***Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (s266B)**
Draft description and summary of threats for the
Warkworth Sands Woodland of the Sydney Basin Bioregion ecological community

1. The Threatened Species Scientific Committee (the Committee) was established under the EPBC Act and has obligations to present advice to the Minister for the Environment (the Minister) in relation to the listing and conservation of threatened ecological communities, including under sections 189, 194N and 266B of the EPBC Act.
2. The Committee will provide its advice on the Warkworth Sands Woodland of the Sydney Basin Bioregion ecological community to the Minister as a draft conservation advice in 2016.
3. The Minister will decide whether to amend the list of threatened ecological communities under Section 184 of the EPBC Act to include the Warkworth Sands Woodland of the Sydney Basin Bioregion ecological community. It is noted that the ecological community is listed under the New South Wales *Threatened Species Conservation Act 1995*.
4. The draft description, summary of threats for and potential listing category of critically endangered for this ecological community is being made available for expert and public comment for a minimum of 30 business days. The Committee and Minister will have regard to all public and expert comment relevant to the consideration of the ecological community.

DRAFT

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1 DESCRIPTION

1.1 Name of the ecological community

The name of the ecological community is Warkworth Sands Woodland of the Sydney Basin Bioregion (hereafter referred to as Warkworth Sands Woodland, or the ecological community). It is low woodland, typically dominated by *Angophora floribunda* (rough-barked apple) in the canopy and *Banksia integrifolia* subsp. *integrifolia* (coast banksia) and/or *Acacia filicifolia* (fern-leaved wattle) in a sub canopy; together with other small trees, shrubs and groundcover species typical of sandy soils in the Hunter Valley region.

1.2 Location and physical environment

The ecological community occurs in the Hunter River catchment, in the Central Hunter region of the Hunter Valley. It occurs in the Hunter Valley IBRA[1] subregion (SYB02), in the north east of the Sydney Basin Bioregion (SYB). The ecological community occurs in the Hunter Local Land Services region. It occupies small areas west of Singleton in the Singleton Local Government Area, on areas of sandy soil classified as the Warkworth Land System (Peake et al., 2002; NSW OEH, 2012).

There are four known occurrences of the ecological community: Wallaby Scrub Road, Warkworth village, Archerfield and Bulga. It may occur on the Warkworth Land System elsewhere in the Central Hunter region.

The Hunter Valley region is at the intersection of a number of bioregions, where ecosystems from the coast, inland and the north and south all meet. The region is bounded on the north east by the Hunter Thrust Fault and on the south by cliffs of Narrabeen Sandstone. It is characterised by low, rolling hills and wide valleys, with a meandering river system on a wide flood plain. The geology of the Hunter Valley region's landscape includes Permian shales, sandstones, conglomerates, volcanics and coal measures. These formations are dissected by unconsolidated alluvial deposits associated with the Hunter River system (Nashar, 1964; Tame, 1992; NSW DMR, 1999). Much of the region (particularly areas with Permian sedimentary bedrock) is underlain with extensively faulted Carboniferous rocks in which coal deposits are targeted for extraction. There is a variety of harsh texture contrast (duplex) soils on the slopes; and deep sandy alluvial loam on the valley floors (Morgan, 2001 in NSW NPWS, 2003).

The ecological community occurs on old dune formations, as well as on swales between the dunes and on sand sheets; all part of the Warkworth Land System (Story et al., 1963; Kovac and Lawrie, 1991). The sand dunes at Warkworth likely formed some 18 000 to 15 000 years ago from the sandy alluvium of Wollombi Brook (Peake, 2011), a tributary of the Hunter River (Galloway 1963). Story et al. (1963) noted that the dunes are generally stable but are subject to blowouts[2].

Warkworth Sands Woodland mostly occupies linear sand dunes, which are between one and six metres high, typically resting on a river terrace, on the undulating valley floor. As well as these

[1] IBRA: Interim Biogeographical Regionalisation of Australia [Version 7 – 2012] in DSEWPAC (2012).

[2] Blowouts: Sandy depressions formed when a patch of protective vegetation in a sand dune ecosystem is lost and strong winds "blow out" sand to form a depression.

deeper sand deposits, the ecological community also occurs on shallow "veneers" of sand separated from the main sand deposit by areas of clay soils developed on Permian sediments.

1.2.1 Climate

The Sydney Basin Bioregion (SYB) generally has a temperate climate, characterised by warm summers with no dry season (NSW NPWS, 2003). Climatic variations across the bioregion are largely due to increasing altitude and distance from the coast, although latitude also plays a part (NSW OEH, 2011). The ecological community occurs in the warmer, drier parts of the bioregion, in the Hunter Valley region, where average daily temperatures exceed 21 ^{o}C in summer and the average minimum temperature in winter is 4.4 ^{o}C. January is the hottest month and July the coldest (ATN, 2014). Average annual rainfall is 750 mm, with the heaviest rainfall in summer and a secondary peak just before winter (ATN, 2014).

1.3 Vegetative components

The ecological community is a mid to low woodland (occasionally forest), typically dominated by *Angophora floribunda* (rough-barked apple) and *Banksia integrifolia* subsp. *integrifolia* (coast banksia), on deeper sands. On the thinner sand sheets, in dune swales and drainage lines, species such as *Banksia integrifolia* are replaced by species that are more tolerant of waterlogged sites such as *Melaleuca thymifolia* (Cumberland Ecology, 2014). Table 1 lists abundant and/or characteristic vascular flora species.

Not all species are present in every stand and the total species list from all stands of the community is considerably larger than Table 1. Whilst the species listed in Table 1 are found regularly in Warkworth Sands Woodland, many also occur in other ecological communities (NSW Scientific Committee, 2011).

The composition of the ecological community (number of species and the above ground relative abundance) at a particular site is influenced by the size of the site, recent rainfall, or drought conditions and by its disturbance history (including clearing, grazing and fire). At any one time, above ground individuals of some species may be absent, but the species may be represented below ground in the soil seed banks or as dormant structures such as bulbs, corms, rhizomes, rootstocks or lignotubers (NSW Scientific Committee, 2011).

1.3.1 Canopy

The canopy of the ecological community is sparse to dense and dominated by *Angophora floribunda* (rough-barked apple) on deeper sand. On the shallower sands in swales *Eucalyptus blakelyi* x *E. tereticornis* (Blakely's red gum x forest red gum hybrid) and *E. crebra* (narrow leaved ironbark) are more likely to dominate. Other canopy species such as *Allocasuarina luehmannii* (bulloak or buloke) and *Callitris endlicheri* (black Cypress-pine) may dominate on the higher, drier portions of the sand system (Peake, 2006; Cumberland Ecology, 2014).

