measured by surveys of audiences of Wollemi Pine presentations / lessons conducted by BGT Community Education, off site collections are planted and interpreted, Wollemi Pine website is maintained, exhibitions at field-days around Wollemi National Park are attended and educational information for general release is produced.

10.5 Recovery objective 5: Support commercial production of Wollemi Pines for sale

Action 10.5.1 *Continue engagement with Wollemi Pine commercialisation process, to maximize benefits to the wild population and conservation in general.*

The public appeal of the Wollemi Pine, its potential marketability as a horticultural plant, and various factors allowing controlled commercialisation of it via propagated material, together allow a unique opportunity to dovetail recovery actions with the commercialisation process. The Recovery Team has maintained close involvement with the external commercial partners Wollemi Australia (WPI and QDPI) to ensure maximum conservation benefits from commercialisation.

The benefits have included:

- Establishment of a stream of revenue for the conservation and management of the Wollemi Pine and other endangered NSW plant species (See Section 8.3.5);
- National and global exposure of team-approved educational messages concerning the conservation of this and other plant species;
- Entrée to an international milieu of potential philanthropic sponsors and donors, and potential scientific collaborators, all of potential benefit to DEC species recovery aims; and
- Establishment of a new international standard for successful, case-specific blending of recovery and commercial actions.

DEC will continue to support the commercial program for the Wollemi Pine in accordance with the Wollemi Pine Agreement.

Performance criterion 10.5.1 The known stands of Wollemi Pine are protected from damage caused by illegal visitation. Revenue from the commercialisation program is returned to the conservation of the Wollemi Pine and other threatened species.

10.6 Recovery objective 6: Coordinate the recovery of the Wollemi Pine

Action 10.6.1 *DEC will coordinate the implementation of the actions outlined in this recovery plan.*

A coordinated approach is essential to oversee and assist in the implementation of the actions outlined in this recovery plan in a timely, cost-

effective and efficient manner. Some of the tasks undertaken during the coordination of this plan (e.g. liaison with other public authorities) will overlap with other identified actions. Coordination of the NSW plan for the Wollemi Pine will also require liaison and information exchange with PWD, BGT, NSW Department of Primary Industries and Wollemi Australia.

Performance Criterion 10.6.1 DEC has coordinated the recovery actions included in this recovery plan for the life of the plan.

11 Implementation

Table 3 details estimated costs and allocates responsibility for the implementation of recovery actions specified in this plan to the relevant Divisions within the Department of Environment and Conservation for the period 2006-2010.

12 Preparation details

This Recovery Plan was prepared by Patricia Meagher from BGT in consultation with the Wollemi Pine Recovery Team.

This Recovery Plan will be reviewed within five years of the date of publication.

Table 3 Wollemi Pine Recovery Plan Implementation Estimates

Action No.	Action Description	Priority	Responsible Party	Fund Source	Cost Estimate ($'s/year)					Total Cost ($'s)
					Yr1	Yr2	Yr3	Yr4	Yr5	
10.1.1	Continue implementation of access strategy and protecting the stands from unauthorised visits	1	DEC (PWD)	Royalties & In-kind	30-50000[1]	30-50000[1]	20-30000[1]	20-30000[1]	20-30000[1]	**120-190000**[1]
10.1.2	Continue implementation of site hygiene protocol and monitoring plant health, including the effects of *Phytophthora cinnamomi*	1	DEC (BGT),(PSD),(PWD)	Royalties & In-kind	2000[2]	2000[2]	2000[2]	2000[2]	2000[2]	**10-20000**[2]
10.1.3	Manage introduction of *Phytophthora cinnamomi* in the wild population by controlling infection and preventing spread within the site	1	DEC (BGT),(PSD),(PWD)	Royalties & In-kind	40000	40000	40000	40000	40000	**200000**
10.1.4	Manage threats to the Wollemi Pines in the catchment	1	DEC (PWD)	Royalties & In-kind	40000[4]	40000[4]	20000	20000	20000	**140000**[4]
10.1.5	Implement Wollemi National Park Fire Plan	1	DEC (PWD)	Royalties & In-kind	10000	10000	10000	10000	10000	**50-75000** [3]
10.1.6	Prepare guidelines for translocation of Wollemi Pine	2	Recovery Team	Royalties & In kind	5000	5000	5000	5000	5000	**25000**
10.1.7	Declaration and enforcement of Critical Habitat and associated regulations	1	DEC (EPRD), Recovery Team	Royalties & In-kind	5000	5000	5000	5000	5000	**25000**
10.2.1	Continue investigation of stand dynamics	2	DEC (PSD, BGT, PWD)	Royalties & In-kind	8000	8000	10000[5]	5000	5000	**36000**
10.2.2	Investigate Gap dynamics (including impacts of fire, wind and rock and tree fall)	2	DEC (PSD, BGT, PWD)	Royalties	5000	5000	10000	10000	10000	**40000**
10.2.3	Understand evolutionary history	3	Recovery Team, PhD student	Royalties			10000	10000	10000	**30000**
10.2.4	Determine the range of genetic variability of the known population	3	Recovery Team, PhD student	Royalties		10000	10000	10000		**30000**
10.2.5	Understand reproductive biology	2	DEC (BGT)	Royalties & In-kind	5000	5000	10000	10000	10000	**40000**
10.2.6	Increase our understanding of the species associated with the Wollemi Pine and its habitat	2 / 3	DEC (PSD, BGT)	Royalties & In-kind	10000	10000	10000	10000	10000	**50000**
10.2.7	Undertake further systematic survey	1	DEC (PSD, PWD)	Royalties	40000	40000	20000	20000	20000	**140000**[5]
10.3.1	Maintain an off-site representative collection of the wild population	1	DEC (BGT)	Royalties & In-kind	40000	40000	30000	5000	5000	**120000**
10.3.2	Research seed biology and store seed	1 /2	DEC (BGT), PhD student	Royalties & In-kind	5000	5000	10000	10000	10000	**40000**
10.3.3	Continue with horticultural research	1 /2	DEC (BGT)	Royalties & In-kind	15000	15000	15000	5000	5000	**55000**
10.4.1	Continue implementation of education and awareness program	2	DEC (BGT, PWS) & Recovery Team)	Royalties & In-kind	35000	15000	10000	10000	10000	**80000**
10.5.1	Continue engagement with Wollemi Pine commercialisation process, to maximize benefits to the wild population and conservation in general	2	Recovery Team, DEC (BGT)	In-kind						
10.6	Coordinate Implemention	1	DEC(all)	In-Kind	4000	4000	4000	4000	4000	**20000**
	Annual and total cost			**Total**	299000-319000	289000-319000	251000-261000	211000-221000	201000-211000	**1251000-1356000**