Other tree species that may be abundant through to absent, include: *E. blakelyi* (Blakely's red gum), *Brachychiton populneus* subsp. *populneus* (kurrajong), *E. glaucina* (slaty red gum) and *E. moluccana* (grey box).

1.3.2 Mid layer (midstorey)

Warkworth Sands Woodland midstorey vegetation comprises species more typical of sand or sandstone-based environments (Peake et al., 2002). A sparse sub-canopy of smaller trees is sometimes present, dominated by *Banksia integrifolia* subsp. *integrifolia* (coast banksia) and /or *Acacia filicifolia* (fern-leaved wattle); *Acacia littoralis* (black sheoak) is occasionally present (Peake, 2006). A sparse to dense shrub layer is usually present; with *Brachyloma daphnoides* subsp. *daphnoides* and *Breynia oblongifolia* (coffee bush) commonly occurring and occasionally *Hovea linearis* (narrow leaf hovea). *Melaleuca thymifolia* (thyme honey-myrtle) may be present at damper sites (Peake, 2006).

1.3.3 Ground layer

The groundcover varies from very sparse to dense and is dominated in most places by *Imperata cylindrica* var. *major* (blady grass) and *Pteridium esculentum* (bracken). Other species that commonly occur include: *Chrysocephalum apiculatum* (common everlasting); *Commelina cyanea* (scurvy weed); *Dichondra repens* (*kidney weed*); *Echinopogon caespitosus* var. *caespitosus* (tufted hedgehog grass); *Glycine clandestina* (twining glycine); *Hibbertia linearis* (guinea flower) *Leucopogon muticus* (blunt beard-heath); *Lomandra confertifolia* (mat rush); *Lomandra leucocephala* subsp. *leucocephala* (woolly mat rush); *Lomandra multiflora* subsp. *multiflora* (many flowered mat rush); *Microlaena stipoides* var. *stipoides* (weeping grass) and *Pimelea linifolia* subsp. *linifolia* (slender rice flower) (Peake et al., 2002, Peake; 2006; NSW OEH, 2012). Table 1 lists the abundant, common and/or characteristic vascular flora species. The community also comprises algae, lichens, mosses, fungi and micro-organisms.

1.3.4 Derived native grassland/shrubland

Native grasslands and shrublands are **not** included in the definition of the ecological community. The exception is where there is a gap in, or at the edge of a patch, or between two patches across a short distance[3].

Derived grasslands and shrublands can be an important part of the broader ecosystem and may have potential for future restoration (i.e. developing a canopy layer that makes them eligible for inclusion in the nationally protected ecological community)[4]. Derived grasslands and shrublands contain much of the native plant biodiversity of the ecological community and act as a seed bank and source of genetic material. Derived grasslands/shrublands also act as buffer zones that can protect woodland remnants from adjacent activities, and act as stepping stones that enable the

[3] Where native grassland/shrubland (whether derived or not) connects discrete patches of the ecological community in close proximity (up to 30 m apart) then it should be treated as part of a single patch. Also where native grassland/shrubland is within a gap in, or at the edge of a patch, (up to 30 m from the edge of the tree canopy/saplings) it should be considered to be part of the patch of the ecological community. See also Section 1.6.1 (*Defining a patch*). Native means vegetation 'dominated by native species'; i.e. that 50% or more of the perennial vegetation cover is native.

[4] Some areas of derived grassland in the Hunter Valley region are protected under the 'White Box-Yellow Box-Blakely's Red Gum Woodland ecological community listing.

movement of fauna between remnant woodlands. For this reason, where not included in a patch, they should be considered as part of the surrounding environment and landscape context for patches of the ecological community (see Section 1.6 *Further information and other significant considerations*).

Evidence that a derived grassland or shrubland originated from a specific woodland or forest type may include: tree stumps, fallen logs, historical records, photographs, surrounding vegetation remnants, underlying substrate, or reliable modelling of pre-European vegetation that a patch of derived grassland/shrubland formerly contained the ecological community. For example, derived grassland and shrubland patches on aeolian sand, which are in the area where the ecological community occurs and meet the ground/mid layer description, may be reasonably inferred from their location to have been the ecological community in the past (unless conditions or other evidence dictate otherwise).

Table 1. Abundant, common and/or characteristic flora species of the Warkworth Sands Woodland. Scientific names are as at October 2015. Source: NSW Scientific Committee, 2002; Peake et al., 2002; Peake, 2006; Cumberland Ecology, 2014.

Scientific name	Common name
Canopy	
Allocasuarina luehmannii	bulloak, buloke
Angophora floribunda	rough-barked apple
Brachychiton populneus subsp. *populneus*	kurrajong
Callitris endlicheri	black Cypress-pine
Eucalyptus blakelyi and *Eucalyptus blakelyi* x *E. tereticornis*	Blakely's red gum and red gum hybrid; Blakely's red gum x forest red gum
Sub-canopy / Mid layer	
Acacia filicifolia	fern-leaved wattle
Acacia parvipinular	silver stemmed wattle
Allocasuarina littoralis	black sheoak
*Amyema pendula (*syn. *A. pendulum)*	drooping mistletoe
Banksia integrifolia subsp. *integrifolia*	coast banksia
Brachyloma daphnoides subsp. *daphnoides*	-
Breynia oblongifolia	coffee bush
Exocarpos cupressiformis	native cherry
Exocarpos strictus	pale-fruit ballart, dwarf cherry
Hovea linearis	narrow leaf hovea
Melaleuca thymifolia	thyme honey-myrtle