[1] includes allowance for increased costs of surveillance if required
[2] includes contingency in case of disease detection of $10,000
[3] includes contingency of $25000 over life of plan in case of wildfire
[4] includes contingency to control weed invasions if detected
[5] visit all sites

Costing table explanation: DEC – Dept of Environment and Conservation, **BGT -** Botanic Gardens Trust **–,PWD –**Parks and Wildlife Division**, PSD –** Policy and Science Division**, EPRD –** Environment Protection & Regulation Division. **Priority ratings: 1** - Action critical to meeting plan objectives, **2** - Action contributing to meeting plan objectives, **3** – Desirable but not essential action.

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Appendix 1: Site Hygiene Procedures

Procedures for hygiene and prevention of entry of disease-causing organisms to wild Wollemi Pines.

Aim: The aim of these procedures is to prevent disease-causing organisms from entering or being transported into the area in which the Wollemi Pines are located. Soil tests performed by the Plant Disease Diagnostic Unit, Royal Botanic Gardens, Sydney showed that *Phytophthora* and other root pathogens did not appear to be present in the wild population when the plants were first discovered. Subsequent testing in 2005 confirmed the presence of *Phytophthora cinnamomi* in Stand 1 and that three trees were exhibiting disease symptoms. It is essential to ensure that further introductions of this pathogen into the site, or transfer within the site is avoided, as the effects are likely to be severe.

The following procedures outline steps that should be taken when it is necessary to enter the site. Such stringent measures are the only means by which it is possible to minimise the entry of these pathogens and to ensure transport within Stand 1 does not occur.

Procedures: The most important pathogens of trees are carried in the soil. All the following procedures aim to prevent entry of soil or to disinfect those soil particles that may adhere to personnel, tools and equipment.

1 All material taken into the site should be free of soil. Preferably it should be cleaned before trips to the site and should be sterilised with an appropriate sterilant such as bleach (sodium hypochlorite), alcohol (70% mentholated spirits) or a commercial disinfectant (eg. biogram). Clothes and backpacks should be washed with a detergent prior to trips to the site. Secateurs, trowels, spades and other such equipment should be sterilised carefully to ensure no possible transportation of pathogens. Shoes and boots should be carefully cleaned prior to trips to the site.

2 A footbath should be used to clean footwear prior to entering the immediate area around and adjacent to the trees. Again a sterilant such as bleach or biogram is appropriate. A sterilant which requires a higher dilution rate is recommended as the amount that is needed to be carried is much less. Shoes should be soaked in the sterilant for one minute. It is advisable to remove shoes as the sterilant can be damaging to the skin of some people. Alternatively, 70% alcohol in a spray pack can be used to clean shoes & equipment prior to entering and within the site.

3 Movement within Stand 1 should always be from infection free into infected areas, sterilising shoes and equipment between each group of trees. If more than one site is to be visited in a trip, disease free stands must be visited prior to visiting Stand 1, where the pathogen *Phytophthora cinnamomi* is currently present.

4 New sterilant should be prepared on each new entry to the site. The life of these sterilants when exposed to soil particles is very short. The old sterilant must be removed from the immediate vicinity of the site. It must never be emptied into watercourses.

Appendix 2: Wollemi Pine Site Access Policy

1 Introduction

The Wollemi Pine was discovered in Wollemi National Park in August 1994 by a group of bushwalkers. The Pine is known to occur in several stands within gorge systems surrounded by sandstone cliffs.

Knowledge of the location of the Wollemi Pine is restricted, with only essential staff being made aware of the location of the wild population. All visits to the site by DEC employees, or by other approved persons, will be conducted in accordance with this Access Policy.

The DEC has formed the Wollemi Pine Recovery Team which has been responsible for overseeing the development and preliminary implementation of a recovery plan for the Wollemi Pine in accordance with the *Threatened Species Conservation Act 1995*. Through the early adoption of a site access protocol and the co-operation of neighbours, staff members and the original bushwalking group, the Team has been able to maintain relatively tight security regarding the location of the sites.

The Team is primarily concerned with threats to the Wollemi Pine arising from visits to the site rather than or arbitrarily restricting access. These threats include trampling of seedlings, the introduction of fungal pathogens, theft of plant material, site pollution, weed introduction, soil compaction and increased risk of wildfires. The Team has adopted a precautionary approach to the management of the Wollemi Pine. This site access policy may be reviewed in future years in association with the Recovery Plan.

2 Definitions

Act means the *National Parks and Wildlife Act 1974*

Regional Manager means the Manager, Blue Mountains Region, NSW National Parks and Wildlife Service, Department of Environment and Conservation.

Pine means the Wollemi Pine (*Wollemia nobilis*)

Wollemi Pine Recovery Team means the DEC approved recovery team established to advise the Director-General of DEC on the conservation of the Wollemi Pine.

3 Purpose of this Policy

3.1 To minimise the risk of damage to the wild population of Wollemi Pines.

3.2 To provide a consistent and transparent policy and procedure for managing requests for access.

4 Outcomes sought

4.1 Visitation to the site is regulated to ensure the risks associated with visits to the site are minimised.

4.2 The Wollemi Pine population within the Park does not decline as a result of threats arising from visitation to the Park; and

4.3 Visitation to the Wollemi Pine Site results in net benefits to threatened species conservation and Wollemi Pine conservation in particular.

5 Policies

5.1 Visits to the Wollemi Pine Site will be restricted to those activities necessary to achieve the recovery plans objectives.

5.2 The number of visits and the number of visitors will be restricted to the minimum number necessary to achieve the recovery plans objectives.

5.3 All visits to the Wollemi Pine Site must be endorsed by the Wollemi Pine Recovery Team and be approved by the Regional Manager (see exception in 5.13).

5.4 Site visits will be restricted to research, threat management and public eduction purposes only (unless otherwise specified within the recovery plan), and will be permitted only where a net benefit to the conservation of threatened species and the Wollemi Pine in particular, has been demonstrated.

5.5 The Regional Manager will determine when visits to the site need to be curtailed. This will be when the Regional Manager determines that 'acceptable risk' has been exceeded. The decision of the Regional Manager will be final.

5.6 Non-DEC applications to visit the Wollemi Pine site must be in writing to the Regional Manager and must clearly demonstrate that the purpose of the site visit is consistent with the Recovery Plan and that there is no practical alternative to the visit. The Regional Manager may refer the application to the Recovery Team if standing approvals do not cover the scope of the application.

5.7 All non-DEC visits to the Wollemi Pine site will be in accordance with a consent issued by the Regional Manager. The number of visits and extent of each visit will be clearly defined within that consent. Additional consents may also be issued for the purposes of other provisions of the Regulations (eg. filming). A confidentiality condition must be included on any consent issued.

5.8 The Regional Manager will nominate supervisors for any non-DEC Wollemi Pine site visitors.

5.9 The costs of this supervision and any other costs incurred by the NPWS in organising site access will be met by the applicant unless otherwise determined by the Regional Manager.

5.10 A Register will be maintained of all persons approved to visit the Wollemi Pine site and of all Wollemi Pine site visits. The register will be presented to the Wollemi Pine Recovery Team at the end of June each year.

5.11 Approvals for DEC staff to visit the site will be reviewed and renewed on an annual basis.

5.12 The continued co-operation of neighbours, local government, bushwalking clubs and previous site visitors will be sought in maintaining site confidentiality and in regulating and monitoring site visits.

5.13 Access for emergency purposes (*Rural Fires Act 1997* or the *State Emergency and Rescue Management Act 1989*) must be kept to the minimum number necessary for effective management of the incident and must be co-ordinated through the Regional Manager or the Manager's representative to minimise threats to the Wollemi Pine population.