Ground layer	
Aristida calycina var. *calycina*	dark wiregrass
Aristida ramosa var. *speciosa*	purple wiregrass
Aristida vagans	three-awn speargrass
Cheilanthes sieberi subsp. *sieberi*	mulga fern, narrow rock-fern
Chrysocephalum apiculatum	common everlasting
Commelina cyanea	scurvy weed
Dianella revoluta var. *revoluta*	blueberry lily, blue flax-lily
Dichondra repens	kidney weed
Echinopogon caespitosus var. *caespitosus*	tufted hedgehog grass
Einadia hastata	berry saltbush, Saloop
Entolasia stricta	wiry panic
Eragrostis brownii	Brown's lovegrass
Glycine clandestina	twining glycine
Glycine tabacina	variable glycine
Hardenbergia violacea	false sarsaparilla, native lilac
Hibbertia linearis	guinea flower
Imperata cylindrica var. *major*	blady grass
Jacksonia scoparia	dogwood
Leucopogon muticus	blunt beard-heath
Lomandra confertifolia	mat rush
Lomandra glauca	pale mat-rush
Lomandra leucocephala subsp. *leucocephala*	woolly mat rush
Lomandra multiflora subsp. *multiflora*	many flowered mat rush
Microlaena stipoides var. *stipoides*	weeping (meadow) grass
Perotis rara	comet grass
Persoonia linearis	narrow-leaved geebung
Pimelea linifolia subsp. *linifolia*	slender rice flower
Pomax umbellata	pomax
Pteridium esculentum	bracken

1.4 Faunal components

The vertebrate fauna of the ecological community are typical of those of similar woodland and forest environments throughout the Hunter Valley region. Because the ecological community is highly fragmented and part of a mosaic of other woodlands (surrounded by a highly modified landscape) no species are known to be restricted to just this ecological community. Rather, most animal species use the habitats provided by the ecological community as part of larger ranges, which may include numerous remnant vegetation types.

Whilst there is no distinctive faunal assemblage confined solely to the ecological community, it provides habitat to a wide variety of vertebrate and invertebrate fauna. The ecological community provides essential resources such as nesting/breeding sites, shelter from predators (for example logs, tree hollows and thicker undergrowth) and sources of food (for example nectar from flowers or invertebrate prey). For example *Allocasuarina luehmannii* (bulloak) is a potential food tree for *Calyptorhynchus lathami* (glossy black cockatoo) (Umwelt, 2013).

Some fauna may be seasonal transients through the community (for example pollinating birds such as honeyeaters are likely to visit during the local flowering season). Other animals may use the patches of the ecological community as stepping stones to other habitats; such as crossing the valley floor, north to south. The ecological community can be valuable as a source of winter-flowering eucalypts for transient threatened species such as *Anthochaera phrygia* (regent honeyeater) and *Lathamus discolor* (swift parrot).

The ecological community supports bat species, for example *Falsistrellus tasmaniensis* (eastern false pipistrelle) and *Saccolaimus flaviventris* (yellow-bellied sheath-tail bat), primarily by providing tree hollows and suitable foraging habitat. The ecological community may not support a diverse reptile component due to the absence of structural elements such as rocky outcrops or deep litter microhabitats. However, it is likely to include various species of lizards (including skinks, dragons, geckoes and monitors) and snakes.

Some ground-dwelling native animals such as *Vombatus ursinus* (common wombat) and *Tachyglossus aculeatus* (short-beaked echidna), as well as bandicoot species, found (or formerly present) in the ecological community play an important ecological role in maintaining soil processes. In other locations in NSW it has been observed that soil disturbances created by these animals can provide benefits by assisting soil aeration, nutrient cycling and water infiltration, as well as the spread and establishment of seedlings (Martin, 2003).

A wide range of fauna taxa, including many species of invertebrates and birds, play an important role in pollination and in transfer of seed. Some mammals such as *Antechinus stuartii* (brown antechinus); *Cercartetus nanus* (eastern pygmy possum); *Petaurus breviceps* (sugar gliders); and *Rattus fuscipes* (bush rat) also contribute to these functions.

1.5 Key diagnostic characteristics and Condition thresholds

In order to be considered a matter of National Environmental Significance under the EPBC Act, areas of the ecological community must meet:

- the *Key diagnostic characteristics* (in Section 1.5.1); and
- at least the minimum patch size of 0.5 ha.

National listing focuses legal protection on patches of this ecological community that are functional and relatively natural, as outlined in the '*Description*'. Key diagnostic characteristics and condition thresholds assist in identifying a patch of the threatened ecological community and determining whether the referral, environment assessment and compliance provisions of the EPBC Act are likely to apply.

Condition categories and thresholds can provide guidance on whether a patch retains sufficient conservation values to be considered as a matter of National Environmental Significance, as defined by the EPBC Act. They can enable the EPBC Act protection provisions to be focussed on the most valuable elements of the ecological community. Where condition thresholds are applied, patches which do not meet the minimum condition thresholds are then largely excluded from national protection.

Because there is less than 500 ha of this ecological community remaining, condition thresholds have not been applied to this ecological community; although patches of less than 0.5 ha in size are not protected as a matter of National Environmental Significance under the EPBC Act.

Species composition of this ecological community is influenced by (amongst other things) the size of the patch, recent rainfall, drought conditions and disturbance history (including fire and grazing). Plant surveys conducted during spring and early summer may more easily identify the ecological community. However, the *Key diagnostic characteristics* (Section 1.5.1) and *Other diagnostic considerations* (Section 1.5.2) are designed to allow identification of the ecological community irrespective of the season.

1.5.1 Key diagnostic characteristics

For EPBC Act referral, environment assessment and compliance purposes the protected national ecological community is limited to patches that meet the following key diagnostic characteristics (and the minimum patch size);

- It occurs in the Central Hunter Valley, in the Hunter Valley IBRA[5] subregion (SYB02) of the Sydney Basin (SYB) Bioregion in New South Wales;

AND

- It occurs on aeolian, or other sandy textured, soils [6]of the Warkworth Land System;

AND

- It is a low woodland (occasionally forest), with a projected crown cover[7] of trees of 10% or more; or with a native tree density of at least 10 native tree stems per 0.5 ha (at least 20 native tree stems/ha) that are at least one metre in height[8];

AND

- A ground layer is present (although it may vary in development and composition), as a sparse to thick layer of native shrubs, bracken, grasses and/or other native herbs;

AND

- It is characterised by multiple flora species in Table 1, although not all species need be present (see Section 1.3 *Vegetative components* for more details on vegetation structure and flora).

[5] IBRA: Interim Biogeographical Regionalisation of Australia [Version 7 – 2012] in DSEWPAC (2012).

[6] Aeolian (also spelled eolian) sands: Sediment, which has been carried, or weathered, by the wind.

[7] Projected cover of canopy trees is calculated by assuming a solid canopy.

[8] This figure is to allow for woodland or forest with a sparse canopy and regenerating areas.

1.5.2 Other diagnostic considerations

- Warkworth Sands Woodland mostly occupies linear sand dunes, which are between one and six meters high, typically resting on a river terrace, on the undulating valley floor.
- As well as these deeper sand deposits, the ecological community also occurs on shallow "veneers" of sand separated from the main sand deposit by areas of clay soils developed on Permian sediments.
- It does not occur on clay soils on Permian sediments, nor does it occur on the sandy colluviums[9] of the widespread Triassic Sandstone plateaus.
- The canopy is typically dominated by *Angophora floribunda* (rough-barked apple) on deeper sands.
- On the shallower sands in swales *Eucalyptus blakelyi* x *E. tereticornis* (Blakely's red gum-forest red gum) and *E. crebra* (narrow-leaved ironbark) are more likely to dominate. Other canopy trees such as *Allocasuarina luehmannii* (bulloak, buloke) and *Callitris endlicheri* (black Cypress pine) may dominate on the higher, drier portions of the sand system.
- Other tree species may include: *Eucalyptus blakelyi* (Blakely's red gum) and *E. glaucina* (slaty red gum); as well as *Brachychiton populneus* subsp. *populneus* (kurrajong) and *E. moluccana* (grey box) in some areas;
- Patches with hybrid eucalypt species are included in the ecological community (i.e. areas should not be excluded on the basis of hybridisation);
- A sparse, sub- canopy layer is likely to be dominated by *Banksia integrifolia* subsp. *integrifolia* (coast banksia) and/or *Acacia filicifolia* (fern-leaved wattle);
- Derived native grasslands and shrublands are **not** included in this nationally protected ecological community. The exceptions are where there is a gap, in or at the edge of a patch; or connecting two patches across a short distance (i.e. 30 m)[10].

[9] Colluvial material / Colluvium: A loose deposit of sharp edged rock debris and/or sediment that has moved downhill to the bottom of the slope (or cliff) without the help of running water in streams.

[10] Where native grassland/shrubland (whether derived from the ecological community or not) connects discrete patches of the ecological community in close proximity (up to 30 m apart) then it should be treated as part of a single patch. Also native grassland/shrubland within a gap in, or at the edge of a patch, (up to 30 m from the edge of the tree canopy/saplings) is part of the patch. See also sections 1.6.1 (*Defining a patch*) and 1.3.4 (*Derived native grassland/shrubland*). "Native" here means vegetation 'dominated by native species'; i.e. that 50% or more of the perennial vegetation cover is native.

1.5.3 Condition thresholds

Because there is less than 500 ha of the ecological community remaining, condition thresholds have not been applied; although patches of less than 0.5 ha in size are not protected as a matter of National Environmental Significance under the EPBC Act.

All patches of the Warkworth Sands Woodland ecological community that:

- meet the *Key diagnostic characteristics* of the ecological community (in Section 1.5.1)

and

- are at least 0.5 ha in size, are considered critical to its survival.

Warkworth Sands Woodland occurs near the edges of Wollemi and Yengo National Parks, in a heavily cleared region of Australia. Much of the native vegetation now only remains as small, fragmented remnants, amongst a matrix of modified agricultural landscapes. It is acknowledged that:

- small patches (≥ 0.5 ha) that remain largely intact have significant conservation value;
- even degraded patches that retain the characteristics of the ecological community need protecting;
- mature locally indigenous trees (and hollow bearing trees) are important for the range of habitats and resources they provide to species in the ecological community and the broader region;
- large intact patches are relatively uncommon in this landscape and;
- larger size and/or connectivity to other native vegetation areas are typically beneficial.

It is not intended to include heavily degraded patches with isolated trees; or small narrow stands of trees over exotic pastures, crops, or weeds that serve as windbreaks or shelter belts; i.e. where the native understorey has effectively become lost and/or the tree canopy is patchy and very discontinuous (i.e. <10% projected canopy cover).

1.6 Further information to assist in determining the presence of the ecological community and significant impacts

Landuse history will influence the current state of a patch of the ecological community. The structural form of the ecological community will also influence its species richness and diversity. The position of the ecological community and its position relative to surrounding vegetation also influence how important a patch of the ecological community is in the broader landscape.

1.6.1 Defining a patch

A patch is a discrete and mostly continuous area of the ecological community[11]. Permanent man-made structures, such as roads and buildings, are typically excluded from a patch. A patch may include small-scale variations and disturbances, such as tracks, paths or breaks (including exposed soil, leaf litter, cryptogams and watercourses/drainage lines), or localised changes in vegetation that do not significantly alter the overall functionality of the ecological community.

Where there is a break in native vegetation cover from the edge of the tree canopy[12] of 30 m or more, then the gap indicates that separate patches are present.

1.6.2 Buffer zone

A buffer zone is a contiguous area adjacent to a patch that is important for protecting the integrity of the ecological community. As the risk of damage to an ecological community is usually greater for actions close to a patch, the purpose of the buffer zone is to minimise this risk by guiding land managers to be aware when the ecological community is nearby and take extra care around the edge of patches. The buffer zone will help protect the root zone of edge trees and other components of the ecological community from spray drift (fertiliser, pesticide or herbicide sprayed in adjacent land) and other damage.

The buffer zone is not part of the ecological community; so whilst having a buffer zone is strongly recommended, it is not formally protected as a matter of National Environmental Significance. For EPBC Act approval, changes in use of the land that falls within the buffer zone must not have a significant impact on the ecological community, but there are exemptions for continuing use. If the use of an area (e.g. grazing land) that directly adjoins a patch of the ecological community is going to be intensified (e.g. fertilised), approval under the EPBC Act may also be required.

The recommended minimum buffer zone is 30 m from the outer edge of the patch. This typically accounts for the maximum height of the vegetation and likely influences on the root zone. A larger buffer zone should be applied, where practical, to protect patches of very high conservation value, or if patches are downslope of drainage lines or a source of eutrophication.

1.6.3 Reconstructed and Revegetated areas and areas of regrowth

Revegetated or replanted sites (or areas of regrowth) are not excluded from the listed ecological community, so long as the patch meets the *Key diagnostic characteristics* and minimum patch size. It is recognised that reconstruction/revegetation often requires longer-term effort and commitment and results are uncertain. Reconstructing a woodland ecological community to a state

[11] Note that NSW vegetation assessment tools define a ‘patch’ as an area of native vegetation, of one or more different communities that occur together, separated by a gap of no greater than a set distance (usually 100 m). However, the Threatened Species Scientific Committee uses the term ‘patch’ to describe any discrete remnant/area of the ecological community in question.

[12] Or where there is no canopy at an edge of a patch, just smaller seedlings (i.e. at least 10 native tree stems per 0.5 ha, that are at least one metre cm in height), then 30 m from the tree seedlings themselves.

that resembles appropriate reference sites can, at best, be extremely slow and may ultimately prove unsuccessful (Wilkins et. al, 2003).