5.14 No more that 5 persons will be permitted to visit the site on any one trip unless otherwise approved by the convenor of the Wollemi Pine Recovery Team or the Regional Manager.

5.15 All persons visiting the site will comply with the Wollemi Pine Site Hygiene Protocol.

6 Procedures

6.1 This policy will be made public as an appendix to the Wollemi Pine Recovery Plan and will also be available as a free publication.

6.2 This policy will be made available to appropriate neighbours, local councils, bushwalking clubs, and all approved site visitors including staff members.

6.3 This policy will be reviewed annually by the Wollemi Pine Recovery Team.

6.4 The Wollemi National Park Plan of Management and Reserve Fire Management Plan and relevant Section 51(1) (b) bush fire management plans will be amended if necessary to incorporate this policy.

7 Relevant legislation

7.1 *National Parks and Wildlife Act 1974*. Section 118A-D states that a person must not "pick" any threatened species or by an act or omission, do anything that causes damage to any habitat of a threatened species if the person knows that the land concerned is habitat of that kind. The habitat of the Wollemi Pine is described in the recovery plan. A person convicted of such an offence faces a maximum penalty of $220,000 and/or 2 years imprisonment and $110, 000

and/or 1 year imprisonment respectively. Section 118C of the *National Parks and Wildlife Act 1974* also makes it an offence for a person to damage any critical habitat. If a map of the critical habitat is published in the Gazette, the prosecution does not need to demonstrate that the person knew that it was declared as critical habitat. Maximum penalty of $220,000 and/or 2 years imprisonment.

7.2 *National Parks and Wildlife (Land Management)* Regulation 2002 Clauses 4(1) of the Regulation enable a park authority to regulate certain activities within a national park. Maximum penalty $3,300.

7.3 The *Threatened Species Conservation* Act 1995 provides for the declaration of critical Habitat (Part 3) and the making of regulations to restrict certain activities in areas so declared.

7.4 The *Environment Protection and Biodiversity Conservation* Act 1999 also has provisions for the protection of species listed on the schedules of the Act and is on e of the listed World Heritage values of the Greater Blue Mountains World Heritage Area. The Wollemi Pine is listed as endangered on the EPBC Act 1999.

8 Relevant policies and documents

8.1 Wollemi Pine Recovery Plan. Provides background information, species ecology and actions and responsibilities for recovery in accordance with the *Threatened Species Conservation Act 1995*.

8.2 Wollemi National Park Plan of Management. Lists the policies and actions to be undertaken to protect the Pine and its site from damage in the context of the planning framework for Wollemi National Park.

8.3 NPWS Threatened Species Information Circulars. Contain information relevant to threatened species management in NSW and the operation of the *Threatened Species Conservation Act 1995* in particular.

9 Contacts

9.1 Manager, Biodiversity Conservation Section, Metropolitan Environment Protection & regulation Branch 02 9585 6952

Manager, Blue Mountains Region NPWS 02 4784 7300.

10 Policy information

10.1 Originally prepared by Bob Conroy, Director, Central Region, National Parks and Wildlife Service, October 1997 and updated by the Wollemi Pine Recovery Team, September 2005 and November 2006.

Appendix 3: Summary of advice by NSW Scientific Committee

Under Section 66A of the TSC Act 1995 (NSW), recovery plans must include a summary of advice by the NSW Scientific Committee, details of the amendments made and reasons for any departure from that advice. The Scientific Committee's comments on the draft Recovery Plan for Wollemi Pine (*Wollemia nobilis*) and details of the amendments made, are tabled below:

Section	Advice	Response
General	Lack of detailed actions dealing with the threat of climate change	Updated actions to incorporate where possible
General	Use of bioclimatic modelling to locate sites that may serve as climate refugia in the future is desirable	Incorporated into Actions 10.1.6 and 10.2.7
General	Plan needs to be updated to incorporate recent finding of *Phytophthora cinnamomi* at Stand 1	updated
General	Systematic disease monitoring of ex situ plants to avoid new pathogens in wild plants	Will occur with on-going ex situ program. No plants re-introduced to wild under this plan.
Action 10.1.6	No details on what the triggers for translocation or reintroduction might be	Incorporated into plan to be developed under Action 10.1.6
10.5.1	How is the reduction in risk from illegal collection to be assessed	On going site surveillance and monitoring as per Action 10.1.1
7.4	Sentence re-wording	corrected
Fig 9	Explain juv code	Details provided
9.5	Complete sentence	completed
9.6.4, 10.3.3	Correct tense	corrected
9.6.10	Possible expansion	Relevant to future research publication, not recovery plan
9.13	Rephrase	Corrected
10.1	Add some relevant text	Text added
References	Various minor corrections	corrected
General	typos	corrected