1.6.4 Sampling protocols

Thorough and representative on-ground surveys are essential to accurately assess the extent of the ecological community. Patches can vary markedly in their shape, size and features that appear within a given patch. As a general principle, sampling protocols and the number of sample plots/transects should address the following:

- significant variation in the vegetation, landscape qualities and management history (where known) across the patch; for instance localised weed cover, drainage lines, grazed areas, saline zones; and
- an appropriate size and number of plots or transects to provide a representative sample across the full extent of the patch (taking into consideration the shape and condition across the site, as well as providing a good representation of the species present).

Plots of 0.04 ha (quadrats of 20 x 20 m) may be suitable (Tozer, 2003; Tozer et al., 2010). Recording the search effort (identifying the number of person hours spent per plot and across the entire patch; along with the surveyor's level of expertise) can be useful for future reference.

1.6.5 Surrounding environment, landscape context and other significant considerations

Actions that may have 'significant impacts[13] on any nationally protected patches of the Warkworth Sands Woodland, require referral under the EPBC Act.

The ecological importance of a patch is influenced by its surrounding landscape; for example, if it is connected to, or near, other native vegetation the patch may contribute substantially to landscape connectivity and function. Similarly, actions beyond the boundary of a patch may have a significant impact on the patch (for example, through changes in hydrology). For this reason, when considering actions likely to have impacts on this ecological community, it is important to also consider the environment surrounding any patches of the ecological community. Other patches may occur in isolation and, in addition to requiring protection, may require management of the surrounding area to link them with other native vegetation.

The following indicators of the ecological context provided by the areas surrounding patches of the ecological community should be considered both when assessing the impacts of actions or proposed actions under the EPBC Act, or when considering priorities for recovery, management and funding.

- Large size and/or a large area to boundary ratio – patches with larger area to boundary ratios are less exposed and more resilient to edge effects (disturbances such as weed invasion and other anthropogenic impacts). However, patches that occur in areas where the ecological

[13] A 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Further information regarding 'significant impact' and the EPBC Act is available at http://www.environment.gov.au/epbc/publications/significant-impact-guidelines-11-matters-national-environmental-significance

community has been most heavily cleared and degraded, may also have importance due to their rarity, genetic significance, or because of the absence of some threats.

- Evidence of recruitment of key native plant species or the presence of a range of age cohorts (including through successful assisted regeneration). For example, tree canopy species are present as saplings through to large hollow-bearing trees.
- Good faunal habitat as indicated by: diversity of landscape; diversity of plant species; mature trees (particularly those with hollows); logs; and rocks.
- High native species richness, possibly including many understorey plant species or native fauna species.
- Patches that contain a unique combination of species and/or rare or important species in the context of the particular ecological community, or local region (e.g. a variant of the patch with unique fauna and/or understorey flora composition; or a patch that contains flora or fauna that has largely declined in the ecological community or region). Presence of EPBC Act or NSW *Threatened Species Conservation Act 1995* listed threatened species.
- Areas with minimal weeds and feral animals, or where these threats can be managed.
- Presence of cryptogams, soil crust and leaf litter on the soil surface, which indicates low (or no) recent disturbance to the natural soil structure and the potential for good functional attributes such as nutrient cycling.
- Derived native grasslands/shrublands, particularly those adjacent or near to forest/woodland remnants. These can be important to the survival of the ecological community in an otherwise fragmented, rural landscape.
- Connectivity to other native vegetation remnants or restoration works (e.g. native plantings) in particular, a patch in an important position between (or linking) other patches in the landscape. This can contribute to movement of fauna and transfer of pollen and seeds.
- Linear road reserves often contain remnant native vegetation in good to moderate condition, representing a diverse range of upper storey, mid-storey and perennial understorey species. These areas also act as important corridor links to larger patches of nearby vegetation. In many instances linear road reserves can represent the only remnant native vegetation occurring in an area where adjacent land has largely been cleared.

1.6.6 Timing of surveys (& seasonal variation)

When assessing the quality (including species richness) of an ecological community and its surrounding environment, the timing of surveys can be an important consideration, because the appearance of vegetation can vary throughout the year and between years, depending on drought-rain cycles. Seasonal factors can determine the visual dominance of taxa. For example, many native grasses are most visually dominant in late spring-early summer; however, the same sites when surveyed in June or July may be dominated by exotic annuals.

Quality assessment should occur in spring and summer to early autumn, when the greatest number of species is likely to be detectable and identifiable. Ideally, surveys should be held in more than one season to maximise the chance of detecting all species present. In years of low

rainfall, assessment should recognise that many species may not be detected. In these situations it is preferable that surveys are carried out over more than one year.

As well as considering the detectability of flora species in the mid and ground layer at different times of their life cycle, timing of surveys should also allow for recovery after recent disturbances to the ecological community (whether natural, or human-induced). Ideally, to maximise the assessment of understorey condition, sites should be assessed during a good season, six months after cessation of disturbance (fire/grazing/mowing/slashing) and within two months of effective rain. At a minimum, it is important to note climate conditions and what kind of disturbance may have happened within a patch and when that disturbance occurred, as far as possible.

1.6.7 Area critical to the survival of the ecological community

Areas that meet the description of the ecological community, or are within the buffer zone, are considered critical to the survival of the ecological community. Additional areas such as adjoining native vegetation are also important to the survival of the ecological community and should be taken into consideration as part of the surrounding environment and landscape context, as outlined in Section 1.6.5.

1.6.8 Geographic extent and patch size distribution

Geographic extent

Prior to European settlement the extent of the ecological community is estimated to have been 3 040 ha; the current extent of the ecological community is estimated to be 470 ha (Peake, 2011).

Available data indicate the ecological community has undergone a decline of 85%. Further losses associated with mining development are expected in the near future.

Patch size

The ecological community is highly fragmented. Peake (2006) estimated that almost all (72%) of the remnants are less than 10 ha in size; and only 3% of patches of the ecological community are larger than 100 ha in size (Peake, 2011).

1.7 Relationship to other vegetation classification systems

Keith (2004) includes the Warkworth Sands vegetation in the broader Sydney Sand Flats Dry Sclerophyll Forests vegetation class and notes that the few communities comprising this class are unique to the Sydney and Hunter regions. Warkworth Sands Woodland occurs on a sand-based soil landscape unique to the Hunter Valley.

The ecological community wholly or partially corresponds to a range of vegetation / map units identified by a number of surveys, mapping projects and databases covering the Hunter Valley region.

Additional/updated information on vegetation classification, subsequent to publication of an approved Conservation Advice for this ecological community, may be published on the Species Profile and Threats Database (SPRAT) profile for this ecological community, on the Department's website at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

The ecological community corresponds wholly or partially to the following vegetation/map units:

- **MU14** Warkworth Sands Woodland (Peake, 2006);
- **MU 124** Rough-barked Apple/ Narrow-leaved Ironbark/Blakely's Red Gum/ Bull Oak/ Coast Banksia/Bracken woodland of Warkworth area (Somerville, 2009);
- **HU600** Rough-barked Apple - Coast Banksia shrubby woodland on Warkworth Sands of the central Hunter Valley, Sydney Basin (**Plant Community Type ID 1112** superseded[14]) (NSW OEH, 2008a); and
- **HU872** (PCT ID 1658[15]) Rough-barked Apple - Narrow-leaved Ironbark - Blakely's Red Gum - Bull Oak - Coast Banksia woodland on sands of the Warkworth area (NSW OEH, 2015).

Areas of the vegetation classifications above that meet the *Key diagnostic characteristics* (in Section 1.5.1) are considered part of the Warkworth Sands Woodland.

1.7.1 Differences to similar or intergrading national ecological communities

The Warkworth Sands Woodland occurs on a highly restricted sand mass. Consequently, it is floristically distinct from other vegetation in the local area which is predominantly various associations of grey box (*Eucalyptus moluccana*), narrow-leaved ironbark (*E. crebra*) and spotted gum (*Corymbia maculata*) (Peake et al., 2002). Warkworth Sands Woodland has also been shown to have a different floristic composition, particularly as regards the suite of dominant species, to other sand-based vegetation communities of the Sydney Basin Bioregion.

Central Hunter Valley eucalypt forest and woodland

The nationally listed Critically Endangered Central Hunter Valley eucalypt forest and woodland ecological community, which occurs adjacent to the Warkworth sand dunes, on Permian clays, shares many species with Warkworth Sands Woodland; however, it has a higher abundance of Permian substrate species, such as *Corymbia maculata* (spotted gum), *Eucalyptus moluccana* (grey box), *Allocasuarina luehmannii* (bulloak, buloke) and *E. crebra* (narrow leaved ironbark).

White Box - Yellow Box - Blakely's Red Gum woodland and derived native grasslands

Warkworth Sands Woodland intergrades and shares characteristics (e.g. ground layer species) with the nationally listed Critically Endangered White Box - Yellow Box - Blakely's Red Gum Woodland and Derived Native Grasslands ecological community (also referred to as the 'Box - Gum Grassy Woodland'), which also occurs in the Hunter region. However the tree layers of the two ecological communities typically have a different species composition; and the Box - Gum Grassy Woodland is more typically grassy, with a shrub cover limit of 30%.

[14] NSW OEH (2008a) 'Biometric Vegetation Types (BVTs) for CMA areas' have been superseded by the NSW Vegetation Information System (VIS) Classification 2.1 BVTs (NSW OEH, 2015).

[15] The NSW Plant Community Type (PCT) classification, established as the NSW master community-level classification, was only recently updated with a new vegetation classification for the Greater Hunter region.

The canopy (where present) of Box – Gum Grassy Woodland is dominated by *Eucalyptus albens* (white box), *E. melliodora* (yellow box), or *E. blakelyi* (Blakely's red gum).

Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion

The nationally listed Endangered Castlereagh Scribbly Gum and Agnes Banks Woodlands ecological community does not occur in the Hunter Valley. It occurs further south; primarily in the Castlereagh area in the north-west of the Cumberland Plain, with other known occurrences just outside the Cumberland sub-region (Tozer et al., 2010; NSW Scientific Committee, 2013). The ecological community occurs primarily on ancient alluvial soils, the Tertiary sands and gravels of the Hawkesbury-Nepean river system.

The canopy contains, and is often dominated by, one or more of the following species: *Angophora bakeri* (narrow leaved apple), *E. parramattensis* subsp. *parramattensis* (Parramatta red gum) and *Eucalyptus racemosa* (syn. *E. sclerophylla*) (scribbly gum, narrow-leaved scribbly gum) (Keith, 2004; Tozer et al., 2010). *Eucalyptus fibrosa* (red ironbark) is also occasionally prominent in the canopy (Keith, 2004; Tozer et al., 2010). In addition, the Agnes Banks vegetation occurs on aeolian sand and can contain a number of species reminiscent of communities closer to the coast, such as *Banksia aemula* (wallum), *Dillwynia glaberrima* and *Ricinocarpos pinifolius* (wedding bush).

As well as the different dominant characteristic canopy species, other tree species such as *Callitris endlicheri* (black cypress pine) and *Exocarpos cupressiformis* (native cherry), *Brachychiton populneus* subsp. *populneus* (kurrajong), *Allocasuarina luehmannii* (bull oak) also make Warkworth Sands Woodland distinct from Castlereagh Scribbly Gum and Agnes Banks Woodlands.

Elderslie[16] *Banksia Scrub Forest of the Sydney Basin Bioregion* [17]

This low scrub-forest or woodland is listed under the NSW TSC Act and does not occur in the Hunter Valley. It occurs to the south west of Sydney, south of Camden near the Nepean River. It occurs on older coastal aeolian sand deposits on the Cumberland Plain. Its canopy is dominated by *Banksia integrifolia* subsp. *integrifolia* (coast banksia), or *Eucalyptus botryoides* (bangalay) in some wetter areas, and may contain *Angophora subvelutina* (rough-barked apple), *E. baueriana* (blue box) and/or *Melaleuca decora* (Tozer et al., 2010; NSW Scientific Committee, 2014). Of these, only *Banksia integrifolia* subsp. *integrifolia* is also a characteristic species of Warkworth Sands Woodland.

Other characteristic / common species of Elderslie Banksia Scrub Forest, which differentiate it from Warkworth Sands Woodland include: *Acacia decurrens* (Sydney green wattle), *A. implexa* (hickory wattle), *A. ulicifolia* (prickly Moses), *Aotus ericoides* (common aotus), *Clerodendrum tomentosum* (hairy clerodendrum), *Dillwynia glaberrima* (smooth-leaved dillwynia), *Duboisia myoporoides* (corkwood), *Hibbertia diffusa* (wedge guinea flower), *Gleichenia dicarpa* (pouched coral fern, tangle fern), *Kunzea ambigua* (tick bush), *Platysace lanceolata* (shrubby platysace) and *Ricinocarpos pinifolius* (wedding bush).

[16] Here Elderslie refers to Elderslie of the Cumberland Plain region, not Elderslie of the Hunter Valley.

[17] Under EPBC Act Assessment as a potentially threatened ecological community.

1.8 Other existing protection

Less than five percent (20 000 ha) of the Hunter IBRA sub-region has the status of terrestrial protected areas (NSW OEH, 2008b; DoE 2013); and most of these are at higher altitudes then the ecological community. None of the known community occurs within conservation reserves (Peake, 2006).

The ecological community corresponds to a NSW listed ecological community and contains habitat for threatened fauna and flora species listed under the EPBC Act and/or NSW state legislation.

1.8.1 Relationship to state-listed ecological communities

The ecological community corresponds to the New South Wales listed Warkworth Sands Woodland in the Sydney Basin Bioregion ecological community (NSW Scientific Committee, 2011).

1.8.2 Listed threatened flora species

Table 2.Threatened flora that may occur in the ecological community

Scientific names are current as at October 2015.

Scientific name	Common name	EPBC Act*	NSW TSC Act*
Ancistrachne maidenii	a scrambling perennial grass	-	V
Cymbidium canaliculatum	black orchid population in the Hunter catchment	-	Endangered population
Eucalyptus glaucina	slaty red gum	V	V
Thesium australe	austral toadflax	V	V

* V= listed as Vulnerable; E= listed as Endangered; CE= listed as Critically Endangered.

Source: Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* Species Profile and Threats Database [EPBC Act SPRAT Database]; NSW *Threatened Species Conservation Act 1995* Database [NSW TSC Act Threatened Species Database]; Peake, 2006; Umwelt, 2013; Cumberland Ecology, 2014.

1.8.3 Listed threatened fauna species

Table 3.Threatened fauna that may occur in the ecological community

Scientific names are current as at October 2015.

Scientific name	Common name	EPBC Act*	NSW Act*
Amphibians			
Heleioporus australiacus	giant burrowing frog	V	V
Litoria aurea	green and golden bell frog	E	V
Birds			
Anthochaera phrygia	regent honeyeater	E	CE
Callocephalon fimbriatum	gang-gang cockatoo	-	V
Calyptorhynchus lathami	glossy black cockatoo	-	V
Chthonicola sagittata	speckled warbler	-	V
Climacteris picumnus victoriae	brown treecreeper (eastern subspecies)	-	V
Daphoenositta chrysoptera	varied sittella	-	V
Glossopsitta pusilla	little lorikeet	-	V
Grantiella picta	painted honeyeater	V	V
Hamirostra melanosternon	black-breasted buzzard	-	V
Lathamus discolor	swift parrot	E	E
Lophoictinia isura	square-tailed kite	-	V
Melanodryas cucullata cucullata	hooded robin (south-eastern form)	-	V
Melithreptus gularis gularis	black-chinned honeyeater (eastern subspecies)	-	V
Neophema pulchella	turquoise parrot	-	V
Ninox connivens	barking owl	-	V
Ninox strenua	powerful owl	-	V
Petroica boodang	scarlet robin	-	V
Pomatostomus temporalis temporalis	grey-crowned babbler (eastern subspecies)	-	V
Stagonopleura guttata	diamond firetail	-	V
Tyto novaehollandiae	masked owl	-	V
Mammals			
Cercartetus nanus	eastern pygmy-possum	-	V
Chalinolobus dwyeri	large-eared pied bat	V	V
Dasyurus maculatus maculatus	spotted-tailed quoll (south-eastern mainland population)	E	V

Scientific name	Common name	EPBC Act*	NSW Act*
Falsistrellus tasmaniensis	eastern false pipistrelle	-	V
Miniopterus australis	little bentwing bat	-	V
Miniopterus schreibersii oceanensis	eastern bentwing bat	-	V
Mormopterus norfolkensis	eastern freetail bat	-	V
Myotis macropus	southern myotis	-	V
Nyctophilus corbeni	Corben's long-eared bat	V	V
Petaurus norfolcensis	squirrel glider	-	V
Petrogale penicillata	brush-tailed rock-wallaby	E	V
Phascogale tapoatafa	brush-tailed phascogale, tuan	-	V
Phascolarctos cinereus	koala	V	V
Pteropus poliocephalus	grey-headed flying fox	V	V
Saccolaimus flaviventris	yellow-bellied sheathtail bat	-	V
Scoteanax rueppellii	greater broad-nosed bat	-	V
Vespadelus troughtoni	eastern cave bat	-	V

*V= listed as Vulnerable; E= listed as Endangered; CE= listed as Critically Endangered.

Source: Cumberland Ecology, 2014; EPBC Act SPRAT Database; NSW TSC Act Threatened Species Database.

2 SUMMARY OF THREATS

The landscape within which the ecological community occurs is subject to a matrix of land uses, primarily: mining (particularly open-cut mining), agricultural and horticultural activities, grazing, and rural-residential housing and industrial development.

The key threats affecting the ecological community are:

- Vegetation clearing and landscape fragmentation. Mining continues to be the main driver of clearing, along with rural, residential and industrial development; remaining areas of the community are highly fragmented, isolated and much less resilient to on-going impacts.
- Rural, residential and industrial development. As well as clearing vegetation, these developments can impact fauna, produce nutrient rich run-off and degrade soil and water quality and hydrology (causing eutrophication) and aid the spread of invasive species.
- Invasive flora species. Weeds compete with locally indigenous flora species for available resources (water, light, nutrients) and lead to a decline in the diversity and regenerative capacity of a native ecosystem.
- Removal of fallen timber and trees. Collection of firewood and ‘tidying up’ the landscape significantly reduces habitat value.

- Detrimental grazing, mowing, slashing and fertilising regimes. These activities can extensively modify the structure, composition and nutrient pathways of the community. Subsequent changes in native plant species composition and diversity may reduce habitat value for fauna; and eutrophication may disrupt foodwebs.
- Altered fire regimes. Fire intensity, frequency, seasonality and patchiness all influence flora and fauna composition and vegetation structure, as well as the success of plant invasions and the subsequent impacts on native biota.
- Introduced animals and aggressive native species. Pest species have impacts through predation and damage to vegetation and soils and competition for resources.
- Climate change. In addition to threatening species that cannot adapt, climate change can exacerbate existing threats such as habitat loss, altered fire and hydrology regimes and the spread of invasive species.

2.1 Summary of Key Threatening Processes

Key threatening processes identified under the NSW TSC Act and EPBC Act that are affecting Warkworth Sands Woodland are:

- Land clearance (EPBC Act); Clearing of native vegetation (NSW TSC Act)
- Alteration of habitat following subsidence due to longwall mining (TSC Act)
- Novel biota and their impact on biodiversity (EPBC Act)
- Invasion of native plant communities by African olive (*Olea europaea* subsp. *cuspidata*) (NSW TSC Act);
- Invasion of native plant communities by exotic perennial grasses (NSW TSC Act); Invasion and establishment of exotic vines and scramblers (NSW TSC Act); Invasion, establishment and spread of Lantana (*Lantana camara*) (NSW TSC Act);
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act/TSC Act)
- Competition and land degradation by rabbits (EPBC Act); Competition and grazing by the feral European Rabbit, *Oryctolagus cuniculus* (NSW TSC Act)
- Loss of hollow-bearing trees (NSW TSC Act); Removal of dead wood and dead trees (NSW TSC Act)
- Ecological consequences of high-frequency fires (NSW TSC Act)
- Competition from feral honeybees (NSW TSC Act)
- Aggressive exclusion of birds from woodland and forest habitat by abundant Noisy Miners *Manorina melanocephala* (NSW TSC Act). Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala*) (EPBC Act)
- Predation by the European red fox (*Vulpes vulpes*) (NSW TSC Act and EPBC Act)
- Predation by feral cats (EPBC Act and NSW TSC Act)
- Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases (EPBC Act); Anthropogenic climate change (NSW TSC Act).

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APPENDIX A – GLOSSARY

Aeolian (also spelled eolian) sands: A type of sediment, which has been carried or weathered by the wind.

Allelopathy: The chemical inhibition of one plant (or other organism) by another, due to the release of substances acting as germination or growth inhibitors.

Alluvium: A general term for clay, silt, sand, gravel or similar unconsolidated (not cemented together into a solid rock) detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi-sorted sediment.

Blowouts: Sandy depressions in a sand dune ecosystem caused by the removal of sediments by wind. They form when a patch of protective vegetation is lost, allowing strong winds to "blow out" sand and form a depression.

Carboniferous Period: A geologic period (298 – 354 Ma). The Carboniferous Period was followed by the Permian Period (251 – 298 Ma). Although European and North American coals were deposited during the Carboniferous Period, virtually no economic Carboniferous coal was deposited in Gondwanaland (the predecessor of Australia and a number of other continents).

Conglomerate: A coarse-grained sedimentary rock composed of rounded fragments embedded in a matrix of cementing material such as silica.

Colluvial material / **Colluvium**: A loose deposit of sharp edged rock debris and/or sediment that has moved downhill to the bottom of the slope (or cliff) without the help of running water in streams. Gravity and sheetwash[18] during rain storms are the predominant agents of colluvium deposition.

Dominant: See Projected canopy cover

Duplex soil: A soil with a texture or permeability contrast layer within the top 80 cm of the profile (e.g. a sand layer, over a clay layer). See also Texture contrast (soil).

Eutrophication: An increase in the rate of supply of (inorganic) nutrients into an ecosystem.

Foodweb: A network of food chains or feeding relationships by which energy and nutrients are passed on from one species of living organisms to another.

Functionality (of an ecological community): This refers to many processes such as: the movement of wildlife and pollinators; the dispersal of spores, seeds and other plant propagules; and the activities of predators.

Geological Periods over the last 350 million years (Ma): Quaternary (0 – 2.6 Ma); Tertiary (2.6 – 66 Ma); Cretaceous (66 – 145 Ma); Jurassic (145 – 201 Ma); Triassic (201 – 251 Ma); Permian (251 – 298 Ma); and Carboniferous (298 – 354 Ma).

Hybrid: The offspring of two animals or two plants of different breeds, varieties, species, or genera (e.g. when two different species cross pollinate). Examples of possible hybrids in this ecological community include *E. tereticornis* x *E. blakelyi* (forest red gum x Blakely's red gum) and *E. tereticornis* x E. *glaucina* (forest red gum x slaty red gum).

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[18] Sheetwash: Sheets of running water rather than by stream flowing in well defined channels

IBRA: The Interim Biogeographical Regionalisation of Australia (IBRA). The latest version (IBRA7) classifies Australia's landscapes into 89 large geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. The 89 bioregions are further refined to form 419 subregions which are more localised and homogenous geomorphological units within each bioregion. The bioregions and subregions are the reporting unit for assessing the status of native ecosystems and their level of protection in the National Reserve System.

Loam: A rich, friable (crumbly) soil containing a relatively equal mixture of sand and silt and a somewhat smaller proportion of clay.

Ma: Million years ago.

Permian: The Permian Period is a geologic period (251 – 298 Ma). It is the last period of the Palaeozoic Era; it occurred after the Carboniferous Period and before the Triassic Period (the first period of the Mesozoic Era). The bulk of Australian coal accumulated during the Permian and Tertiary periods; the majority of Australia's resources of metallurgical coking and bituminous thermal coal occur in the Permian deposits of the Sydney and Bowen Basins of NSW and Queensland (Hutton, 2009).

Projected canopy cover: A way of assessing tree dominance in a patch of woodland/forest. Dominant, in this document means accounting for more than 50% of the projected canopy cover. Projected cover of canopy trees is calculated by assuming a solid canopy. Projected canopy cover is the preferred benchmark for dominance; except in regenerating areas with few mature canopy trees. Where this is the case, tree basal area is the next best surrogate for crown cover, since it measures biomass to some degree.

SYB: Designates a subregion of the Sydney Basin (SYB) IBRA Bioregion.

Tertiary Period: A geologic period (2.6 – 66 Ma). It marks the beginning of the Cenozoic Era. The Tertiary Period was followed by the Quaternary Period (0 – 2.6 Ma). The bulk of Australian coal accumulated during the Permian and Tertiary periods (Hutton, 2009).

Texture contrast (soil): A significant increase in texture over a vertical distance of less than 5 cm (referred to by the term ‘over’). This is commonly a sand layer over a sandy clay loam to clay layer, or a loam over a clay. Texture contrast soils have a clear, abrupt or sharp boundary between the A and B horizon together with an increase in clay in the B horizon of at least 20% (Isbell, 1996).